Assessment Report of Selected Lakes Within the Pomme de Terre River Watershed

Minnesota Pollution Control Agency

Water Monitoring Section

Lakes and Streams Monitoring Unit

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Minnesota Pollution Control Agency
520 Lafayette Road North
Saint Paul, MN 55155-4194
http://www.pca.state.mn.us
651-296-6300 or 800-657-3864 toll free
TTY 651-282-5332 or 800-657-3864 toll free
Available in alternative formats

Author

Lee Engel

Editing

Steve Heiskary
Dana Vanderbosch

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Minnesota River Basin

Intensive Watershed Monitoring 2009

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Table of Contents

List of Figures

List of Tables

Executive Summary

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring for a variety of objectives. Staff within the MPCA's Lakes and Streams Monitoring Unit sample approximately 100 lakes per year, coordinate citizen volunteer monitoring through the Citizen Lake Monitoring Program, and manage Surface Water Assessment Grants given to local groups to monitor lake and stream water quality. Watershed-based monitoring emphasizes large lakes (500 acres or greater) whenever possible. All water quality data from these activities are compared to state water quality standards to determine if a given lake is fully supporting or not supporting standards set for recreational use (e.g., swimming, wading, etc.). Lakes not supporting aquatic recreational use are termed "impaired" and are placed on a list biennially. This list is formally termed the 303(d) list (referencing the section within the federal Clean Water Act that requires us to assess for condition); it is also commonly called the "Impaired Waters List". A lake placed on the Impaired Waters List is required to be intensively researched through a Total Maximum Daily Load (TMDL) study to determine the source and extent of the pollution problem. The study also requires the development of a restoration plan. For unimpaired waters, a protection plan will be developed following the assessment process. It should be noted that a great deal of lake monitoring is also carried out by various other MPCA staff and local groups who are undertaking TMDL studies or other, special projects.

The Pomme de Terre River (HUC 8) Watershed spans seven counties in western Minnesota, eight sub-watersheds (HUC 11), and has a total of 217 established lake basins. This report includes a summary of lake water quality related information on the Pomme de Terre River Watershed. It also includes details on each of sub-watershed (HUC 11). Thirty lakes in the Pomme de Terre Watershed have some level of assessment data. Individual lakes summaries were included only on the 11 lakes that have two years of assessment level data (Table 1). Eleven lakes have been fully assessed against water quality standards set for aquatic recreation and the findings indicate that seven fully support aquatic recreational uses and four do not. Nineteen lakes have some water quality data, but the datasets have insufficient data to allow assessment.

Water quality in the Pomme de Terre River Watershed is highly variable. Lakes clustered in the northern headwaters of the Pomme de Terre River watershed tend to have good water quality. The majority of assessed lakes were found to be fully supporting and are located within the Pelican Creek and the northern portion of the Upper Pomme de Terre HUC-11 watersheds. Geology and lake morphology are the main drivers of water quality in this area. Midway through the watershed, a transition in geology, lake morphology, and land use causes lake water quality to diminish. Very few lake basins are located in the mid- to southern portions of the watershed. Assessed lakes in the southern portion of the Upper Pomme de Terre and Little Muddy Creek HUC-11 watersheds were found to be non supporting.

Introduction to the Watershed Approach

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring for a variety of objectives. One of our key responsibilities per the federal Clean Water Act is to monitor and assess lakes in Minnesota to determine whether or not these lakes support their designated uses. This type of monitoring is commonly referred to as condition monitoring. While the MPCA conducts its own lake monitoring, local partners (SWCDs, watershed districts, etc.) and citizens play a critical role in helping us because their efforts greatly expand our overall capacity to conduct condition monitoring. To this end, the MPCA coordinates citizen volunteer lake monitoring through the Citizen Lake Monitoring Program (CLMP), and manages Surface Water Assessment Grants given to local groups to monitor lake water quality. All of the data from these activities are combined with our own lake monitoring data to assess the condition of Minnesota lakes. Lake condition monitoring activities are focused on assessing the recreational use-support of lakes and identifying trends over time. The MPCA also assesses lakes for aquatic consumption use-support, based on fish-tissue and water-column concentrations of toxic pollutants.

The primary organizing approach to MPCA's condition monitoring is the "major" watershed (8-digit hydrologic unit code). There are 81 major watersheds in Minnesota, and the MPCA has established a schedule for intensively monitoring 6-8 of them annually (Figure 1). With this strategy, we will cycle through all 81 watersheds every ten years. The MPCA began aligning its stream condition monitoring to this watershed approach in 2007. Lake monitoring was brought into this framework in 2009. The year 2017 will mark the final year of the first 10-year cycle. The watershed approach provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, and results measures. By intensively monitoring lakes and streams within a given watershed at the same time, the lake and stream data can be considered together to provide a comprehensive picture of water quality status and a determination can be made regarding how best to proceed with development of restoration and protection strategies.

Even when pooling MPCA, local group and citizen resources, we are not able to monitor all lakes in Minnesota. The primary focus of MPCA monitoring is lakes $\geq$500 acres in size ("large lakes"). These resources typically have public access points, they generally provide the greatest aquatic recreational opportunity to Minnesota's citizens, and these lakes collectively represent 72% of the total lake area (greater than 10 acres) within Minnesota. Though our primary focus is on monitoring larger lakes, we are also committed to directly monitoring, or supporting the monitoring of, at least 25% of Minnesota's lakes between 100-499 acres ("small lakes"). In most years, we monitor a mix of large and small lakes, and provide grant funding to local groups to monitor lakes that fall in the 10-499 acre range. Currently, we are fully meeting the "large" lake goal, and with our local partners' help we are greatly exceeding the "small" lake monitoring goal.

Major watersheds are defined by the Minnesota Department of Natural Resources (MDNR) and use a standardized numbering convention called Hydrologic Unit Codes (HUC). HUC is a way of identifying all drainage basins in the United States in a nested arrangement from largest (basin) to smallest (catchment). A drainage basin is an area or region of land that catches all precipitation falling within that area and funnels it to a particular creek, stream, river, lake or ocean. MPCA's watershed approach focuses on eight-t and eleven-digit HUCs. HUCs with fewer digits represent larger HUC systems, while HUCs with more digits are smaller components of larger HUCs.

Pomme de Terre River Watershed Background

HUC-8 Watershed Characteristics

The Pomme de Terre River watershed covers a 226,717 hectare (560,231 acres) area in west central Minnesota. The watershed is within the Minnesota River Basin and covers portions of three ecoregions: North Central Hardwood Forests (NCHF) in the north, Northern Glaciated Plains (NGP) throughout the central and southern portions, and Western Corn Belt Plains (WCBP) near the southern tip (Figure 1). The Pomme de Terre River drains the watershed to the south to the Minnesota River. Eight HUC-11 minor watersheds further subdivide the watershed. Five of these HUC-11 watersheds have lakes with assessment data. Additional background information regarding these minor watersheds is presented in the Appendix.

A summary of the lakes with available assessment data and their current status within each HUC-11 for the Pomme de Terre River watershed is presented in Table 1. The watershed contains 217 lakes greater than 10 acres with a Minnesota Department of Natural Resources protected designation. Only about 5 percent have been assessed. There are 19 lakes that have been determined to have insufficient data for assessment (Table 1).

Table 1. Assessment Status of Lakes within 11-digit HUCs of the Pomme de Terre Watershed.

HUC 11 Name	Area acres	Total Basins	Basins > 10 acres	Total Lakes	Full Support (FS)	Not Supported (NS)	Insufficient Data (IF)
Drywood Creek	65,101	32	15	13			2
Fairfield-Tara	18,677	3	2	1			
Lake Oliver	12,771	10	7	5			1
Little Muddy Creek	52,424	20	11	11		1	
Lower Pomme de Terre	67,435	5	2	2			
Muddy Creek	37,484	12	3	2			
Pelican Creek	95,786	155	120	61	2	1	7
Upper Pomme de Terre	210,289	228	164	122	5	2	9
Total	**559,968**	**465**	**324**	**217**	**7**	**4**	**19**

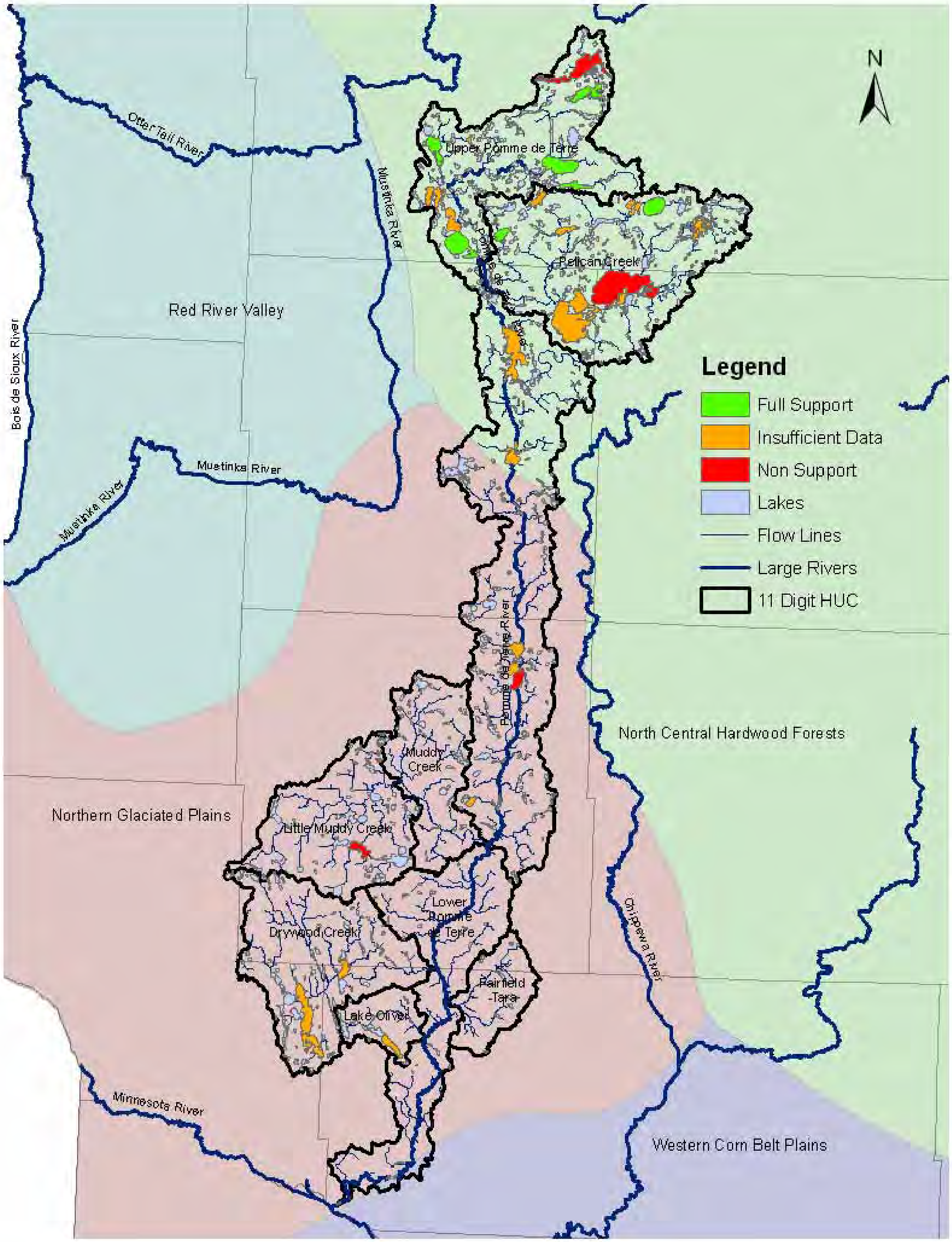
Eleven lakes have been assessed in the Pomme de Terre River watershed. All assessed lakes are located within three 11-digit HUCs: the Upper Pomme de Terre, Pelican Creek, and Little Muddy Creek. Lake morphometry characteristics and impairment status for individual lakes are given in Table 2. Seven lakes have been assessed as full support and four as not supporting. The four shallowest lakes assessed were all found to be not supporting (Table 2). Full support, not supporting, and insufficient data lakes are mapped throughout the watershed in Figure 1.

Table 2. Morphometry of Assessed Lakes Within the Pomme de Terre Watershed.

HUC-11 Name	Lake Name	Lake ID	Area (ac)	Max Depth (m)	Mean Depth (m)	% Littoral	Watershed / Lake	Impairment Status
Little Muddy Creek	Hattie	75-0200	454	2.4	1.5	100	20 : 1	NS
Pelican Creek	Christina	21-0375	3,955	4.4	1.5	0	10 : 1	NS
	Clear	56-0559	390	8.8	5	43.5	10 : 1	FS
	Eagle	56-0253	898	14	9	18.6	5 : 1	FS
Upper Pomme de Terre	Long	56-0390	373	26.8	4.8	67.4	17 : 1	FS
	North Turtle	56-0379	1,542	5.8	2.1	98.4	5 : 1	NS
	South Turtle	56-0377	630	10.7	3.1	63.2	17 : 1	FS
	Perkins	75-0075	505	3	2	100	527 : 1	NS
	Stalker	56-0437	1,337	29	6.3	44.9	28 : 1	FS
	Swan	56-0781	725	13.4	5.6	55	12 : 1	FS
	Ten Mile	56-0613	1,408	15.2	5	42.3	52 : 1	FS

FS- Full Support, NS- Non Support

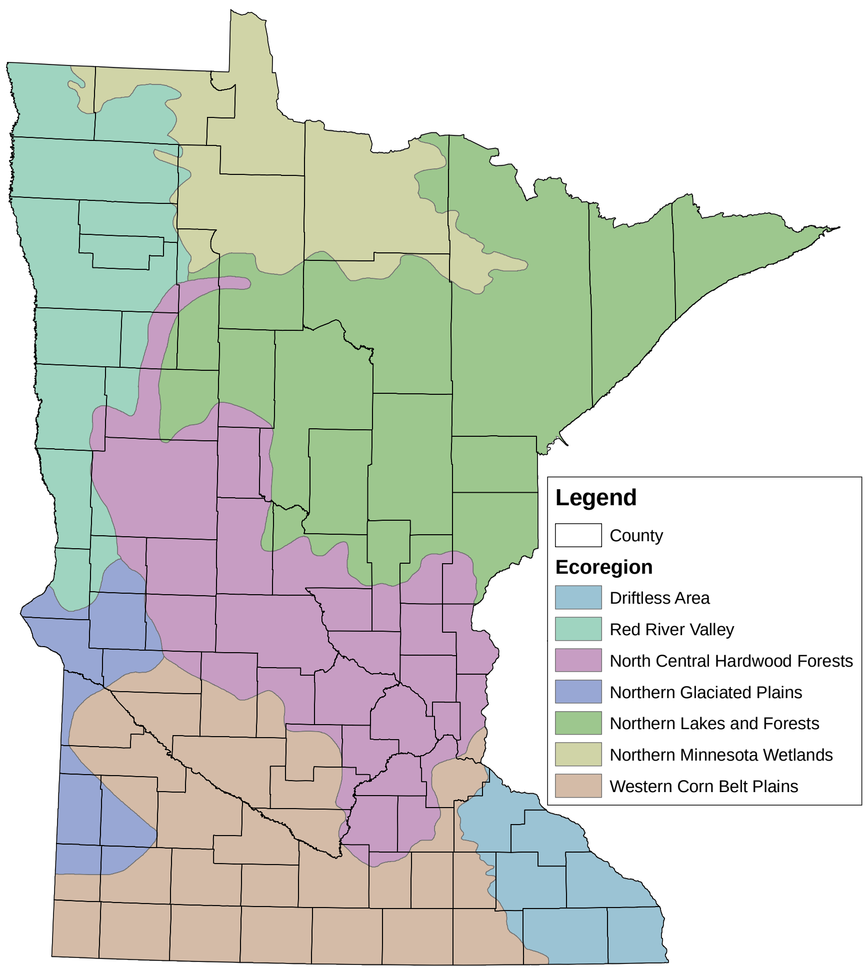
Figure 1. Pomme de Terre Watershed Assessment Status.



Ecoregions

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, defined by soils, land surface form, natural vegetation, and current land use (Figure 2). Data gathered from representative, minimally impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. The Pomme de Terre River watershed is located in the North Central Hardwood Forest (NCHF), Northern Glaciated Plains (NGP), and the Western Corn Belt Plains (WCBP) ecoregions.

Figure 2. Minnesota's Seven Ecoregions as Mapped by USEPA.



Geology and Soils

The geology and soils found within the Pomme de Terre River watershed help explain the distribution and hydrologic connections of its water bodies. Lake water budgets consist of direct precipitation, ground water, and runoff. The pathways and duration it takes water to move through the watershed has a direct effect on water quality. Soil characteristics and types influences runoff amounts and infiltration rates along with the duration it takes for water to reach lakes and streams. These factors can have effects on water chemistry and lake levels.

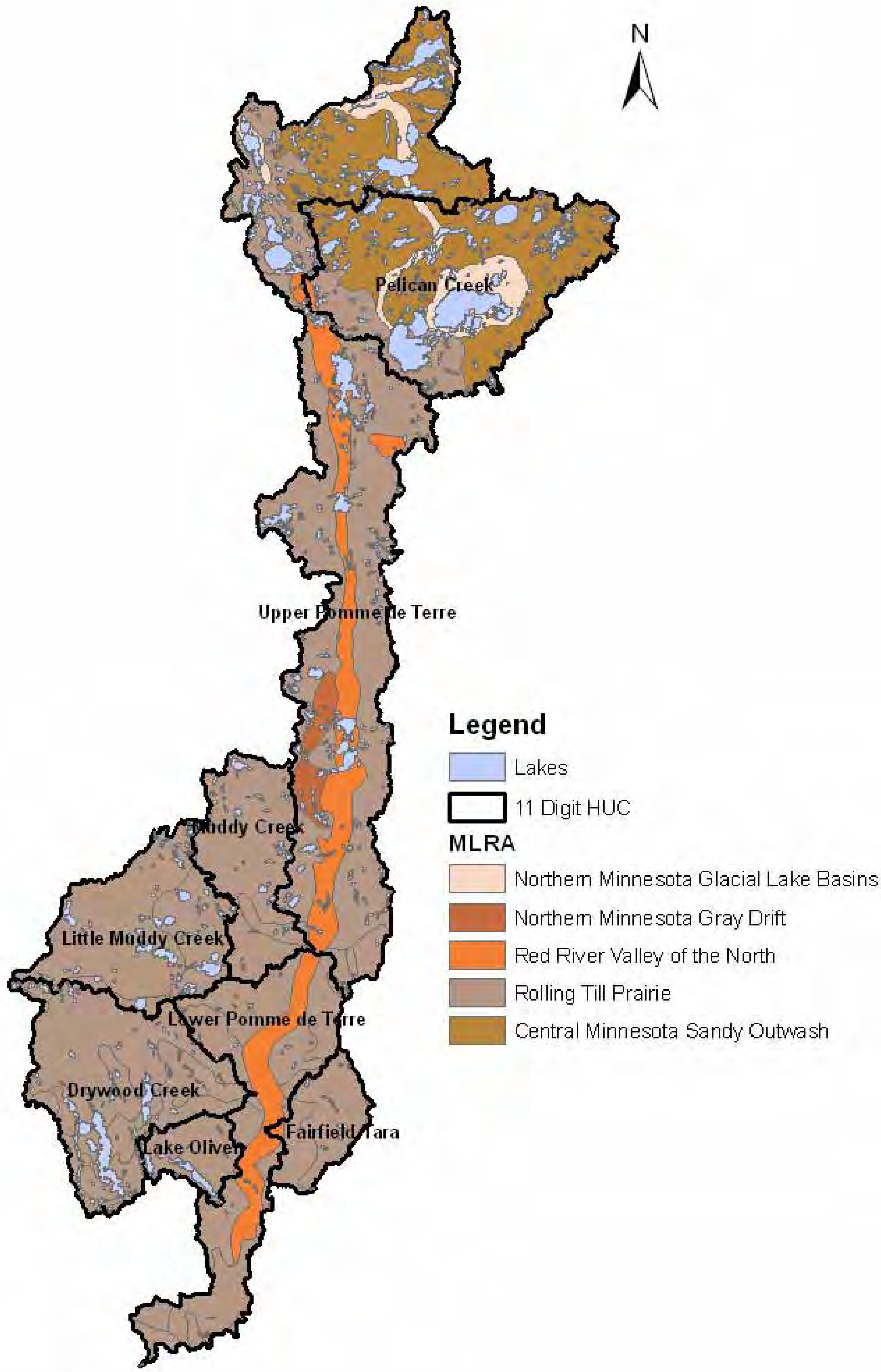
The United States Department of Agriculture (USDA) has categorized the dominant physical characteristics of Major Land Resource Areas (MLRA's). MLRA descriptions can be found at http://soils.usda.gov/survey/geography/mlra/ . In the context of this report data regarding the geology and soils of the Pomme de Terre watershed will be examined. There are five MLRAs found in the Pomme de Terre River watershed, but only three cover significant portions of the watershed (Figure 3).

The northeastern portion of the Pomme de Terre watershed is categorized as Central Minnesota Sandy Outwash. This consists of coarse-textured outwash with a thin, discontinuous mantle of loamy material. The thickness of the outwash ranges from 3 feet (1 meter; m) to more than 100 feet (30 meters). Loamy glacial till typically underlies the outwash. Organic material is in many of the larger basins and depressions. The dominant soil orders in this MLRA are Mollisols and Histosols. The soils on uplands generally are well drained to excessively drained. Very poorly drained Histosolsare lines large basins and depressions.

The majority of the watershed is considered to be Rolling Till Prairie. The dominant landforms in this area are stagnation moraines, end moraines, glacial outwashplains, terraces, and flood plains. Cretaceous Pierre Shale underlies the till in most of the area. Precambrian rocks also occur at depth. The dominant soil order in this MLRA is Mollisols. The soils generally are very deep, well drained to very poorly drained, and loamy.

The center of the Pomme de Terre River watershed is considered to be Red River Valley of the North. This area is the former bed of glacial Lake Agassiz. It is a glacial lake plain with remnants of gravelly beaches marking its eastern border. The erosion resistance of the gravel causes the beaches to appear as ridges in an otherwise flat landscape. Some dunes have formed in areas near the beaches where sand has been deposited. The dominant soil orders in this MLRA are Mollisols and Vertisols. They are very deep, somewhat poorly drained to very poorly drained, and loamy or clayey.

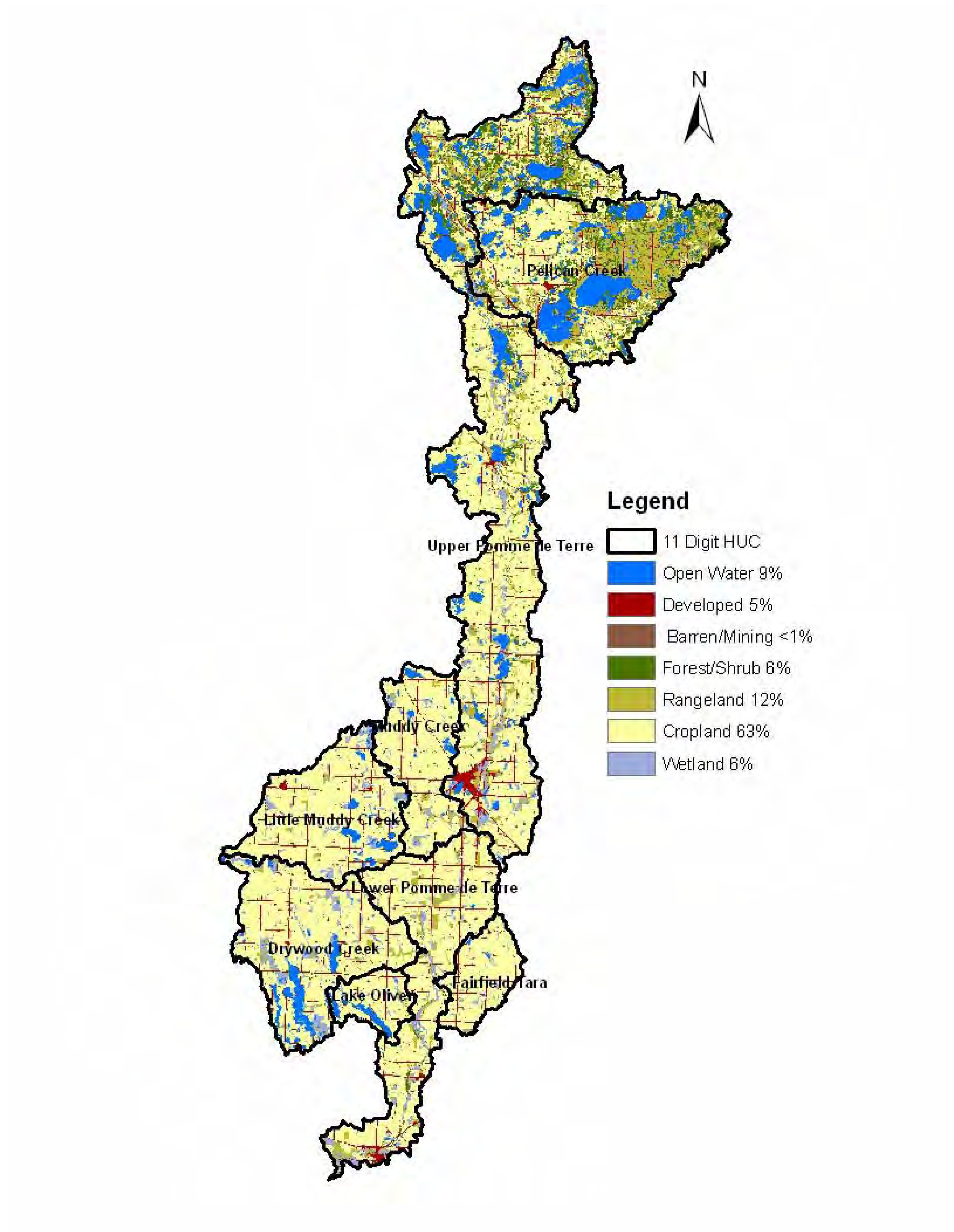
Figure 3. MLRA's in the Pomme de Terre River Watershed.



Watershed Land Use

Land use characteristics change throughout the Pomme de Terre River watershed. The northern portion of the watershed is a mixture of forest, rangeland, and cropland. Moving south, land use changes exclusively to agriculture primarily cropland (63%) and rangeland (12%). The area is sparsely populated and has low density development outside the largest city, Morris Minnesota. Total developed area is approximately 5% of the watershed. Water quality and the productivity of lakes are influenced by the land use and size of each lakes watershed. In order to better understand the interactions between land use and lake water quality at a fine scale, land use and lakeshed maps were produce for each HUC-11. Assessed lakes with be presented later in the report. Figure 4 displays land use for the Pomme de Terre River watershed.

Figure 4. Land Use in the Pomme de Terre River Watershed.



Precipitation and Climate

Minnesota's climate is highly variable throughout the state. This holds true even at a smaller scale within each of Minnesota's 81 major watersheds. Precipitation is important to lake water budgets in the Pomme de Terre River watershed. Stream inflow and groundwater recharge are major components to the water budget of lakes and are driven by annual precipitation. The interconnectedness of these water pathways help to explain differences in water quality. High intensity convective storms have the ability to drop inches of water in a localized area within a short period of time. How water moves through the watershed may influencing in-lake water quality and lake levels.

Based on state climatology records from 2008-2009, precipitation averages between 0.61 – 0.71 m (24 and 28 inches) annually in the Pomme de Terre River watershed (Figure 5). Typical evaporation and runoff values for lakes in this area are 0.94 meters per year (m/yr) of evaporation and 0.1 m/yr of runoff. This implies that evaporation typically exceeds precipitation on the surface of the lake. Thus, unless watershed runoff or groundwater inputs are sufficient to maintain lake level, lake levels will decline over the summer open water period in most years. The 2008 water year precipitation departure from normal was about 0.1-0.15 m (4-6 inches) higher in the northern and southern portions of the watershed and about 0.05-0.1 m (2-4 inches) below normal for the central portion of the watershed (Figure 6). Departure from normal maps depict the difference between annual precipitation totals and the historical "normal," a 1971-2000 average. The units are in inches. (1961-1990 normal period used before 2002).

Figure 5. 2009 Minnesota Water Year Precipitation and Departure from Normal.

Prepared by State Climatology Office DNR Waters

Values are in inches

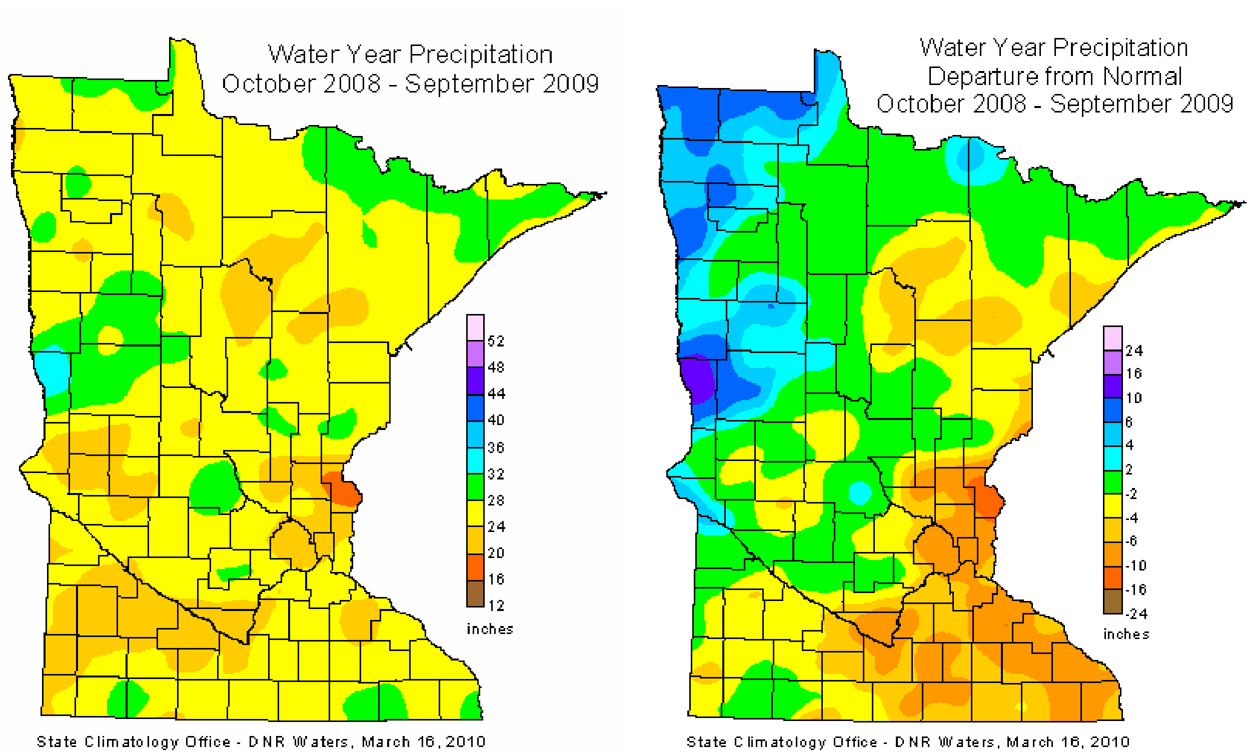
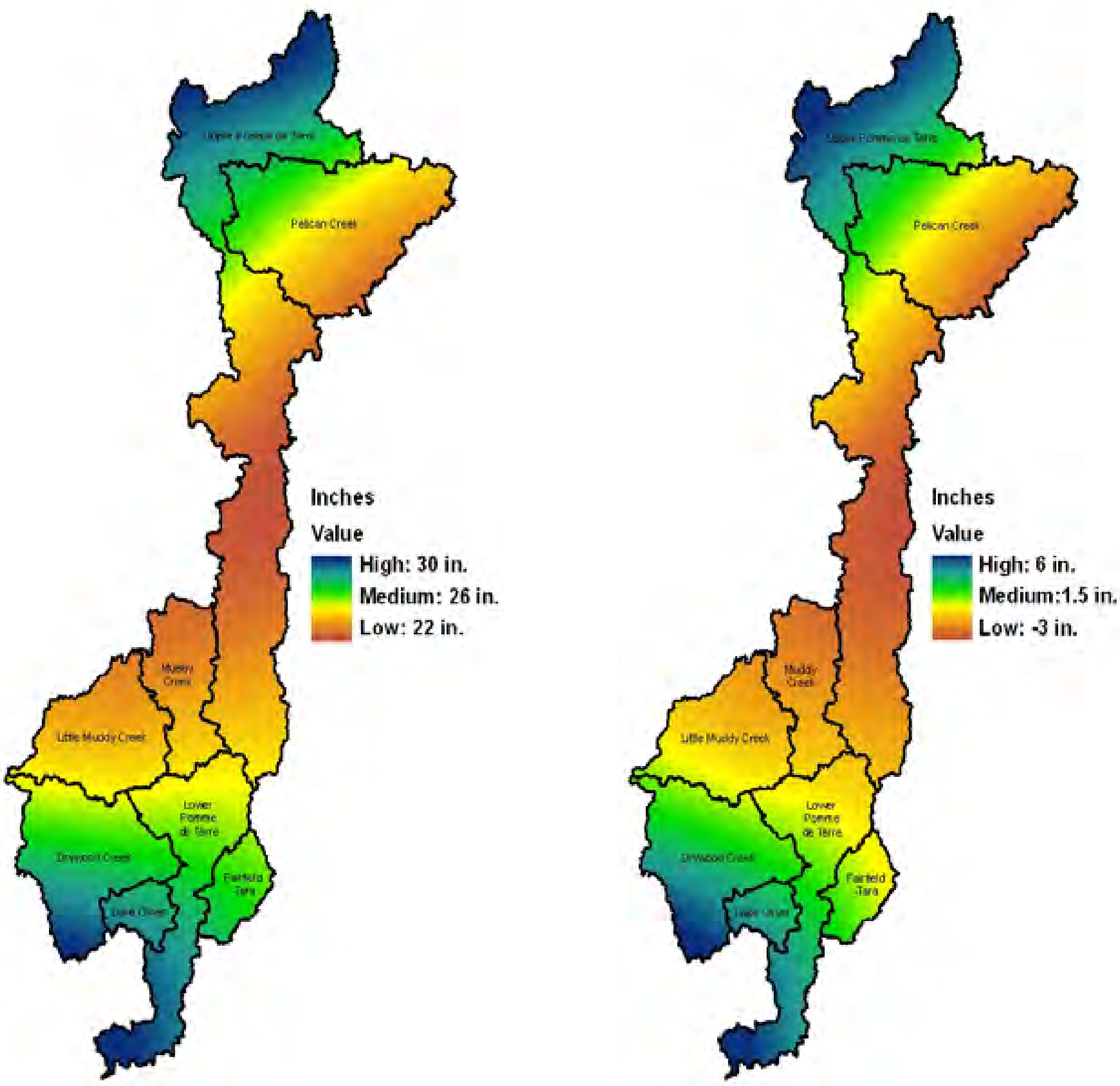
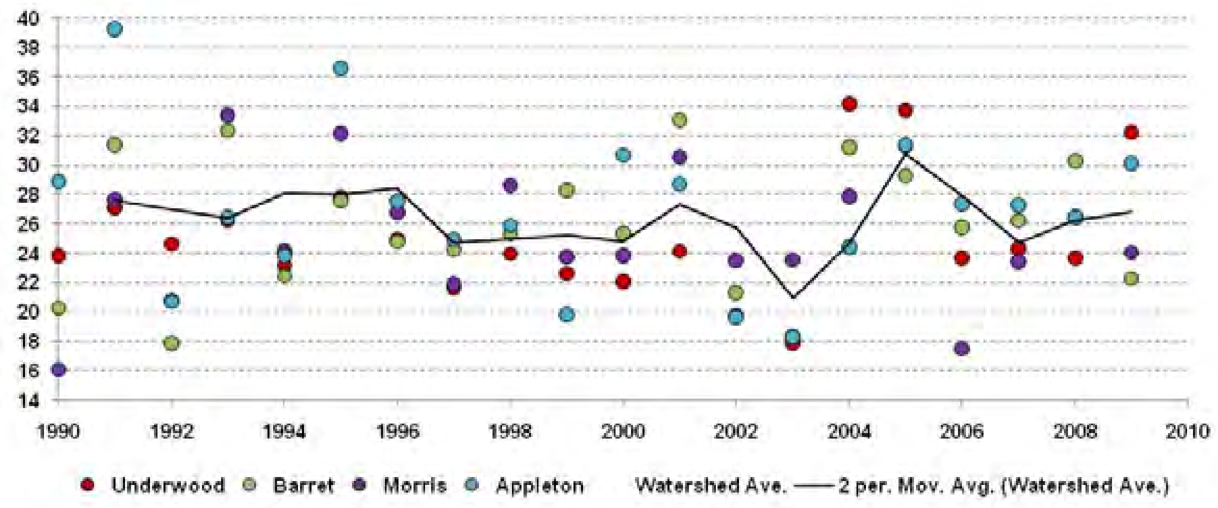


Figure 6. 2009 Water Year Precipitation and Departure from Normal for Pomme de Terre River Watershed.



Annual precipitation values were taken approximately every 40 km (25 miles) from north to south throughout the Pomme de Terre watershed. Precipitation data was taken from weather stations near the cities of Underwood, Barret, Morris, and Appleton. The annual precipitation values are given for each town with a two year moving average for all the stations sampled (Figure 7). Variations can be seen from year to year for each location and within the entire watershed.

Figure 7. Pomme de Terre River Watershed Areal Mean Annual Precipitation.



Methods

Lake Monitoring Methods

The majority of lake water quality data in the Pomme de Terre River watershed was collected by local organizations and submitted to the MPCA.

Lakes sampled by MPCA staff collected data from May through September. Lake surface samples were collected with an integrated sampler, a poly vinyl chloride (PVC) tube 2 meters (6.6 feet) in length, with an inside diameter of 3.2 centimeters (1.24 inches). Depth total phosphorous (TP) samples were collected with a Kemmerer sampler. Temperature, dissolved oxygen profiles, and Secchi disk transparency measurements were also taken. Sampling procedures were conducted as described in the MPCA Standard Operating Procedure for Lake Water Quality document, which can be found at: http://www.pca.state.mn.us/publications/wq-s1-16.pdf.

Laboratory analysis of samples collected by the MPCA was performed by the Minnesota Department of Health laboratory using United States Environmental Protection Agency-approved methods (Table 3). Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, chloride, and chlorophyll-a (Chl-a).

Table 3. Laboratory Methods and Precision.

Parameter and unit	Reporting limit	Method number	Precision: [1] mean difference	Difference as percent of observed
Total Phosphorus µg/L	3.0	EPA365.1	4.8	2.7 %
Total Kjeldahl N mg/L	0.1	EPA351.2	0.05	2.8 %
$NO_2 + NO_3$ mg/L	0.05	EPA353.2		
Total Suspended Solids mg/L	1.0	SM2540D	2.8	9.6 %
Total Suspended Volatile Solids mg/L	1.0	SM2540E	--	--
Alkalinity mg/L CaCO3	10	SM 2320 B	--	--
Chloride mg/L	1.0	EPA 325.2		
Color CU	5	EPA 110.2		
Chlorophyll-a µg/L		SM10200H	1.7	7.4 %
Pheophytin		SM10200H	--	--

Through the use of the MPCA's Citizen Monitoring Program, water quality data has been collected by volunteers throughout the Pomme de Terre watershed. All agency and volunteer lake sampling locations are shown if Figure 8.

Evaluation of lake trophic status was calculated using Carlson's Trophic State Index (TSI) (Carlson 1977). TSI values aid in interpreting relationships among TP, chl-*a*, and Secchi disk transparency. TSI values are calculated as follows:

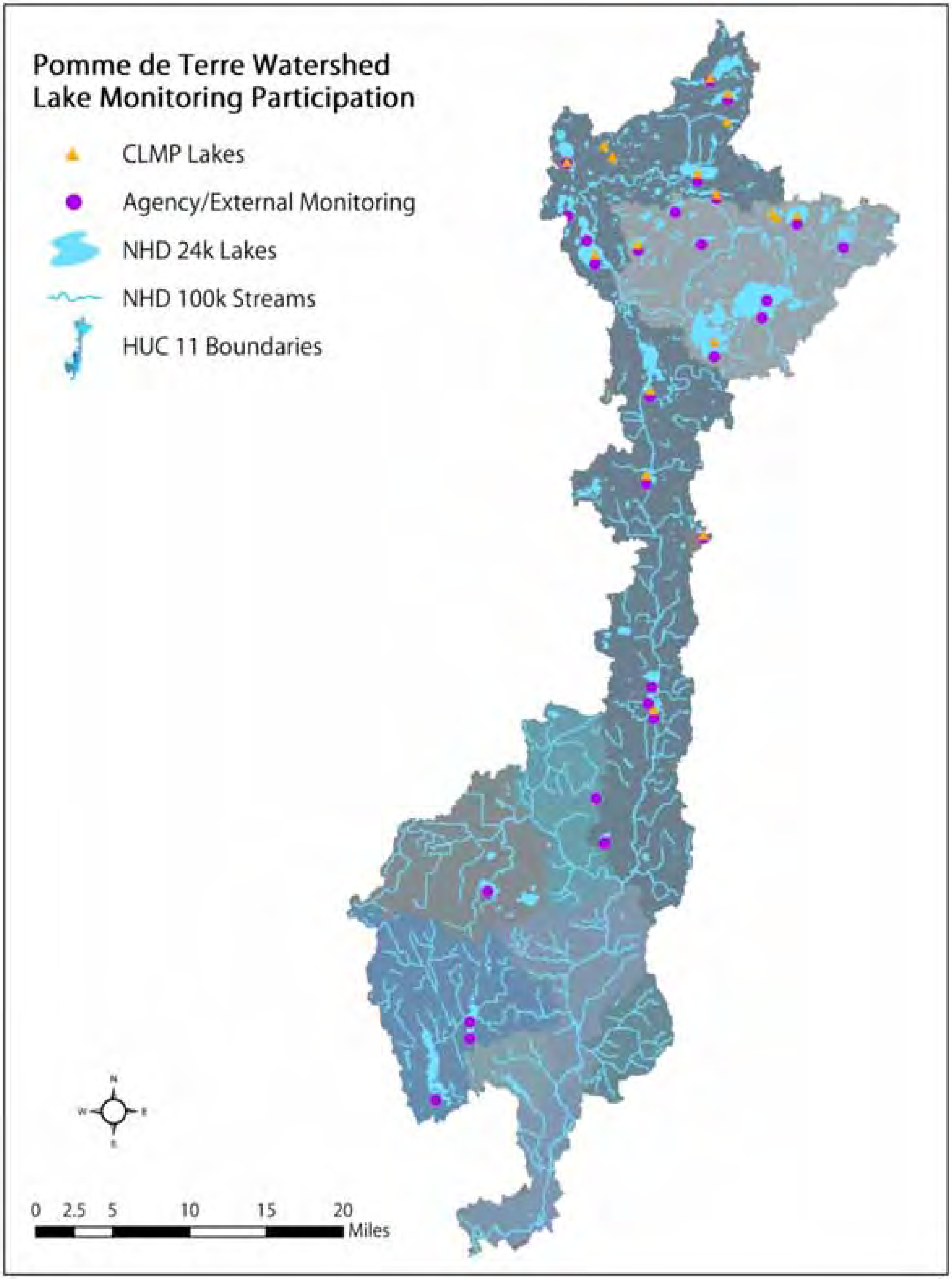
Total Phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

Chlorophyll-*a* TSI (TSIC) = 9.81 ln (chl-*a*) + 30.6

Secchi disk TSI (TSIS) = 60 – 14.41 ln (SD)

TP and chl-*a* are expressed in µg/L and Secchi disk is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass. Comparisons of individual TSI measures provides a basis for assessing relationships among TP, chl-*a*, and Secchi.

Figure 8. Lake Sampling Location in the Pomme de Terre River Watershed.



Modeling

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake.

MINLEAP was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). The model predicts in-lake TP based on lake size and depth, watershed area, ecoregion-based stream TP and water inputs and standardized lake model routines. Chlorophyll-a (Chl-a) and Secchi are predicted based on Minnesota lakes-based empirical models. A sub-routine in MINLEAP estimates background TP as a function of lake alkalinity and mean depth based on empirical equations developed by Vighi and Chiaudani (1985).

Observed TP, Chl-a, and Secchi are compared to MINLEAP-predicted values to aid in assessment of lakes in the Pomme de Terre watershed. In some instances, MINLEAP was calibrated for some lakes located directly on the Pomme de Terre River in order to better reflect inflow TP and improve estimates of P loading rate. This was done because the model cannot account for sedimentation (trapping) of P in upstream lakes. This often results in excessively high watershed P loading rates and high estimates of in-lake P.

303 (d) Assessment

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing and swimming. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. A water body is “impaired” if it fails to meet one or more water quality standards.

Under Section 303(d) Impaired Waters List of the Clean Water Act, the state is required to asses all waters of the state to determine if they meet water quality standards. Waters that do not meet standards are added to the 303(d) Impaired Waters List and updated every even-numbered year. If a water resource is listed, an investigative study termed a Total Maximum Daily Load (TMDL) is conducted to determine the sources and magnitude of the pollution problem, and to set pollutant reduction goals needed to restore the waters. The MPCA is responsible for monitoring surface waters, assessing condition of lakes and streams, creating the 303(d) Impaired Waters List, and conducting or overseeing TMDL studies in Minnesota.

TP, Chl-a, and Secchi transparency standards are used to determine the recreational suitability of Minnesota lakes. Table 4, lists the assessment criteria used for lakes based on ecoregion expectations. Values for the NCHF, WCBP, and NGP ecoregions were used for assessing lakes within the Pomme de Terre River watershed. Individual assessment results for each of the lakes will be discussed in the lake summary portion of the HUC-11 watershed sections within this report.

Data from October 1999 through September 2009 was used for the 2010 assessment for streams and lakes. Data was compiled and compared to water quality standards. Preliminary assessment findings were reviewed by internal MPCA staff by individual assessment units within a major watershed (e.g. Pomme de Terre River). Recommendations from the internal review were presented in watershed-specific meetings with regional MPCA staff and external stakeholders (professional judgment group). Final assessment recommendations were the result of the professional judgment group meetings. These recommendations make up the draft 303(d) Impaired Waters list and the list of fully supporting waters for this assessment year.

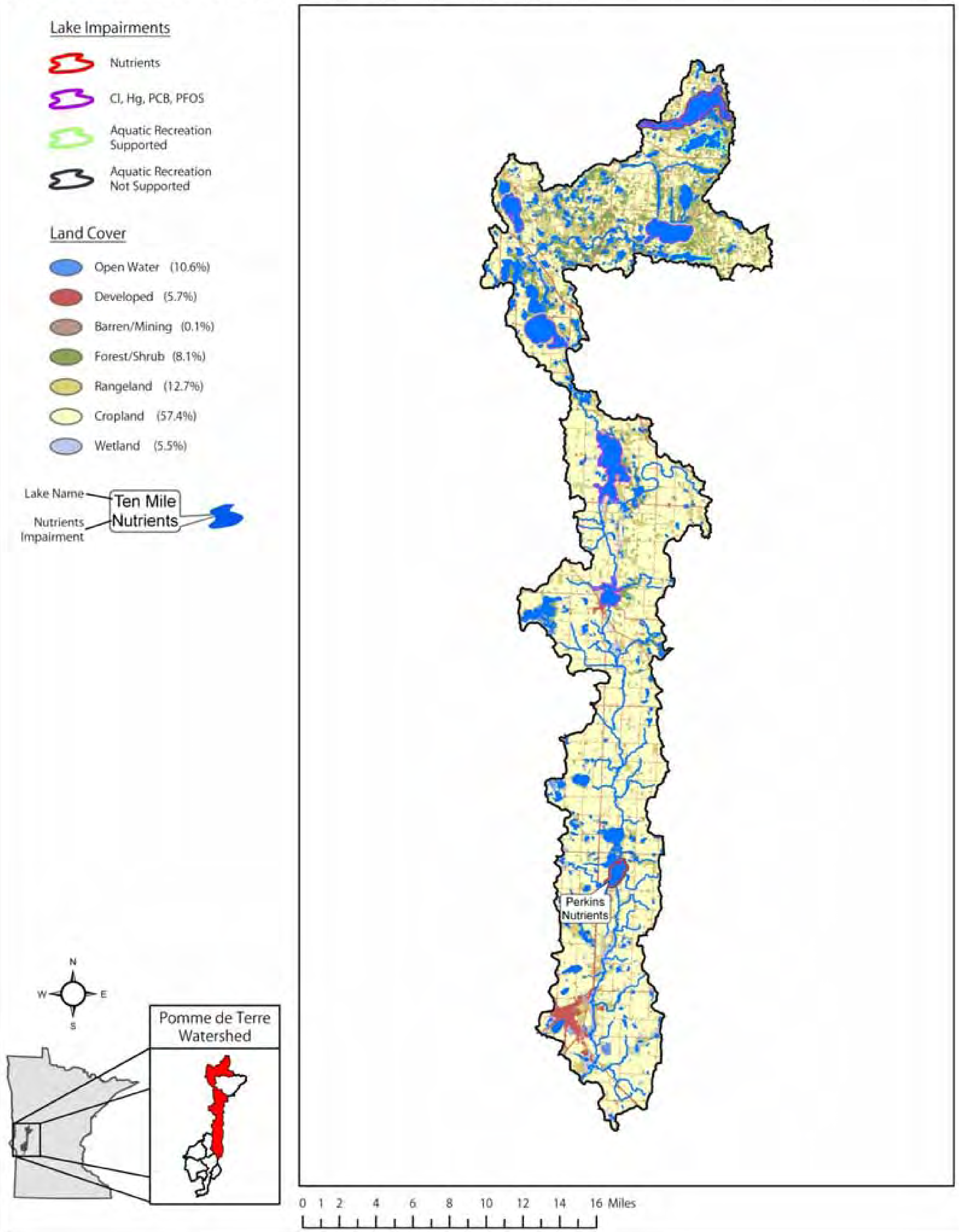
Table 4. Minnesota Lake Eutrophication Standards by Ecoregion and Lake Type (Heiskary and Wilson, 2005) and 2010 303(d) Assessment Values.

Ecoregion	TP	Chl-a	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCBP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCBP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

Huc-11 Lake Assessment

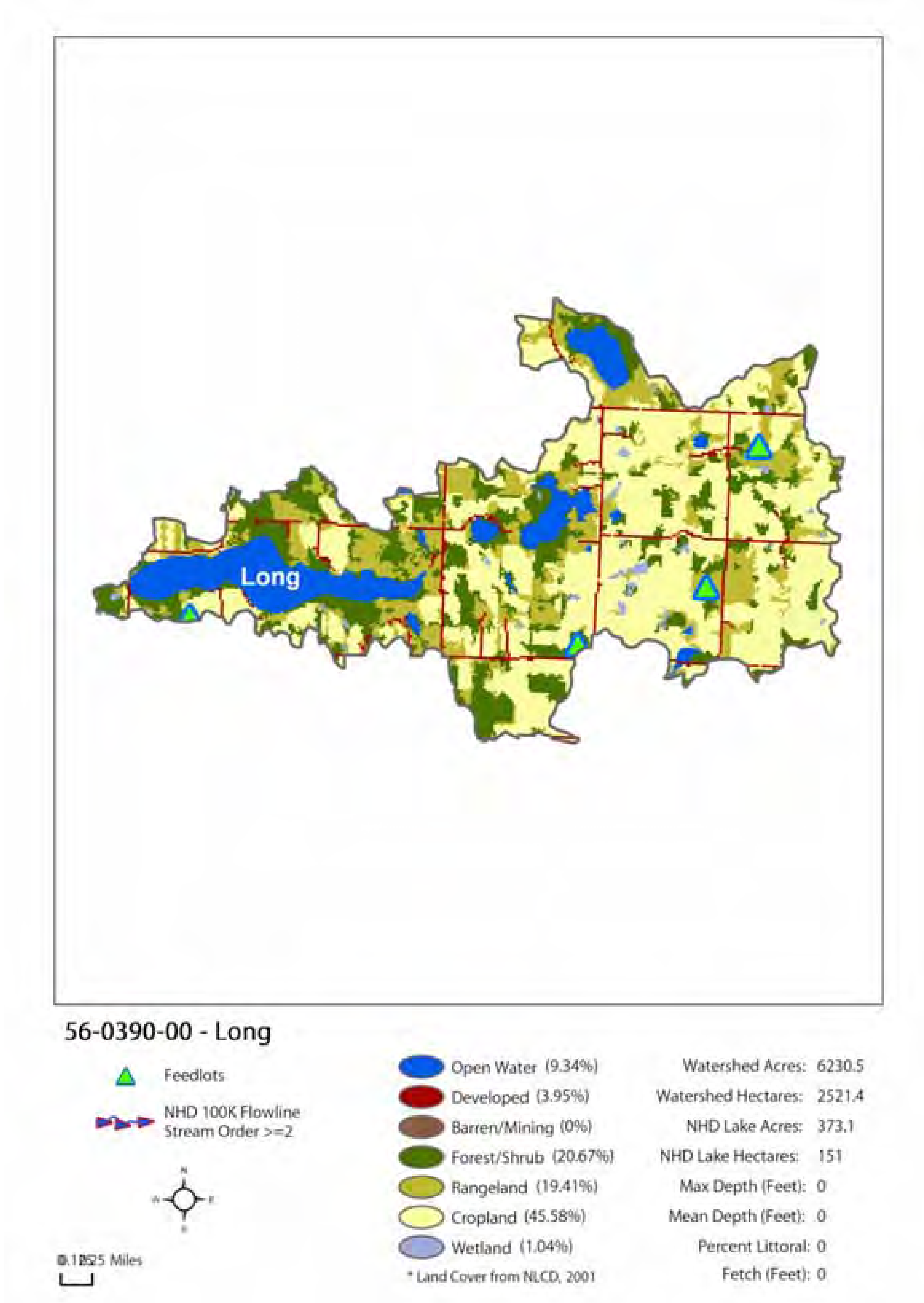
The Pomme de Terre River watershed is comprised of eight HUC-11 minor watersheds. Five of these HUC-11 watersheds have lakes with assessment data. Additional background information regarding these minor watersheds is presented in the Appendix. Eleven lakes have been assessed in the Pomme de Terre River watershed. All assessed lakes are located within three 11-digit HUCs: the Upper Pomme de Terre, Pelican Creek, and Little Muddy Creek. Seven lakes have been assessed as full support and four as not supporting.

Upper Pomme de Terre Watershed Unit - HUC 07020002010



The Upper Pomme de Terre (07020002010) HUC-11 watershed is the largest HUC-11 covering 38 percent of the Pomme de Terre River watershed. This 210,289 acre watershed drains the lake-rich headwaters through the Pomme de Terre River. Land use is primarily cropland (57%); however, it is notable that the headwaters of the watershed do have interspersed forest and shrub land. Assessment of seven lakes has occurred with five designated as full support and two not supporting (Table 2).

Long Lake (56-0390)



Long Lake is a 151-hectare (373 acre) mesotrophic lake located in south-central Otter Tail County approximately five miles east of Dalton, MN. Long Lake is dimictic and has a maximum lake depth of 26.8 m. The catchment watershed area is 2521.4 hectares (6230.5 acres) and has a catchment to lake surface area ratio of 17:1. Land use is dominated by cropland, rangeland, and forest. Though there is substantial cropland and three feedlots in the "mapped" total watershed area there are no obvious tributaries or ditches that might convey runoff from these areas to Long Lake. In contrast land use in the more immediate watershed of the lake is forest and rangeland dominated. In general the Long Lake's watershed is relatively undeveloped.

Water quality data from 2006-2007 indicate that Long Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to NCHF eutrophication standards (Table 5). Concentrations remain relatively low, though subtle late summer increases in TP are evident (Figure 9).TSI calculations made from 2005 through 2009 data showing a trend of good water quality in Long Lake (Figure 10).

Table 5. Long Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Long Lake 2006-2007 Averages	21	7	2.9

Figure 9. Long Lake 2006 and 2007 Monthly Phosphorus, Chlorophyll-a, and Secchi.

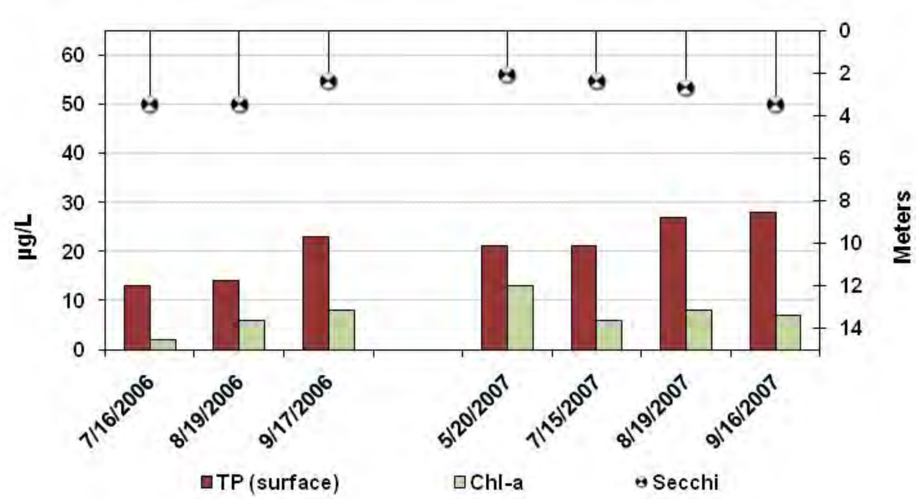
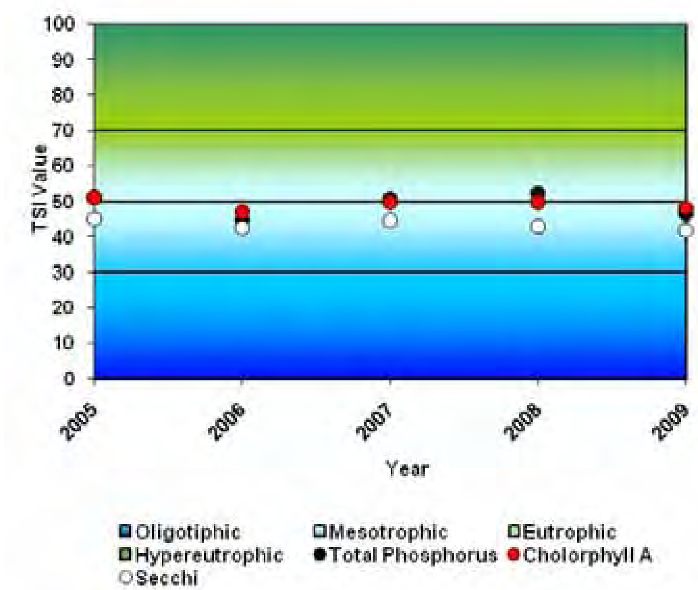


Figure 10. Long Lake Trophic Status Index Values.
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

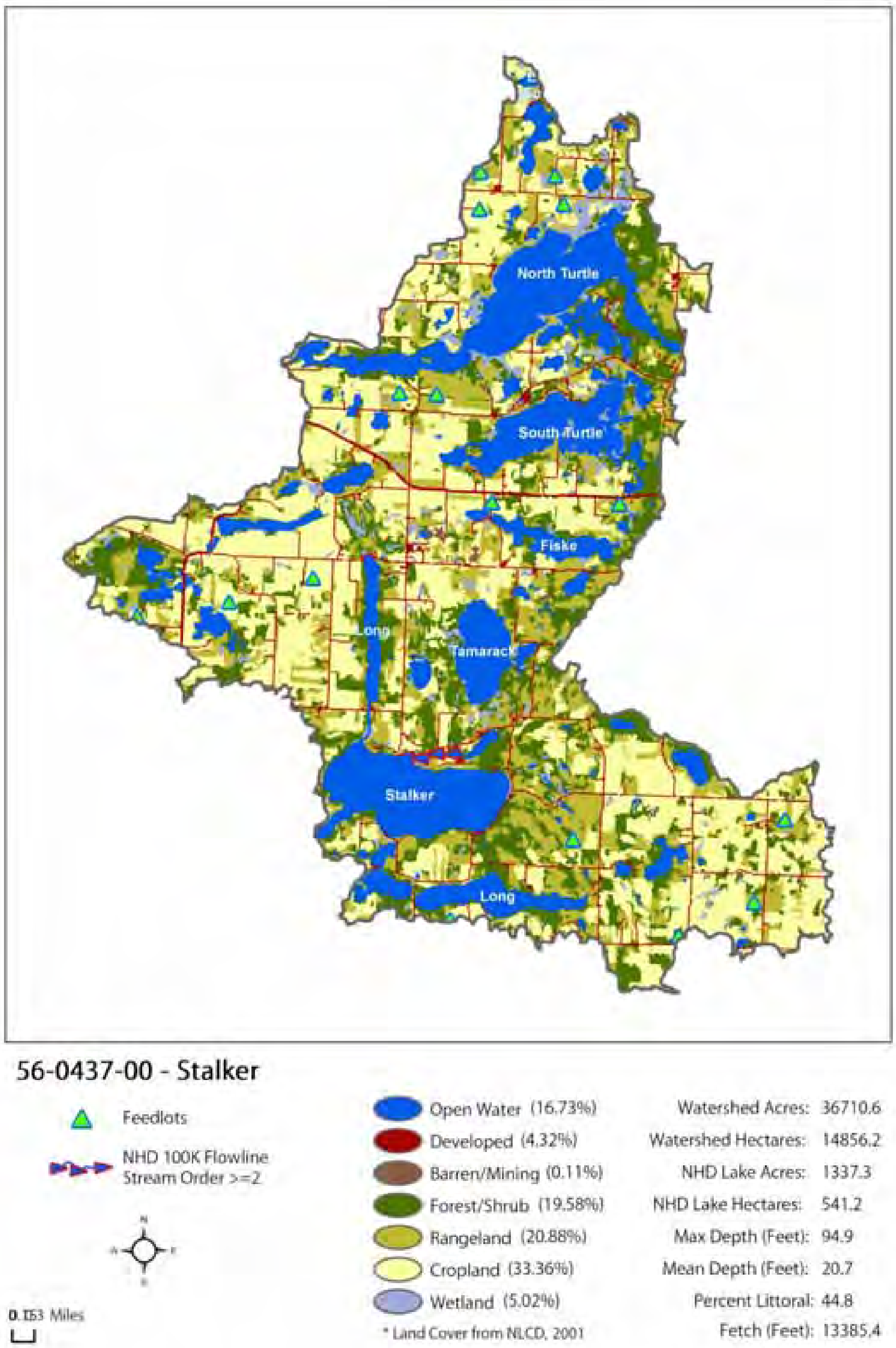


Long Lake is located in the NCHF ecoregion and the model was run using NCHF ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for Long Lake are given in Table 6. The typical NCHF stream P inflow concentration in MINLEAP is 148 micrograms per liter (µg/L). This stream inflow value resulted in an overestimate of in-lake P as compared to observed (Table 6). In order to yield a more accurate estimate of the P loading rate to Long Lake the stream P inflow concentration was calibrated. A P value of 30 µg/L was used for calibration because there are no inlets or outlets connected to the lake. Using 30 µg/L may be unrealistic; however, it demonstrates predicted concentrations for areas with limited input of P, such as groundwater, and is more representative of forested regions. This resulted in a predicted in-lake P, Chl-a, and Secchi that were not significantly different than observed (Table 6). Vighi & Chiaudani TP was not calculated because no alkalinity data were available for Long Lake.

Table 13. MINLEAP Model Results for Long Lake.

Parameter	2008-2009 Long Lake Observed	MINLEAP Predicted NCHF Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	21	45 (±16)	18 (±5)
Chl-*a* (µg /L)	7	17.3 (±10.7)	4.5 (±2.6)
Secchi (m)	2.9	1.4 (±.6)	3.2 (±1.2)
P loading rate (kg/yr)	-	530	144
P retention (%)	-	0.72	0.58
P inflow conc. (µg/L)	-	159	43
Water Load (m/yr)	-	2.21	2.21
Outflow volume (hm^3/yr)	-	3.34	3.34
Residence time (yrs)	-	2.2	2.2
Vighi & Chiaudani		NA	NA

Stalker Lake (56-0437)



Stalker Lake is a 541-hectare (1,337 acre) lake located in southwestern Otter Tail County approximately seven miles southeast of Underwood, MN. Stalker Lake is dimictic and has a maximum depth of 29 m. The Pomme de Terre River outlet is located along the southwest shoreline of the lake. Stalker Lake's catchment watershed area is 14,856.2 hectares (36,710.6 acres) and has a catchment to lake surface area ratio of 27:1. The lake's catchment watershed is composed primarily of cropland, rangeland, and hardwood forest. Stalker Lake's morphometry is diverse with many humps and bars.

Water quality data from 2008-2009 indicate that Stalker Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to the NCHF standards (Table 7). Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant Figure 11. TSI data from 1994 to 2009 indicate a consistent trend of good water quality in Stalker Lake (Figure 12).

Table 7. Stalker Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Stalker Lake 2008-2009 Averages	20	7	3.2

Figure 11. Stalker Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

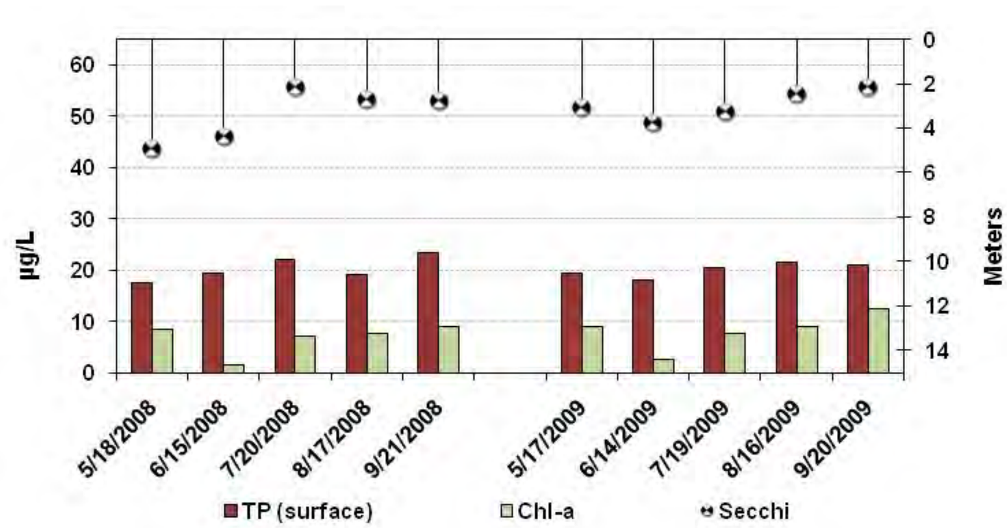
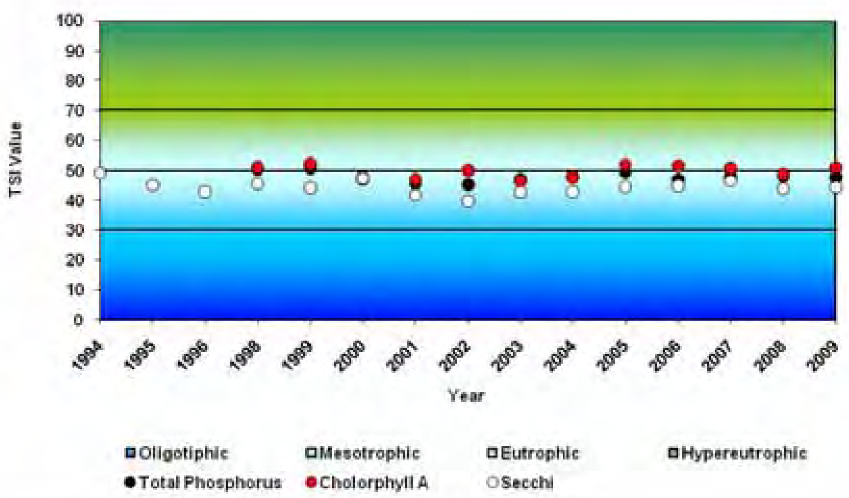


Figure 12. Stalker Lake Trophic Status Index Values
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

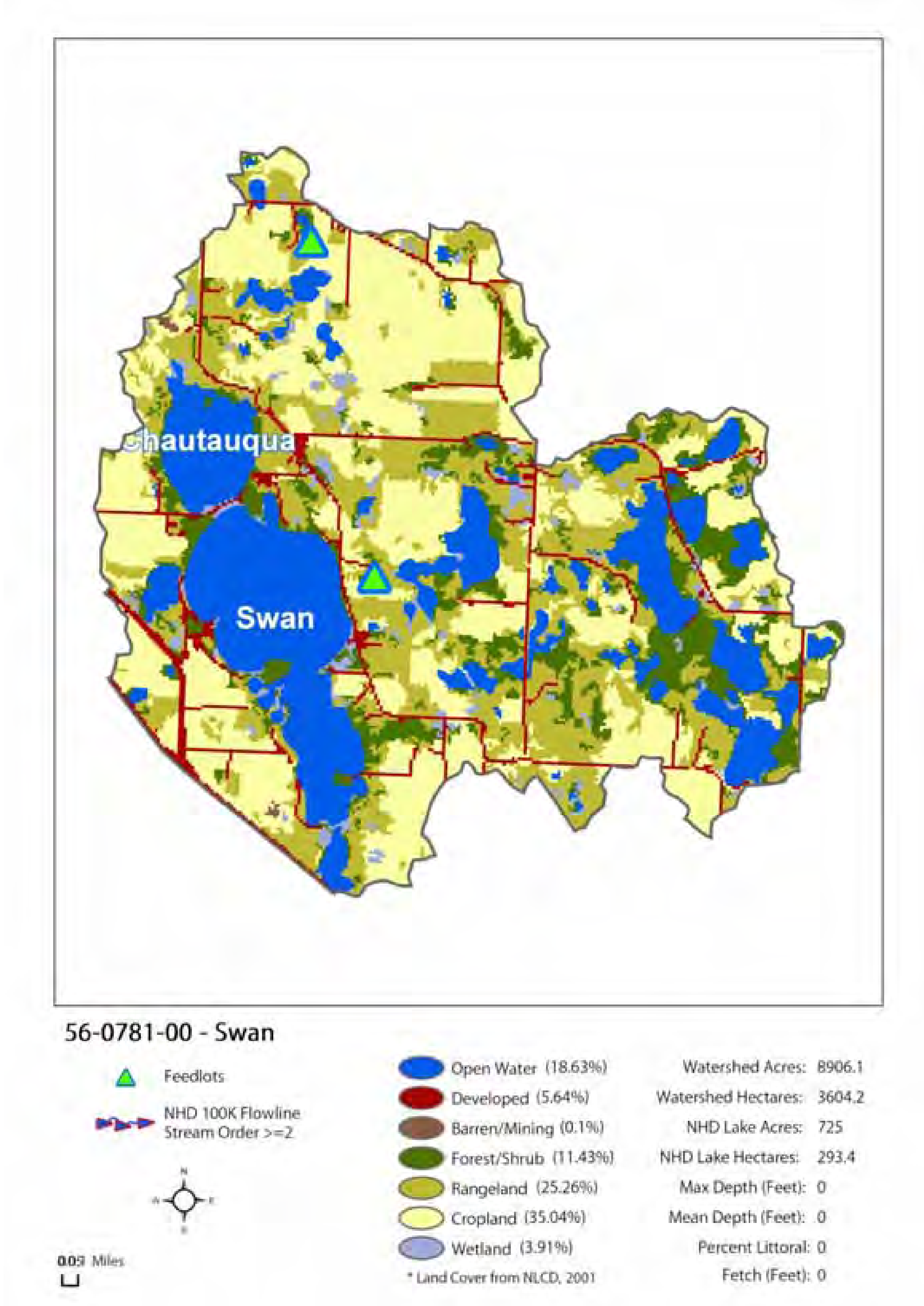


Stalker Lake was modeled run using NCHF ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for Stalker Lake are given in Table 8. The typical NCHF stream P inflow concentration in MINLEAP is 148 µg/L. This stream inflow value resulted in an overestimate of in-lake P as compared to observed (Table 8). In order to yield a more accurate estimate of the P loading rate to Stalker Lake stream P inflow concentration was calibrated based on measured values from Long Lake (56-0390) and at the inlet to Stalker (S004-565). In-lake concentrations for Long Lake (56-0390) were about 25 µg/L and Stalker Lake (S004-565) inlet averaged 74 µg/L based on data from1993-2002. Another inflow to Stalker Lake (culvert #33) was sampled from 1993-2003, but appears to be a point source and had an average P concentration of 822 µg/L so this value was not used in calibration of MINLEAP. A P value of 50 µg/L representing both the Stalker inlet (S004-565) and Long Lake (56-0390) inlet were used for calibration. This resulted in a predicted in-lake P, Chl-a, and Secchi that were not significantly different than observed (Table 8). Vighi & Chiaudani TP was not calculated because no alkalinity data were available for Stalker Lake.

Table 8. MINLEAP Model Results for Stalker Lake.

Parameter	2008-2009 Stalker Lake Observed	MINLEAP Predicted NCHF Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	20	48 (±16)	24 (±7)
Chl-a (µg /L)	7.0	19 (±11.6)	6.9 (±3.9)
Secchi (m)	3.2	1.4 (±.6)	2.5 (±1.0)
P loading rate (kg/yr)	-	3021	1128
P retention (%)	-	0.69	0.58
P inflow conc. (µg/L)	-	155	58
Water Load (m/yr)	-	3.61	3.61
Outflow volume (hm^3/yr)	-	19.53	19.53
Residence time (yrs)	-	1.7	1.7
Vighi & Chiaudani		NA	NA

Swan Lake (56-0781)



Swan Lake is a 293-hectare (725 acre) lake located in southwestern Otter Tail County approximately three miles southeast of Fergus Falls, MN. Swan Lake is dimictic and has a maximum depth of 13.4 m. The Pomme de Terre River outlet is located along the south shoreline of the lake. Swan Lake's catchment watershed area is 3,604.2 hectares (8,906.1 acres) and has a catchment to lake surface area ratio of 12:1. Land use is dominated by agricultural cropland and rangeland, with numerous small lakes throughout the watershed. A majority of the lakeshore has been developed.

Water quality data from 2008-2009 indicate that Swan Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to the NCHF standards (Table 9). Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant Figure 13. TSI data from 1986 to 2009 show a consistent trend of good water quality in Swan Lake (Figure 14).

Table 9. Swan Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Swan Lake 2008-2009 Averages	27	7	3.0

Figure 13. Swan Lake 200 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

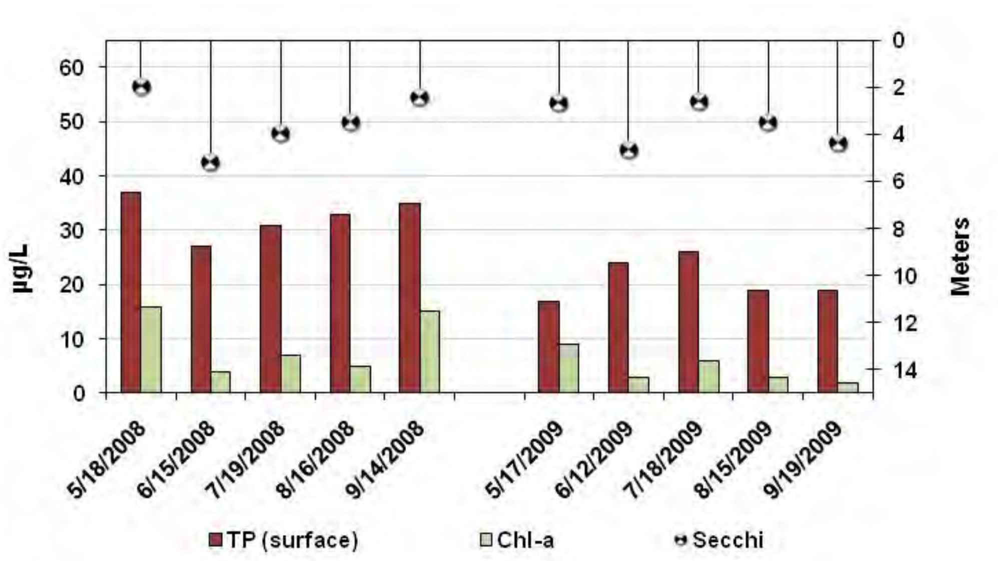
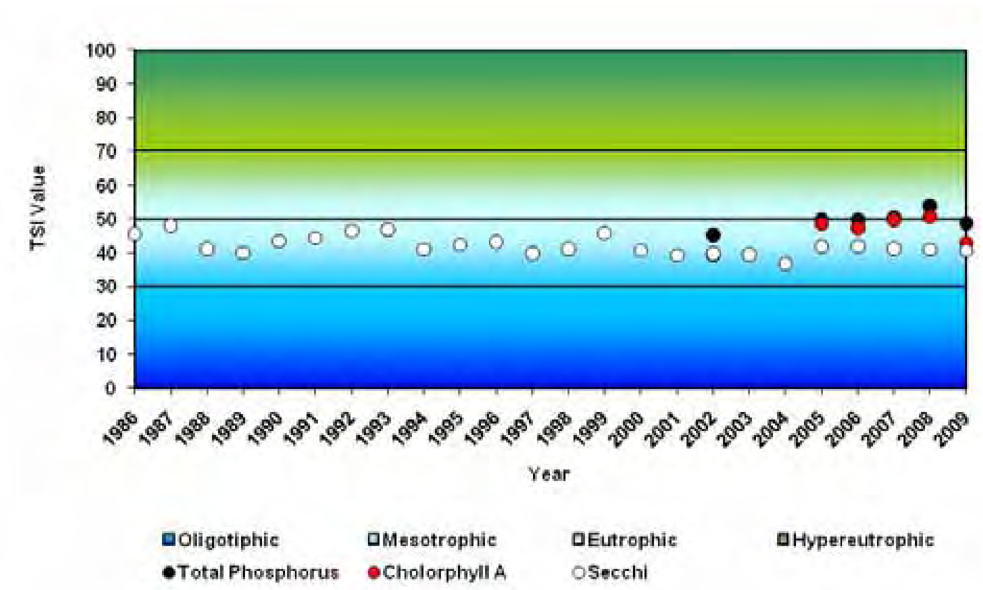


Figure 14. Swan Lake Trophic Status Index Values
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

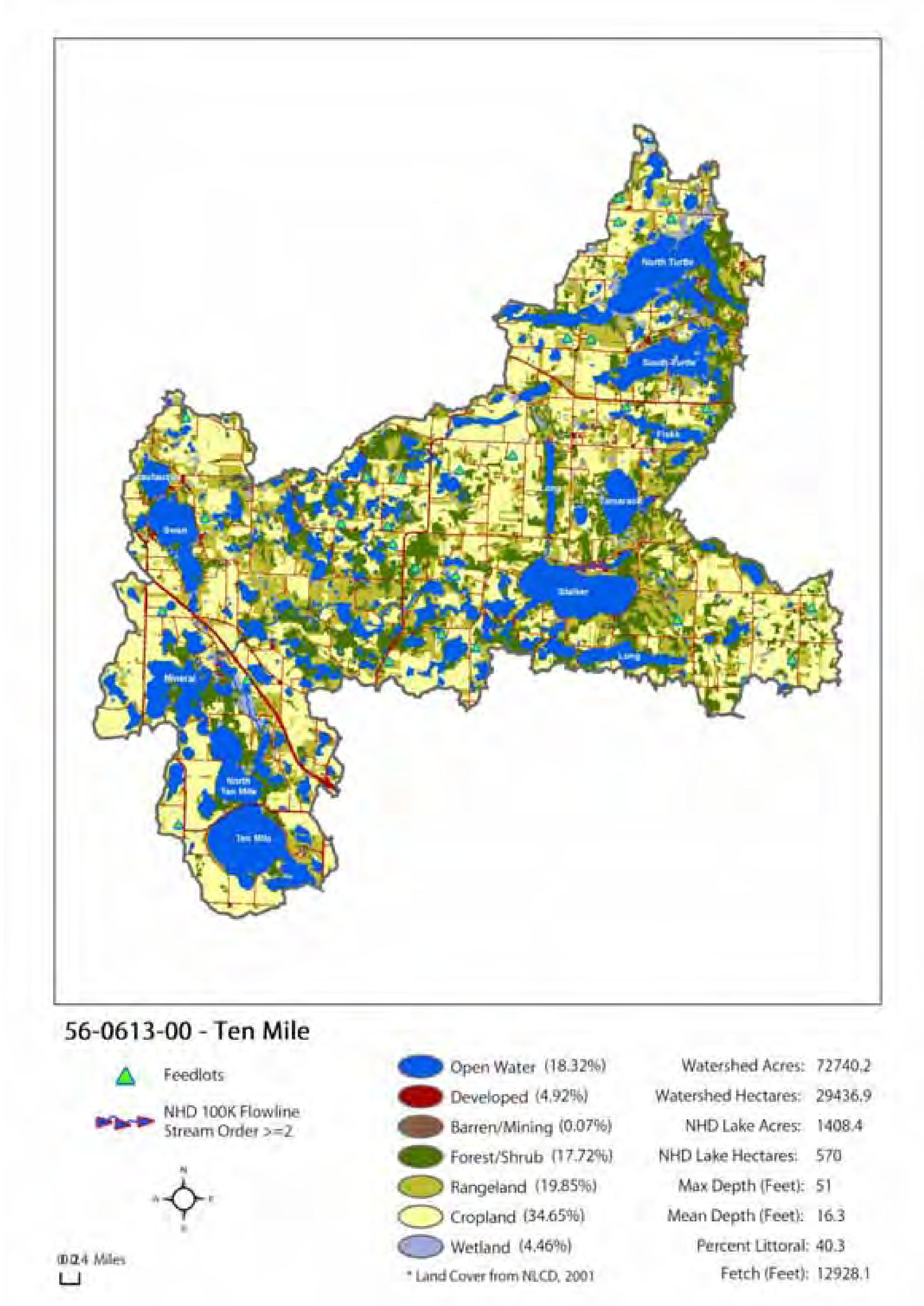


Swan Lake was modeled using NCHF ecoregion-based inputs. The observed TP, Chl-*a*, and Secchi values for Swan Lake are given in Table 10. Observations for 2008-2009 were compared to MINLEAP predictions. This resulted in a predicted in-lake P, Chl-a and Secchi that were not significantly different than observed (Table 10). Vighi & Chiaudani TP was not calculated because no alkalinity data was available for Swan Lake.

Table 10. MINLEAP Model Results for Swan Lake.

Parameter	2008-2009 Swan Lake Observed	MINLEAP Predicted
TP (µg/L)	27	38 (±14)
Chl-*a* (µg /L)	7.0	13.5 (±8.7)
Secchi (m)	3.0	1.7 (±0.7)
P loading rate (kg/yr)	-	781
P retention (%)	-	0.76
P inflow conc. (µg/L)	-	163
Water Load (m/yr)	-	1.64
Outflow volume (hm^3/yr)	-	4.80
Residence time (yrs)	-	3.4
Vighi & Chiaudani	-	NA

Ten Mile Lake (56-0613)



Ten Mile Lake is located in southwestern Otter Tail County approximately five miles southwest of Dalton, MN. Ten Mile Lake is dimictic and has a maximum depth of 15.2 m. Ten Mile Lake is a 570-hectare (1,408 acre) mesotrophic lake that is part of the Pomme de Terre River watershed. The Pomme de Terre River inlet is located along the north shore while the outlet is located along the south shore. The inlet is navigable by boat through a culvert into North Ten Mile Lake. Ten Mile Lake's watershed area is 29,436.9 hectares (72,740.2 acres) and has a watershed to lake surface area ratio of 52:1. Cropland, rangeland, and forests are the predominant land uses in the watershed; however, there are numerous upstream lakes that trap and process TP from watershed runoff, which minimizes downstream loading to Ten Mile Lake.

Water quality data from 2008-2009 indicate that Ten Mile Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to NCHF standards (Table 11). Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant Figure 15. TSI calculations made from 1992 to 2009 and show a trend of good water quality in Ten Mile Lake (Figure 16).

Table 11. Ten Mile Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Ten Mile Lake 2008-2009 Averages	23	6	2.7

Figure 15. Ten Mile Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

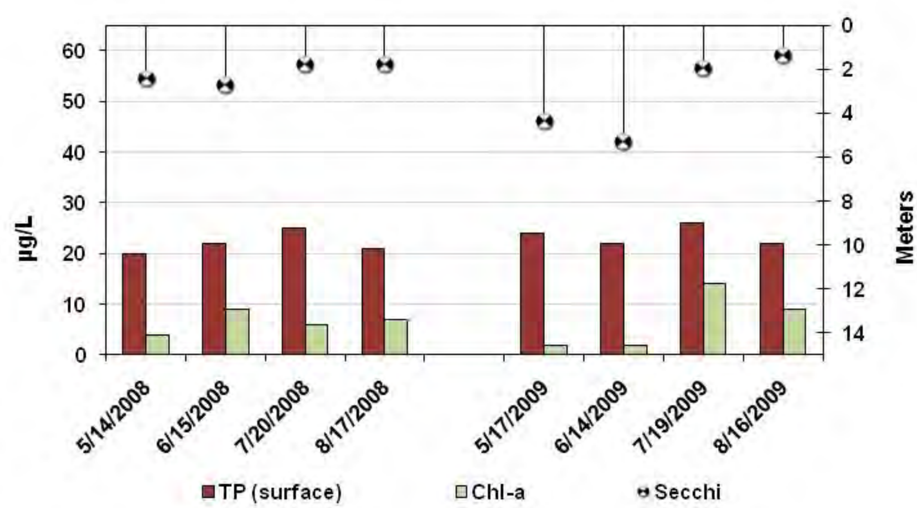
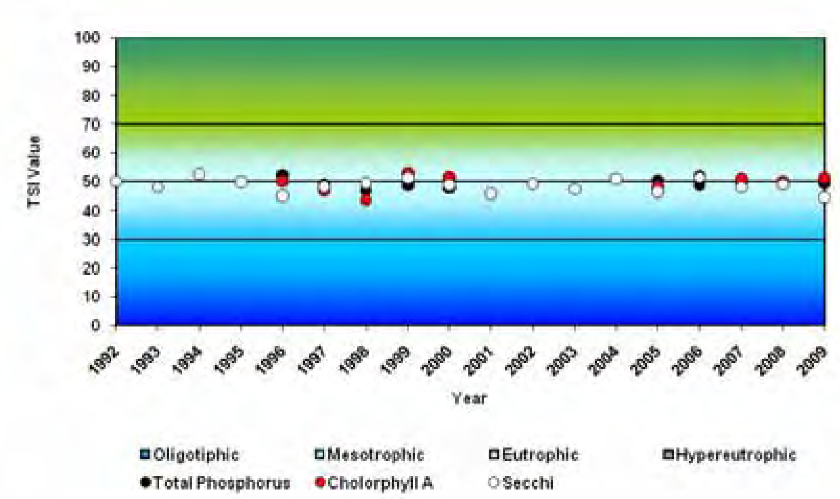


Figure 16. Ten Mile Lake Trophic Status Index Values Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

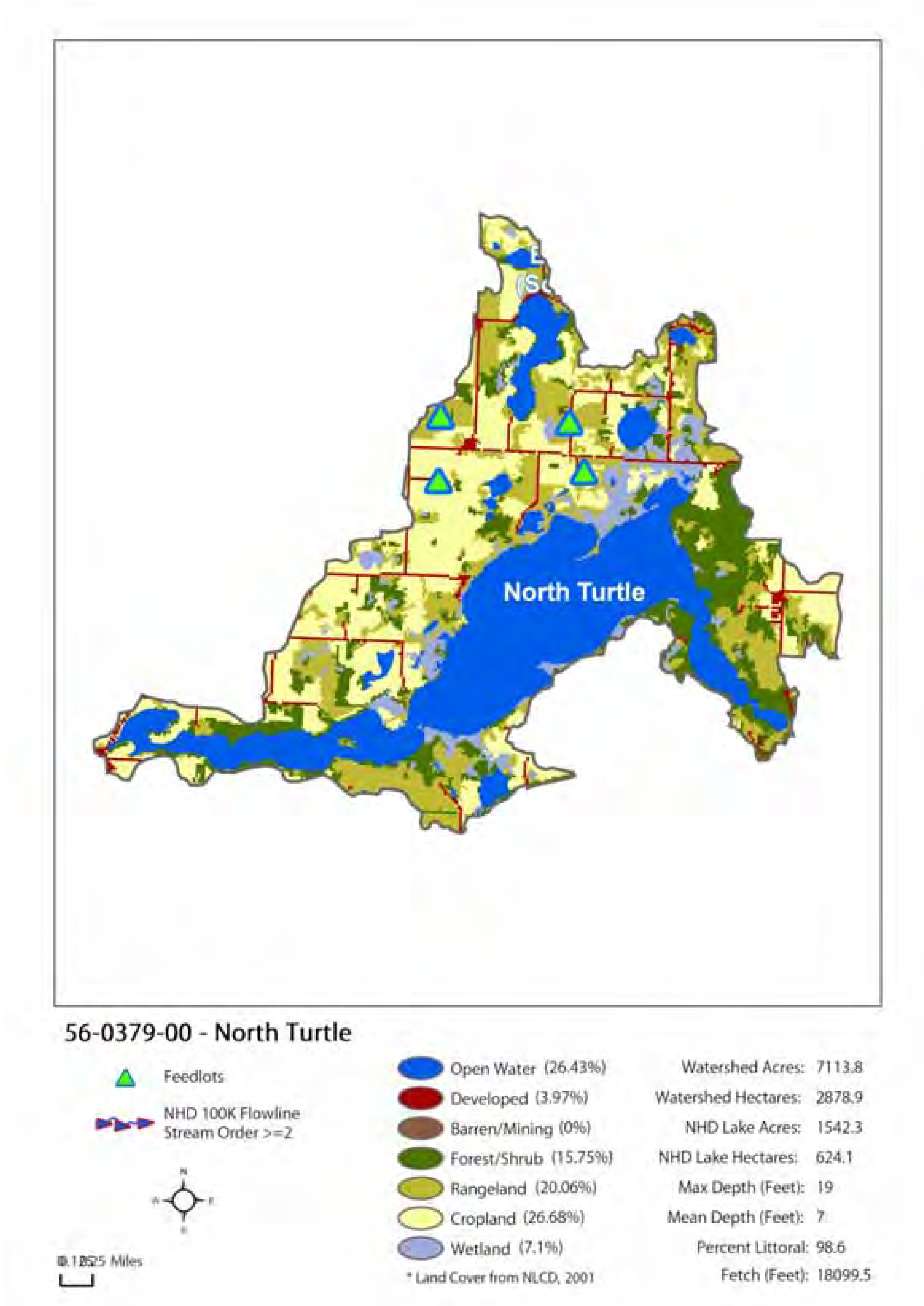


Ten Mile Lake was modeled using NCHF ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for Ten Mile Lake are given in Table 12. The typical NCHF stream P inflow concentration in MINLEAP is 148 µg/L. This stream inflow value resulted in an overestimate of in-lake P as compared to observed values (Table 12). In order to yield a more accurate estimate of the P loading rate to Ten Mile, the stream P inflow concentration was calibrated based on measured values form North Ten Mile Lake and the stream crossing at CSAH-35 which, is the main inlet to Ten Mile Lake. In-lake concentrations for North Ten Mile Lake were about 25 µg/L. Stream samples were also taken at the outlet of North Ten Mile biannually from 1993 to 2002. Concentrations over this time period averaged 37 µg/L. Since stream flow measurements were taken in June and October, inflows to Ten Mile Lake were assumed to be between lake and stream concentrations. Therefore, a P value of 35 µg/L was used for calibration. This resulted in a predicted in-lake P, Chl-a and Secchi that were not significantly different than observed (Table 12). Also, observed TP is similar to predicted background P (Table 12).

Table 12. MINLEAP Model Results for Ten Mile Lake.

Parameter	2008-2009 Ten Mile Lake Observed	MINLEAP Predicted NCHF Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	23	64 (±19)	23.0 (±6)
Chl-*a* (µg /L)	6.0	28.7 (±16.1)	6.3 (±3.2)
Secchi (m)	2.7	1.1 (±.4)	2.6 (±0.9)
P loading rate (kg/yr)	-	5835	1510
P retention (%)	-	0.58	0.42
P inflow conc. (µg/L)	-	152	39
Water Load (m/yr)	-	6.75	6.75
Outflow volume (hm^3/yr)	-	38.50	38.50
Residence time (yrs)	-	0.7	0.7
Vighi & Chiaudani		NA	26.8

North Turtle Lake (56-0379)



North Turtle Lake is a 624-hectare (1,542 acre) eutrophic lake located in central Otter Tail County immediately northeast of Underwood, MN. North Turtle Lake is likely polymictic with a maximum depth of 5.8 m. North Turtle Lake is part of the Otter Tail River watershed. There are no navigable inlets or outlets. North Turtle Lake's catchment area is 2,878.9 hectares (7,113.8 acres) and has a catchment to lake surface area ratio of 5:1. Land use mostly consists of agricultural cropland, rangeland, and forest/shrub land. There are also four feedlots in relatively close proximity to the lake. It is not know whether any direct runoff from these feedlots or land application sites reach North Turtle Lake.

Water quality data from 2008-2009 indicate that North Turtle lake has high concentrations of TP, Chl-a, and good Secchi transparency as compared to NCHF ecoregion standards (Table 13). Seasonal patterns in TP were not consistent among the two summers. In 2008, TP was rather stable throughout the summer averaging about 60-70 µg/L, while 2009 was marked by increasing TP from early to late summer with concentrations ranging from 60-120 µg/L. Accordingly, Chl-a was much higher in 2009 as compared to 2008 (Figure 17). Severe nuisance blooms were common in 2009. TSI calculations made from 2008 to 2009 and show water quality in North Turtle Lake is eutrophic and subject to nuisance algae blooms (Figure 18).

Table 13. North Turtle Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
North Turtle Lake 2008-2009 Averages	79	29	2.1

Figure 17. North Turtle Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

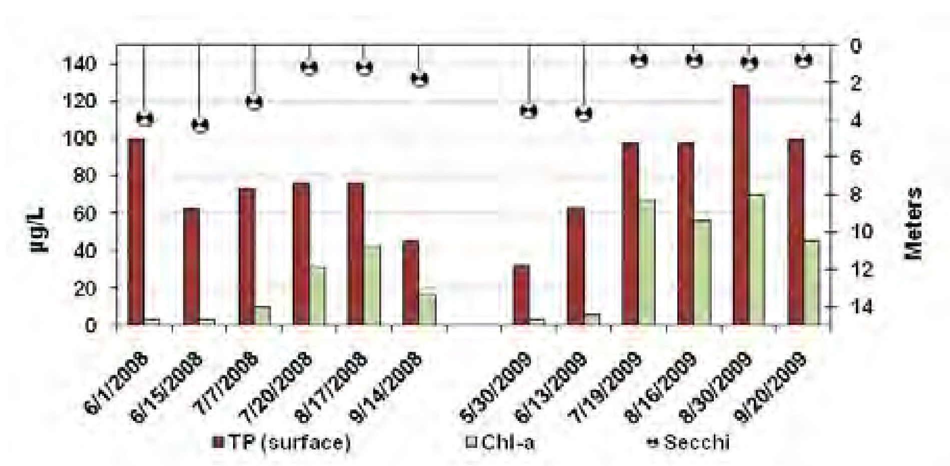
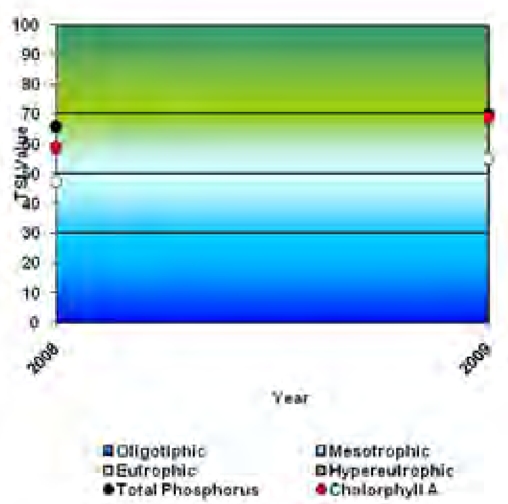


Figure 18. North Turtle Lake Trophic Status Index Values
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

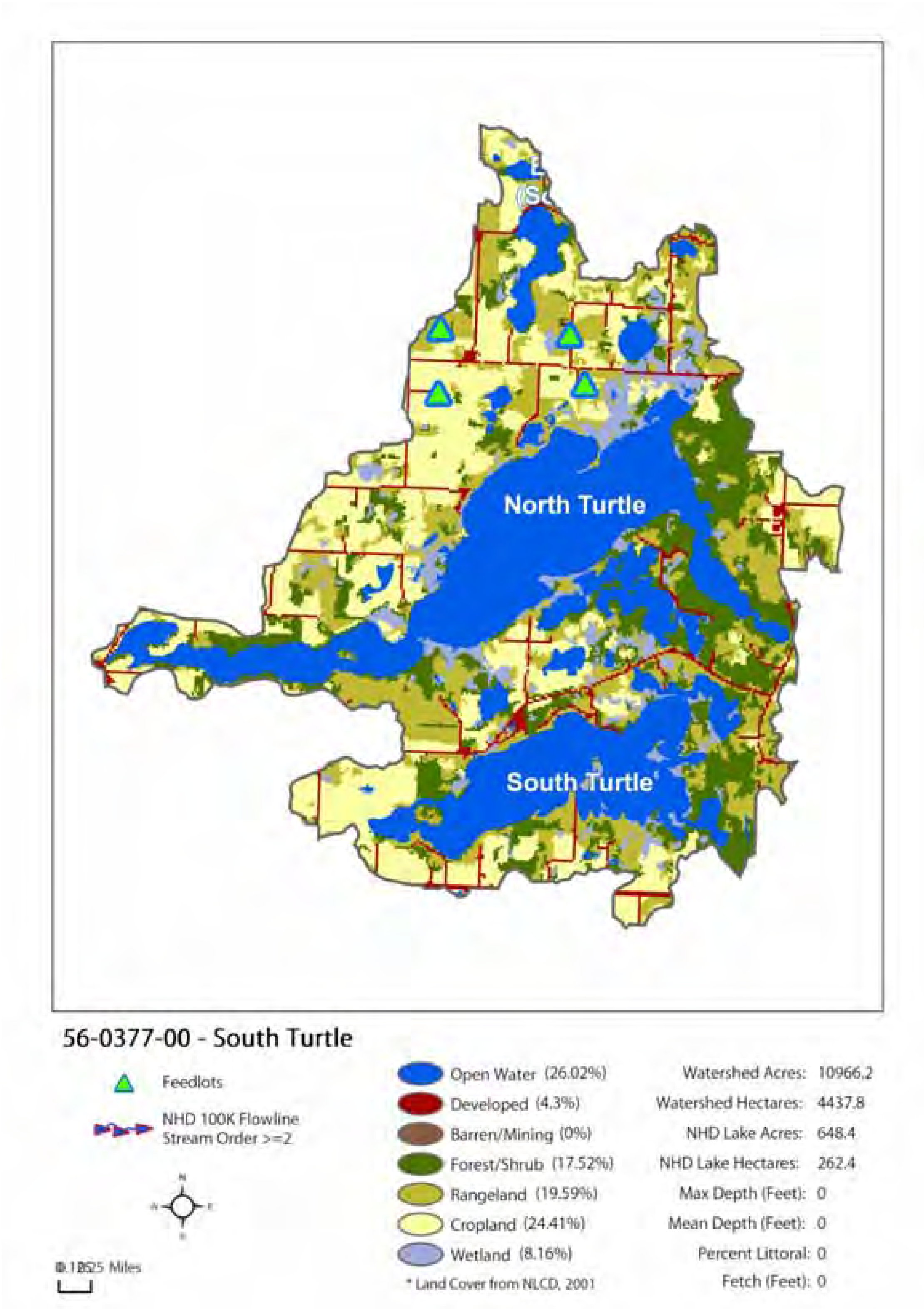


North Turtle Lake was modeled using NCHF ecoregion-based inputs. Observed TP is significantly higher than what is predicted for a lake of North Turtle's size, depth and watershed area in the NCHF. This results in much higher observed Chl-a values (Table 14). NCHF stream P inflow concentration in MINLEAP is 148 µg/L; however, given the high observed P it is likely that P inflow concentrations and loads are higher than the typical range.

Table 14. MINLEAP Model Results for North Turtle Lake.

Parameter	2008-2009 Observed	MINLEAP Predicted
TP (µg/L)	79	42 (±16)
Chl-*a* (µg /L)	29.0	15.6 (±10.1)
Secchi (m)	2.1	1.5 (±.7)
P loading rate (kg/yr)	-	741
P retention (%)	-	0.77
P inflow conc. (µg/L)	-	186
Water Load (m/yr)	-	0.64
Outflow volume (hm^3/yr)	-	3.99
Residence time (yrs)	-	3.3
Vighi & Chiaudani	-	NA

South Turtle Lake (56-0377)



South Turtle Lake is located in central Otter Tail County approximately four miles east of Underwood, MN. South Turtle Lake is a 262-hectare (648 acre) moderately fertile lake that is located within the Otter Tail River watershed. The lake's catchment area is 4,437.8 hectares (10,966.2 acres) and has a catchment to lake surface area ratio of 17:1. The immediate watershed is composed primarily of agricultural land interspersed with hardwood woodlots. The maximum depth is 10.7 m; however, 63 percent of the lake is less than 4.6 m deep. The north and west shorelines have been extensively developed. Homes, cottages, and resorts compose the majority of the development. The 1996 lake resurvey referenced 112 homes/cabins and two resorts/campgrounds. A state-owned public access is located 0.5 miles south of County Road 122 along the north shoreline of the lake. The shoal water substrates consist primarily of sand, gravel, and rubble. South Turtle Lake is composed of two distinct basins. The west basin is deeper and more developed. A large stand of hardstem bulrush is located along the east and south shorelines. The east basin is shallower, 4.6 m (15 feet) and less developed.

Water quality data from 2008-2009 indicate that South Turtle Lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to NCHF standards (Table 15). Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant Figure 19. TSI calculations made from 2002 to 2009 and show a trend of good water quality in South Turtle Lake (Figure 20).

Table 15. South Turtle Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
South Turtle Lake 2008-2009 Averages	15	3	6.1

Figure 19. South Turtle Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

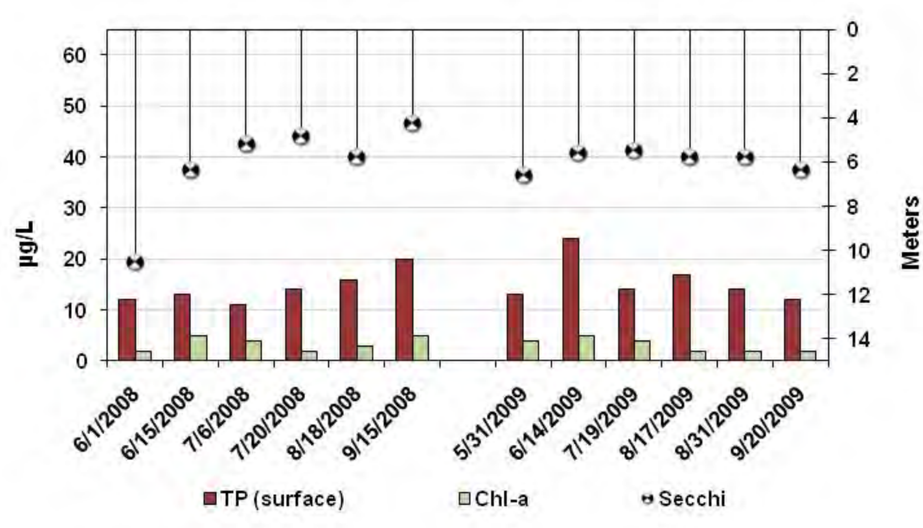
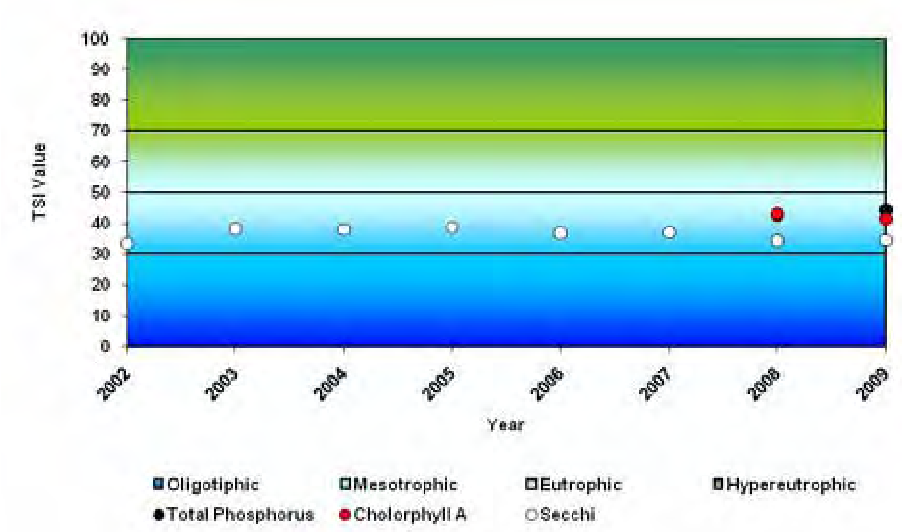


Figure 20. South Turtle Lake Trophic Status Index Values Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

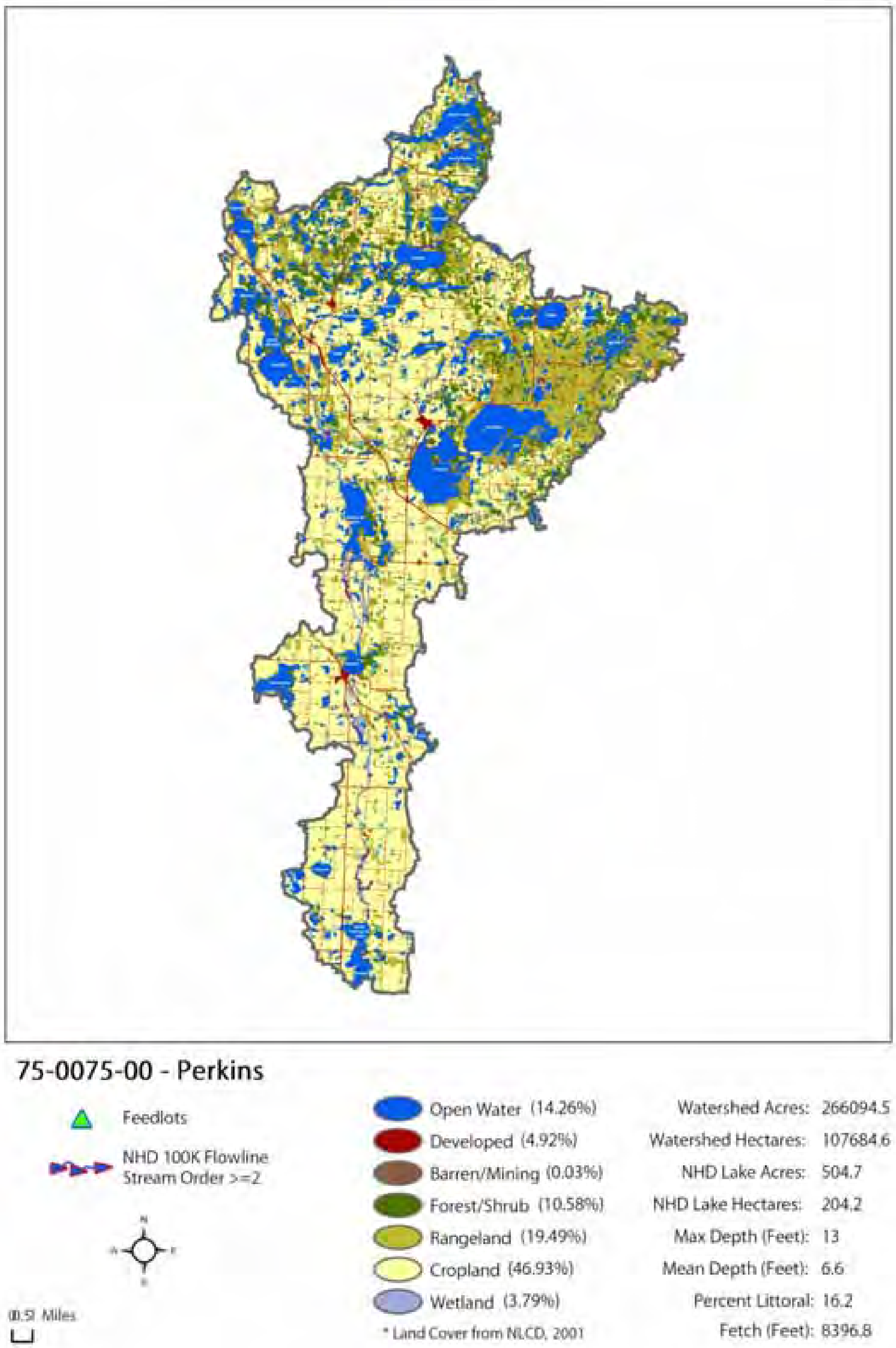


South Turtle Lake was modeled using NCHF ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for South Turtle Lake are given in Table 16. The typical NCHF stream P inflow concentration in MINLEAP is 148 µg/L. This stream inflow value resulted in an over estimate of in-lake P as compared to observed values (Table 16). In order to yield a more accurate estimate of the P loading rate to South Turtle Lake the stream P inflow concentration was calibrated based on measured values form North Turtle Lake. In-lake concentrations for North Turtle Lake were about 80 µg/L. This resulted in a predicted in-lake P, Chl-a, and Secchi that were slightly higher than observed values (Table 16). The two distinct basins of South Turtle Lake likely have different TP, Chl-a, and Secchi values. The shallow eastern basin receives the majority of P inflow which exits the lake through wetlands to the south. This causes the deeper western basin to receive only diffuse P inflows.

Table 16. MINLEAP Model Results for South Turtle Lake.

Parameter	2008-2009 South Turtle Lake Observed	MINLEAP Predicted NCHF Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	15	54 (±18)	36 (±11)
Chl-*a* (µg /L)	3.0	22.1 (±13.2)	12.5 (±7.2)
Secchi (m)	6.1	1.3 (±0.5)	1.7 (±0.7)
P loading rate (kg/yr)	-	935	540
P retention (%)	-	0.66	0.61
P inflow conc. (µg/L)	-	159	92
Water Load (m/yr)	-	2.24	2.24
Outflow volume (hm^3/yr)	-	5.89	5.87
Residence time (yrs)	-	1.4	1.4
Vighi & Chiaudani		NA	NA

Perkins Lake (75-0075)



Perkins Lake is 204-hectare (504 acre) shallow, turbid lake located on the Pomme de Terre River in Stevens County. It is located in the NGP portion of the Pomme de Terre River watershed. The lake is polymictic and has a maximum depth of 3.0 m. Perkins Lake catchment area is 107,684.5 hectares (266,094.5 acres) and has a catchment to lake surface area ratio of 527:1. Nearly half of the land use in the catchment is agricultural cropland. Large amounts of rangeland with interspersed forest/shrub land make up the remainder of the land use.

Poor water quality, lack of submerged aquatic vegetation, and degraded aquatic habitat has been described in lake survey reports since the initial survey in 1947. The river transports excessive amounts of nutrients and sediments through the lake. High TP and total suspended solids (TSS) concentrations have been documented in annual water quality monitoring conducted by the Perkins Lake Association. Observations of dense blue-green algae blooms are common in July and August. Water quality data from 2000-2001 indicate that Perkins Lake has high concentrations of TP and poor Secchi transparency as compared to the typical NCHF ecoregion values (Table 17). Concentrations for individual sampling events during the 2000-2001 field seasons appear to fluctuate throughout the open water season Figure 21. TSI calculations made from 1985 to 2002 show water quality in Perkins Lake is eutrophic/hypereutrophic and subject to nuisance algae blooms (Figure 22).

Table 22. Perkins Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7
Perkins Lake 2000-2001 Averages	126	18	0.67

Figure 21. Perkins Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

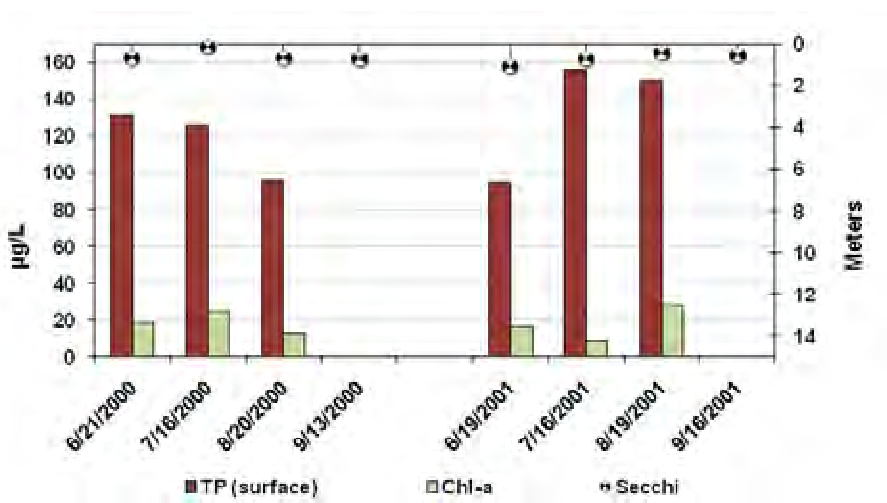
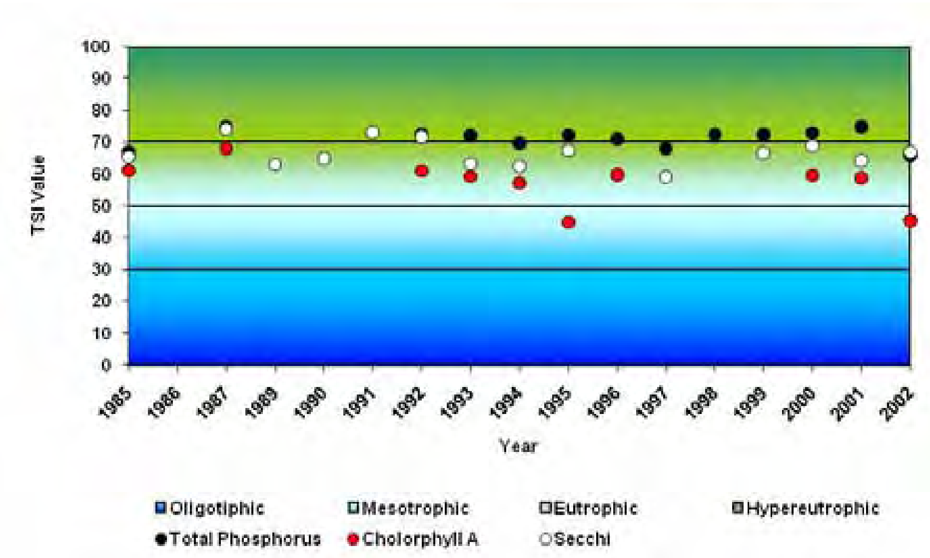


Figure 22. Perkins Lake Trophic Status Index Values
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

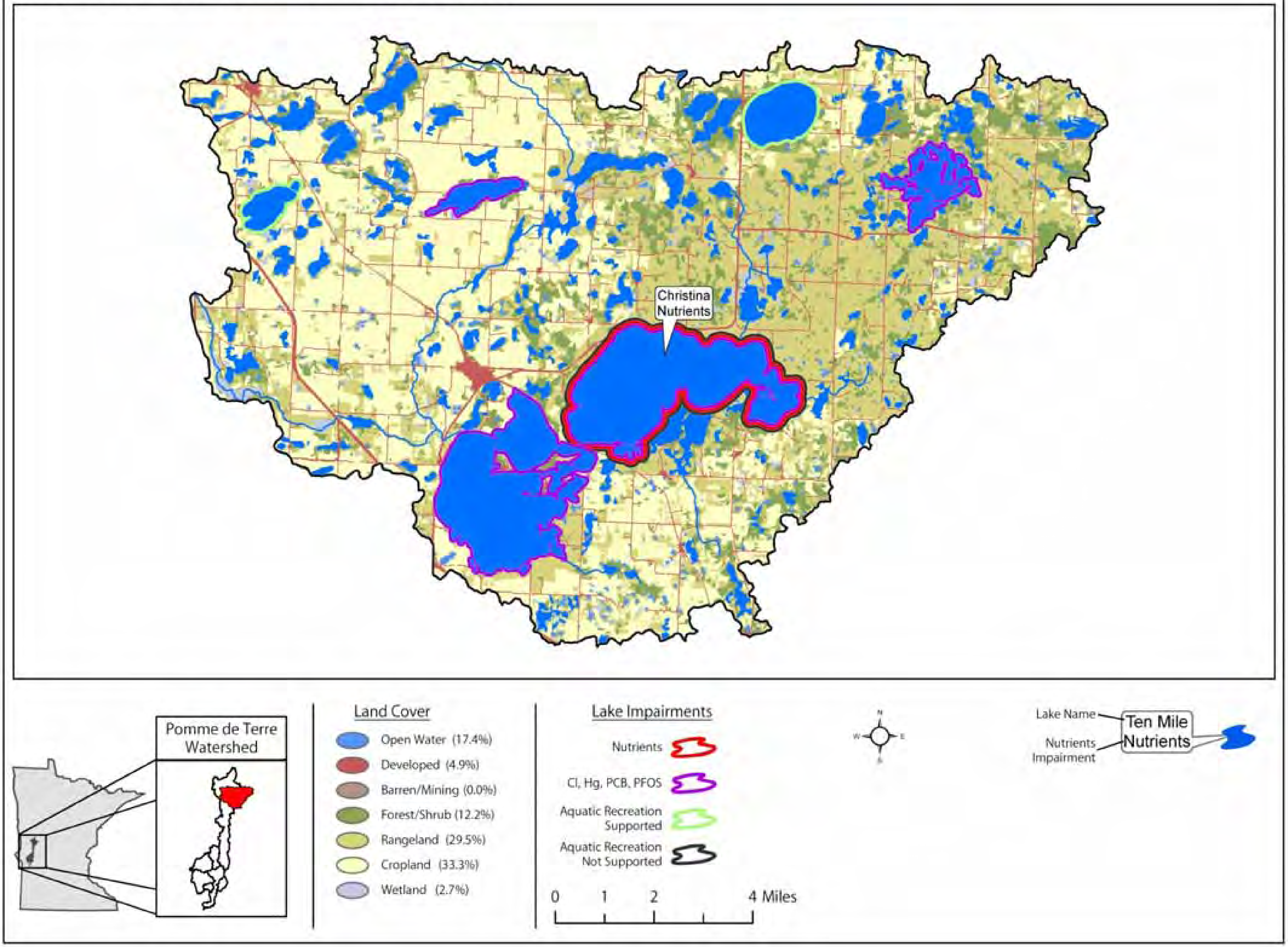


Perkins Lake is located in the NGP; however much of the upper watershed drains through the NCHF. Initially modeling was done using NGP ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for Perkins Lake are given in Table 18. The typical NGP stream P inflow concentration in MINLEAP is 1,500 µg/L, which accounts for high event-based P runoff and internal recycling and inefficient sedimentation, which is common in the shallow NGP lakes. This stream inflow value resulted in an over estimate of in-lake P as compared to observed (Table 18). The majority of Perkins watershed originates in the NCHF ecoregion and drains south through the Pomme de Terre River to Perkins. In order to yield a more accurate estimate of the P loading rate to Perkins the stream P inflow concentration was calibrated based on NCHF ecoregion values of 148 µg/L. In-lake concentrations for Middle Pomme de Terre Lake, which is directly upstream of Perkins, were examined but did not provide reasonable MINLEAP predictions. Modeling on Perkins Lake may be too complicated for MINLEAP. A large watershed, multiple ecoregions, and flow-through lakes present may challenges that other model maybe able to represent more thoroughly.

Table 18. MINLEAP Model Results for Perkins Lake.

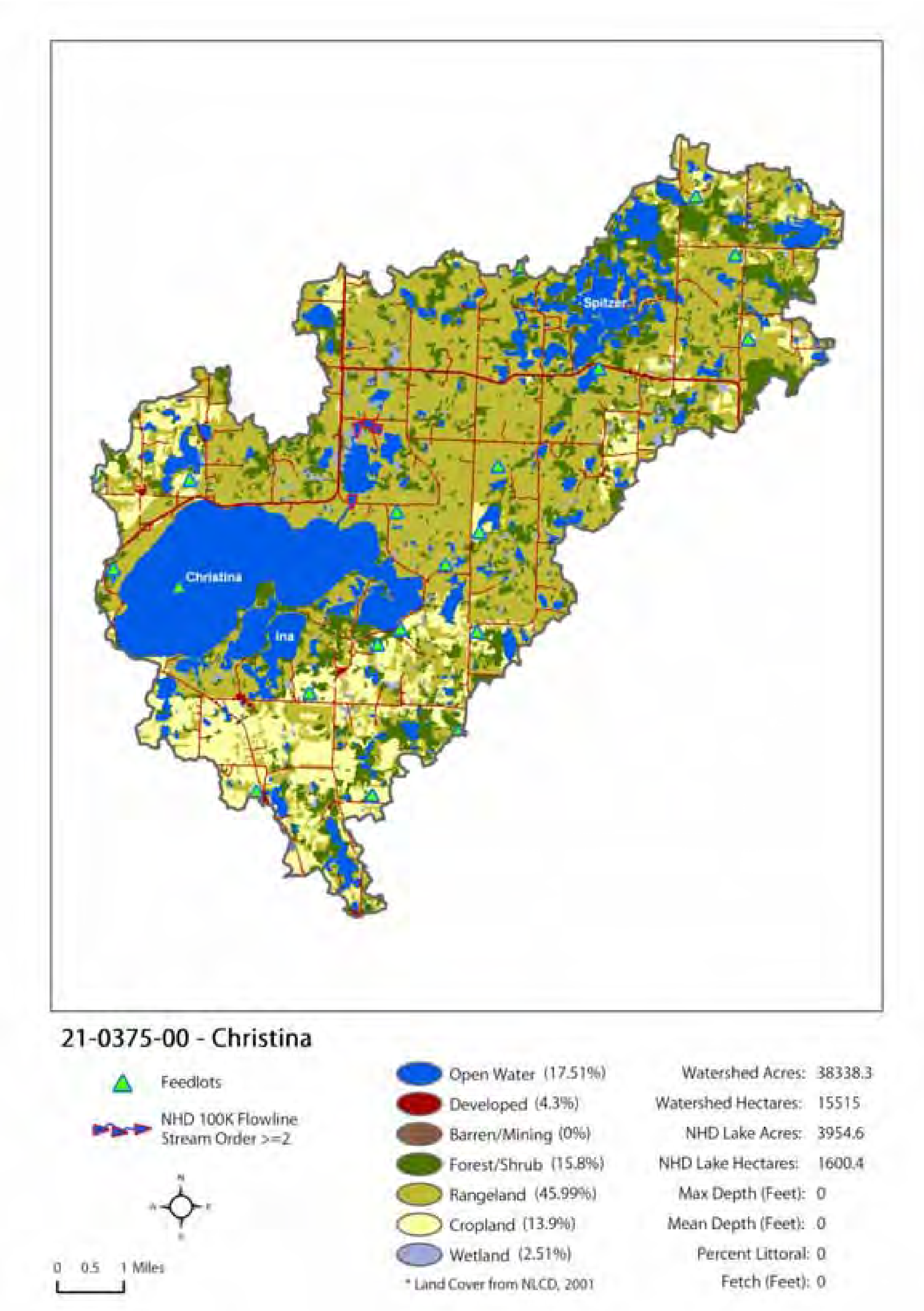
Parameter	2008-2009 Perkins Lake Observed	MINLEAP Predicted NGP Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	126	701 (±200)	120 (±24)
Chl-*a* (µg /L)	18.0	943.1 (±551)	71.7 (±33.1)
Secchi (m)	0.7	0.1 (±0.1)	0.6 (±0.2)
P loading rate (kg/yr)	-	80825	20780
P retention (%)	-	.54	.19
P inflow conc. (µg/L)	-	1508	148
Water Load (m/yr)	-	26.25	68.60
Outflow volume (hm^3/yr)	-	53.60	140.07
Residence time (yrs)	-	0.1	0.0
Vighi & Chiaudani		38.2	38.1

Pelican Creek Watershed Unit - HUC 07020002020



Pelican Creek (07020002020) HUC-11 watershed covers 17 percent of the Pomme de Terre River watershed. This 38,763 hectare (95,786 acre) watershed has a high density of lakes some of which are very large and relatively shallow. Land use is primarily cropland (33%), rangeland (30%) and forest/shrub (12.2%). Assessment of three lakes has occurred with two designated as full support and one not supporting (Table 2).

Lake Christina (21-0375)



Lake Christina is a large shallow, polymictic lake located just east of Ashby, MN The lake is nationally recognized as a critical staging area for migrating waterfowl. Management strategies have caused the lake to alter between a clear water state in which aquatic macrophytes are dominant and a turbid phase characterized by poor water clarity and high phytoplankton density. Rotenone treatments were used in 1987 and 2003 to reduce the existing fish community. This reduced disturbance and redistribution of sediments by fish activity have allowed aquatic macrophytes to reestablish, in turn improving water quality. Lake Christina will continue to be a Wildlife Management Lake and is closed to fishing.

Lake Christina has a robust water quality data set with readings periodically taken from 1965 through 2007. Water levels have changed 0.9 meters (2.97 feet) with 714 observations taken throughout the period of record. A summary of water quality data for the entire period of record and the most recent year of data are given in Table 19. Rotenone appears to have the greatest effect in years immediately following treatment, with results diminishing thereafter. Pre and post treatment effects can be seen in Figure 23. Rotenone was applied in the fall of 2003 and water quality data for 2006 shows a drastic reduction in the concentrations of TP, Chl-a, and improved Secchi transparency. Transitions from a turbid to clear water state are evident in the lakes TSI values (Figure 24). Further details may be found in Hanson et al. (2006).
http://files.dnr.state.mn.us/eco/nongame/projects/consgrant_reports/2006/swg_2006_hanson_etal.pdf

Table 20. Lake Christina Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Lake Christina –period of record Averages	75	33.3	0.6
Lake Christina –2003 Averages (Pre-Treatment)	89	39.7	0.3
Lake Christina –2006 Averages (Post-Treatment)	41	13.5	0.9

Figure 23. Lake Christina 2003 and 2006 Monthly Phosphorus, Chlorophyll-a, and Secchi.

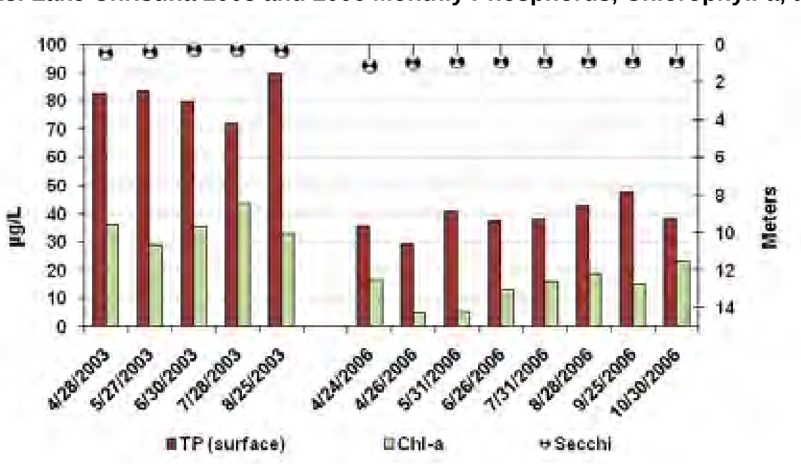
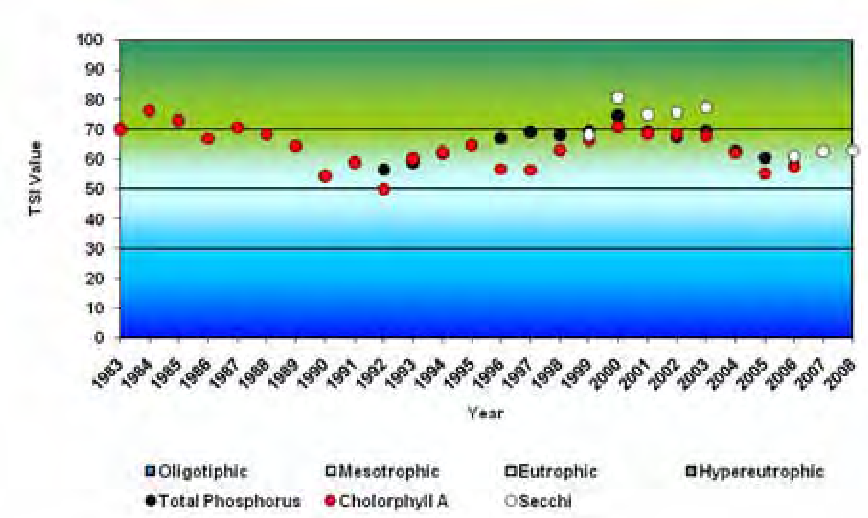


Figure 24. Lake Christina Trophic Status Index Values Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

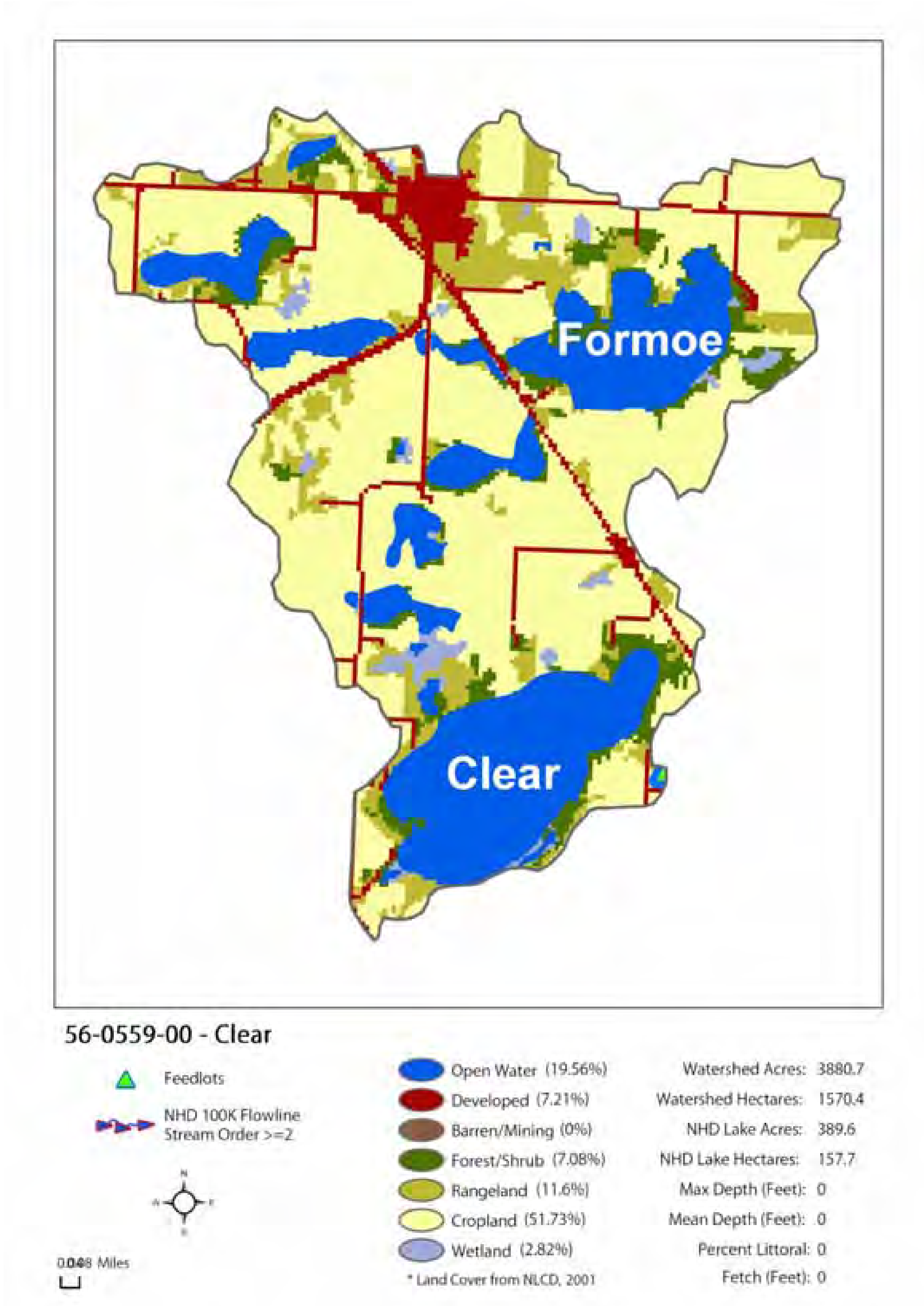


Lake Christina is located in the NCHF ecoregion and the MINLEAP model was run using NCHF ecoregion-based inputs. Observed TP, Chl-a, and Secchi values for Lake Christina are given in Table 20 for three time periods. Observations for pre-treatment, post-treatment, and entire record were compared to MINLEAP predictions. Post-treatment TP is about one-half the pre-treatment value. Chl-a is over two-fold lower and Secchi three-fold higher. Post-treatment values are similar to or lower than MINLEAP-predicted values (Table 20). 2006 post-treatment TP was below the NCHF shallow lakes criteria, while Chl-a and Secchi were very close to the criteria.

Table 20. MINLEAP Model Results for Lake Christina.

Parameter	Period of Record Observed	2003 Pre-Treatment Observed	2006 Post-Treatment Observed	MINLEAP Predicted
TP (µg/L)	74.0	89.0	40.0	59 (±19)
Chl-*a* (µg /L)	13.5	39.7	13.5	25.5 (±15)
Secchi (m)	0.9	0.3	0.9	1.1 (±0.5)
P loading rate (kg/yr)	-	-	-	3,465
P retention (%)	-	-	-	0.65
P inflow conc. (µg/L)	-	-	-	167
Water Load (m/yr)	-	-	-	1.30
Outflow volume (hm^3/yr)	-	-	-	20.81
Residence time (yrs)	-	-	-	1.2
Vighi & Chiaudani	-	-	-	39.1

Clear Lake (56-0559)



Clear Lake is a small 158-hectare (390 acre), mildly eutrophic lake located in southwest Otter Tail County approximately two miles south of Dalton, MN. Maximum lake depth is 8.8 m. Clear Lake's catchment area is 1,570 hectares (3,880 acres) and has a catchment to lake surface area ratio of 10:1. Land use is dominated by agricultural cropland and the lake catchment is relatively undeveloped.

Water quality samples were taken for chemistry from May through September 2008 and 2009 by CLMP volunteers along with Secchi readings which have been observed since 1999. The average TP and Chl-a concentrations for Clear Lake were well below impairment criteria for shallow lakes within the NCHF ecoregion (Table 21). Concentrations over the 2008 through 2009 sampling seasons are shown in Figure 25. Long-term trends in TSI values show that the water quality in Clear Lake has remained relatively constant (Figure 26).

Table 21. Clear Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Clear Lake 2008-2009 Averages	37	13	2.4

Figure 25. Clear Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

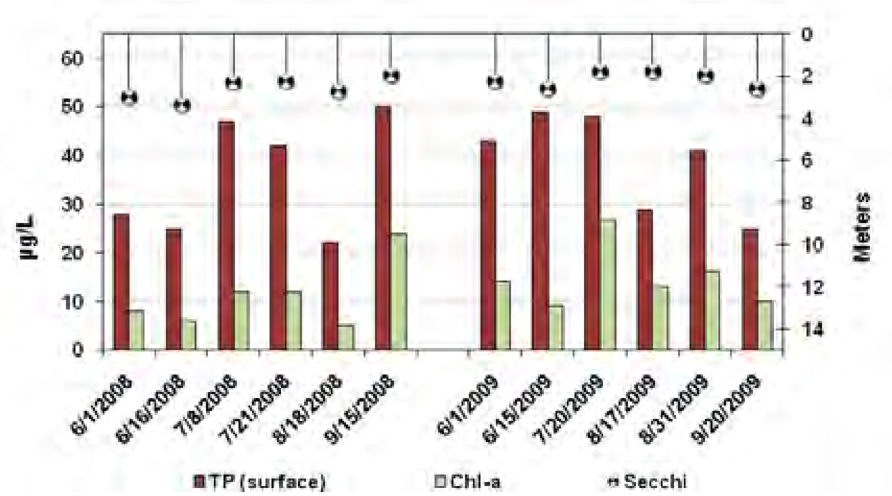
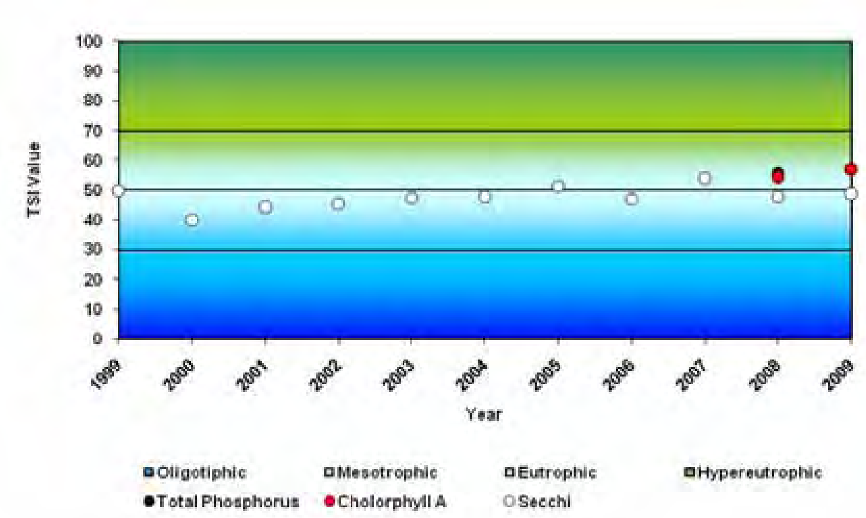


Figure 26. Clear Lake Trophic Status Index Values
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

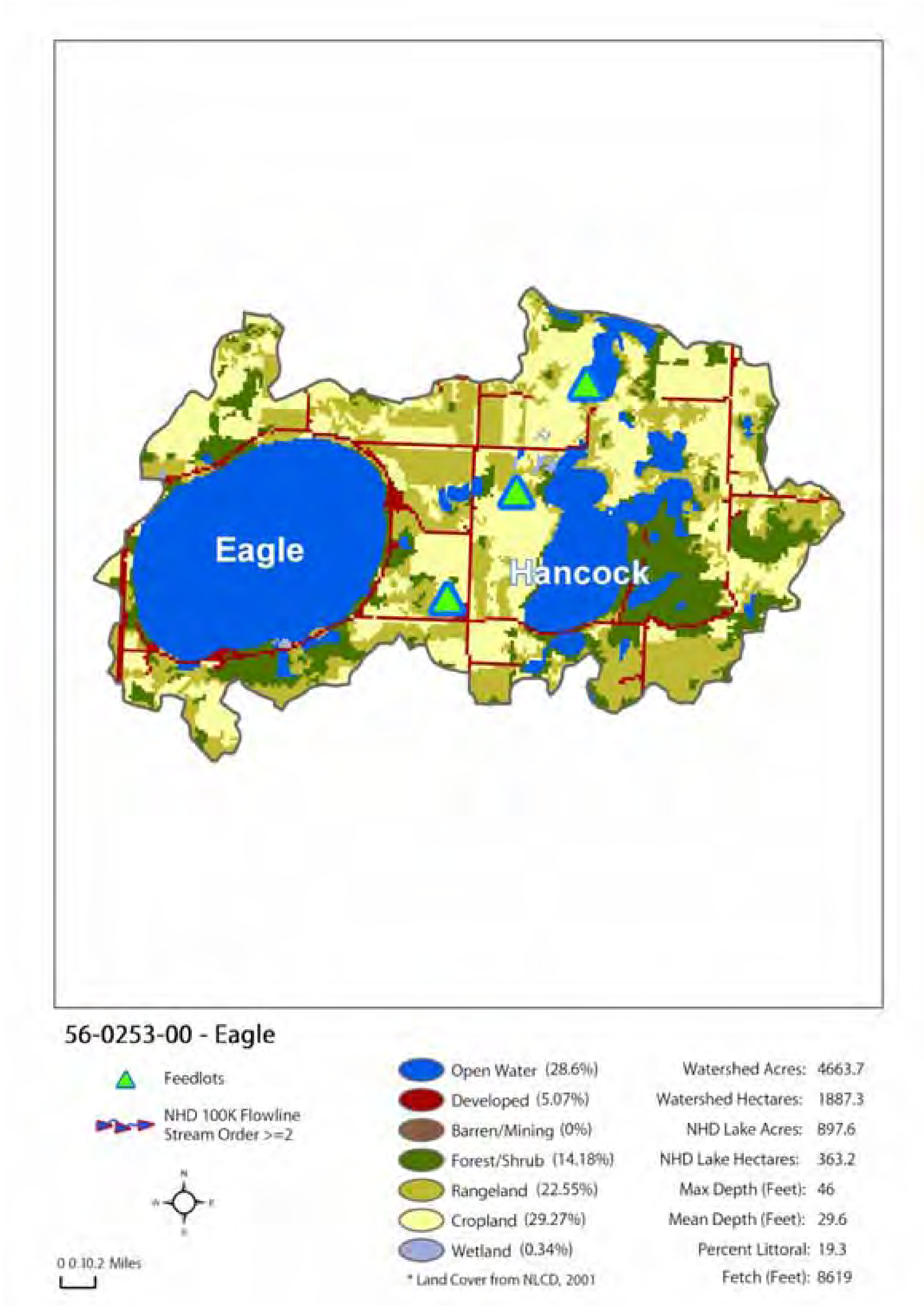


Clear Lake is located in the NCHF ecoregion and the model was run using NCHF ecoregion-based inputs. Observed and predicted TP, Chl-a, and Secchi values for Clear Lake are given in Table 22. Observed and predicted values were in close agreement, which implies that Clear Lake's trophic status is quite close to that predicted for a lake of its size and depth in the NCHF ecoregion. Vighi & Chiaudani TP was not calculated because no alkalinity data were available for Clear Lake.

Table 22. MINLEAP Model Results for Clear Lake.

Parameter	2008-2009 Observed	MINLEAP Predicted
TP (µg/L)	37.0	37 (±14)
Chl-*a* (µg /L)	13.0	13.1 (±8.5)
Secchi (m)	2.4	1.7 (±0.7)
P loading rate (kg/yr)	-	349
P retention (%)	-	0.78
P inflow conc. (µg/L)	-	166
Water Load (m/yr)	-	1.33
Outflow volume (hm^3/yr)	-	2.10
Residence time (yrs)	-	3.7
Vighi & Chiaudani	-	NA

Eagle Lake (56-0253)



Eagle Lake is a 363-hectare (898 acre) mesotrophic lake located in south-central Otter Tail County approximately eight miles south of Battle Lake, MN. Eagle Lake is dimictic and has a maximum depth of 14 m. The catchment area is 1,887.3 hectares (4,663.7 acres) and has a catchment to lake surface area ratio of 5:1. Land use mostly consists of agricultural cropland, rangeland, forest/shrub land and open water.

Water quality data from 2008-2009 indicate that Eagle lake has low concentrations of TP, Chl-a, and good Secchi transparency as compared to the typical NCHF ecoregion values (Table 23). Concentrations for individual sampling events during the 2008-2009 field seasons remain relatively constant Figure 27.TSI calculations made from 1970 to 2009 show a trend of good water quality in Eagle Lake (Figure 28).

Table 23. Eagle Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2B)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
Eagle Lake 2008-2009 Averages	7	3	5.7

Figure 27. Eagle Lake 2008 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

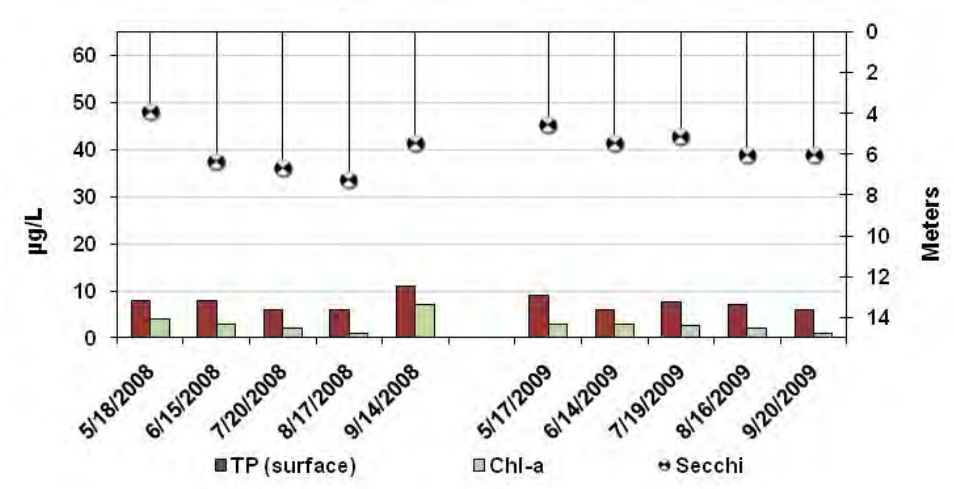
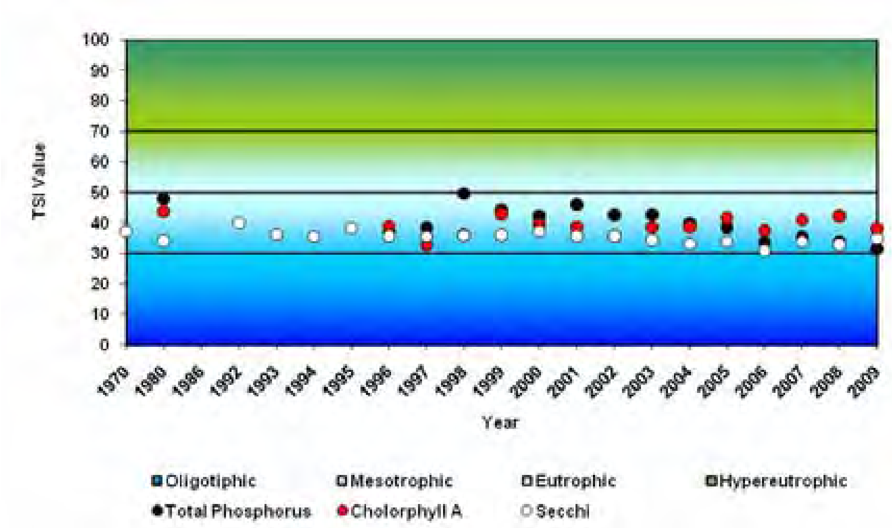


Figure 28. Eagle Lake Trophic Status Index Values Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

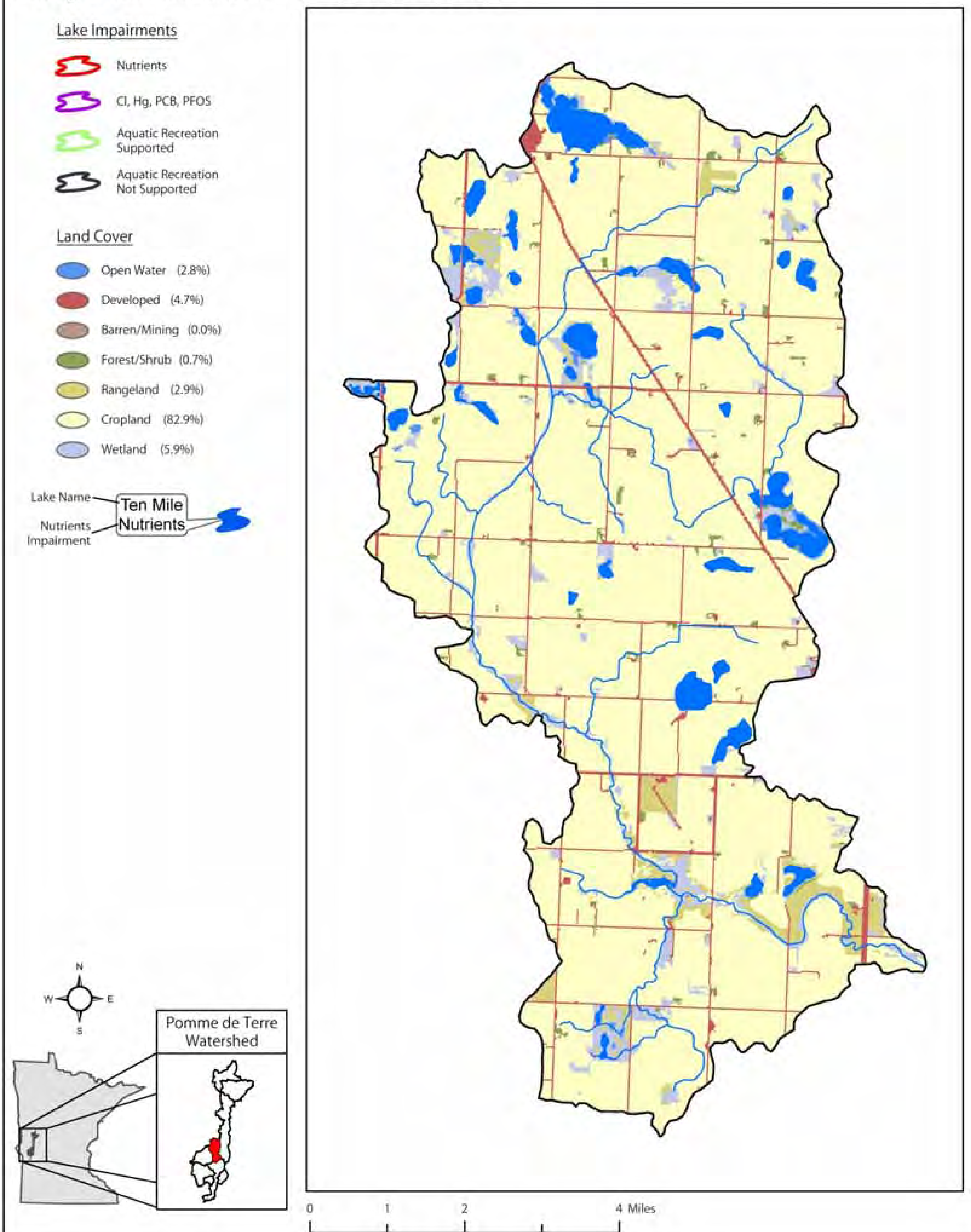


Eagle Lake is located in the NCHF ecoregion and the model was run using NCHF ecoregion-based inputs. The observed TP, Chl-a, and Secchi values for Eagle Lake are given in Table 24. The typical NCHF stream P inflow concentration in MINLEAP is 148 µg/L. This stream inflow value and the lack of an outlet for the lake (model assumes outflow from the lake) resulted in an overestimate of in-lake P as compared to observed (Table 24). In order to yield a more accurate estimate of the P loading rate to Eagle Lake, the stream P inflow concentration was calibrated. A P value of 0 µg/L was used for calibration because there are no surface inlets to the lake. Using 0 µg/L may be unrealistic; however, it provides a basis for improving the estimated P budget for the lake and reflects the difficulty in developing estimates for groundwater-dominated lakes. This resulted in a predicted in-lake P, Chl-a, and Secchi that were not significantly different than observed (Table 24).

Table 24. MINLEAP Model Results for Eagle Lake.

Parameter	2008-2009 Eagle Lake Observed	MINLEAP Predicted NCHF Ecoregion	MINLEAP Calibrated NCHF Ecoregion
TP (µg/L)	7.0	23 (±9)	9 (±3)
Chl-*a* (µg /L)	3.0	6.4 (±4.5)	1.7 (±1.1)
Secchi (m)	5.7	2.6 (±1.2)	5.7 (±2.4)
P loading rate (kg/yr)	-	472	109
P retention (%)	-	0.87	0.78
P inflow conc. (µg/L)	-	182	42
Water Load (m/yr)	-	0.72	0.72
Outflow volume (hm^3/yr)	-	2.60	2.60
Residence time (yrs)	-	12.6	12.6
Vighi & Chiaudani		22.7	22.8

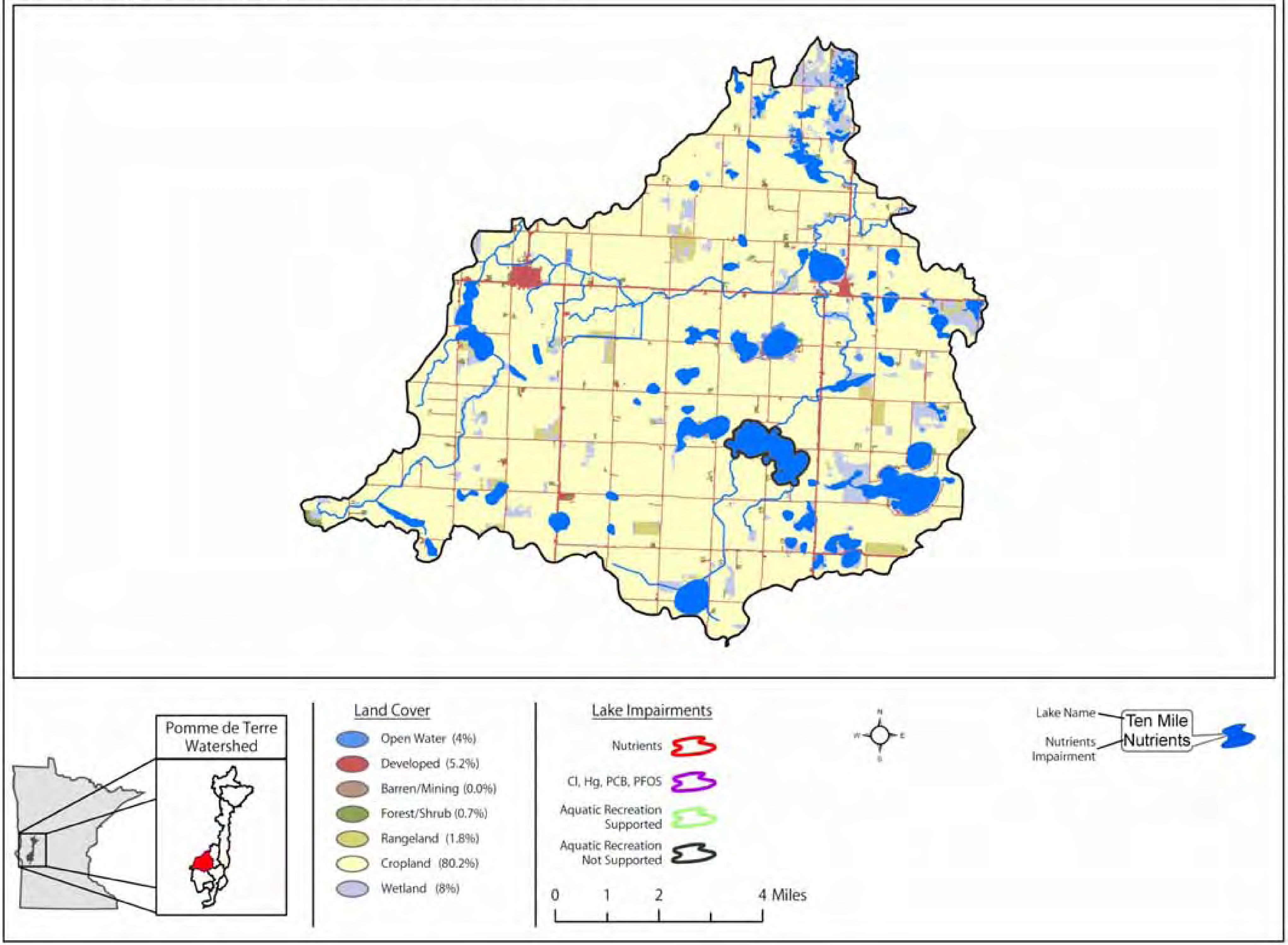
Muddy Creek Watershed Unit - HUC 07020002040



Muddy Creek Watershed– No Aquatic Recreation Lakes

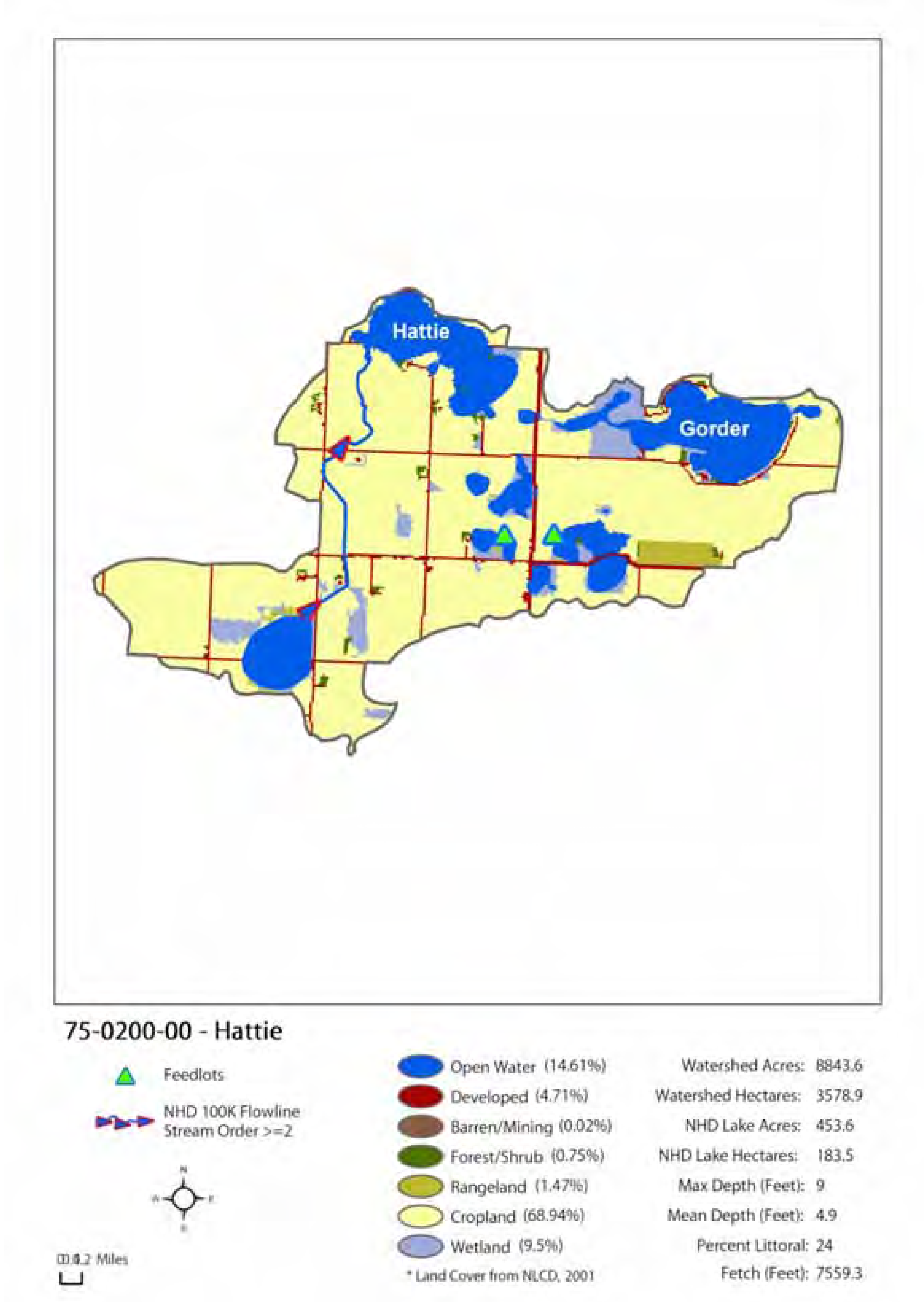
Muddy Creek (07020002040) HUC-11 watershed covers 7 percent of the Pomme de Terre River Watershed. This 15,169 hectare (37,484 acre) watershed only has two lakes and land use is almost exclusively cropland (83%). At this time no assessment level data have been collected for either lake.

Little Muddy Creek Watershed Unit - HUC 07020002030



Little Muddy Creek (07020002030) HUC-11 watershed covers 9 percent of the Pomme de Terre River Watershed. This 21,215 hectare (52,424 acre) watershed has 11 lakes and land use is primarily cropland (80%). Assessment of one lake, Hattie, has occurred and it was found to be not supporting (Table 2).

Hattie Lake (75-0200)



Hattie Lake is a hypereutrophic, shallow, turbid, polymictic lake located in Stevens County three miles south of Alberta, MN in the NGP ecoregion. Hattie Lake's catchment watershed area is 3,578.9 hectares (8,843.6 acres) and has a large catchment to lake surface area ratio of 19:1. Land use is dominated by agricultural cropland and the lake catchment is relatively undeveloped.

Water quality data have been collected periodically from 1985 through 2009. Hattie was used as a NGP reference lake in the 1980s, which accounts for the earlier samplings (Heiskary and Wilson 2005). The most recent two years of data show that extremely high TP and Chl-a concentrations, which promote severe algal blooms (Figure 29). Mid- to late-summer peaks in TP are evident in both years (Figure 29).TSI values for the entire record confirm that Hattie Lake has been hypereutophic for some time (Figure 30). Water quality data for 2009 are compared to NGP lake eutrophication standards in Table 25.

Table 25. Hattie Lake Compared to Eutrophication Standards by Ecoregion and Lake Type.

Ecoregion	TP	Chl-*a*	Secchi
	µg/L	µg/L	meters
NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7
Hattie Lake 2003 and 2009 Averages	305	79	0.7

Figure 29. Hattie Lake 2003 and 2009 Monthly Phosphorus, Chlorophyll-a, and Secchi.

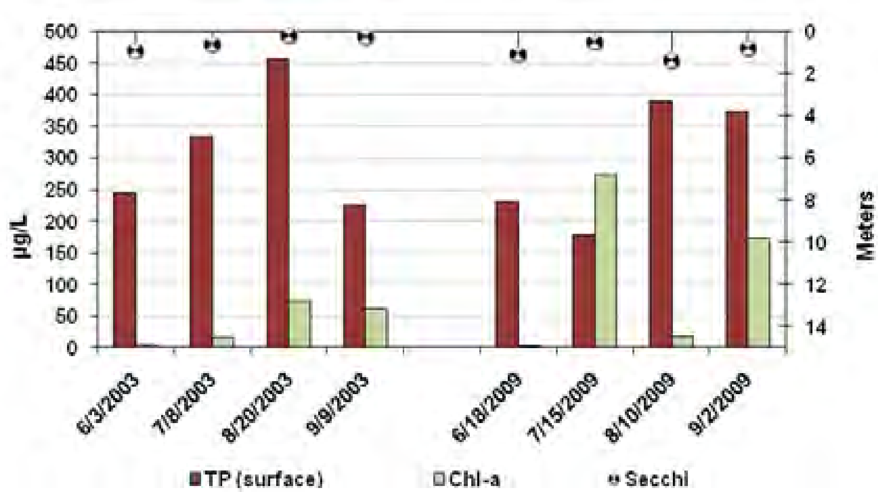
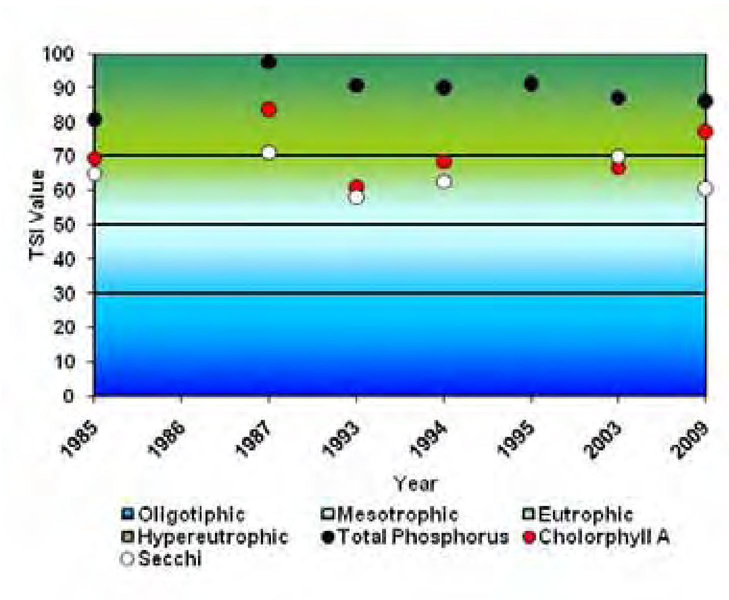


Figure 30. Hattie Lake Trophic Status Index Values.
Based on Summer Mean Total Phosphorus, Chlorophyll-a, and Secchi.

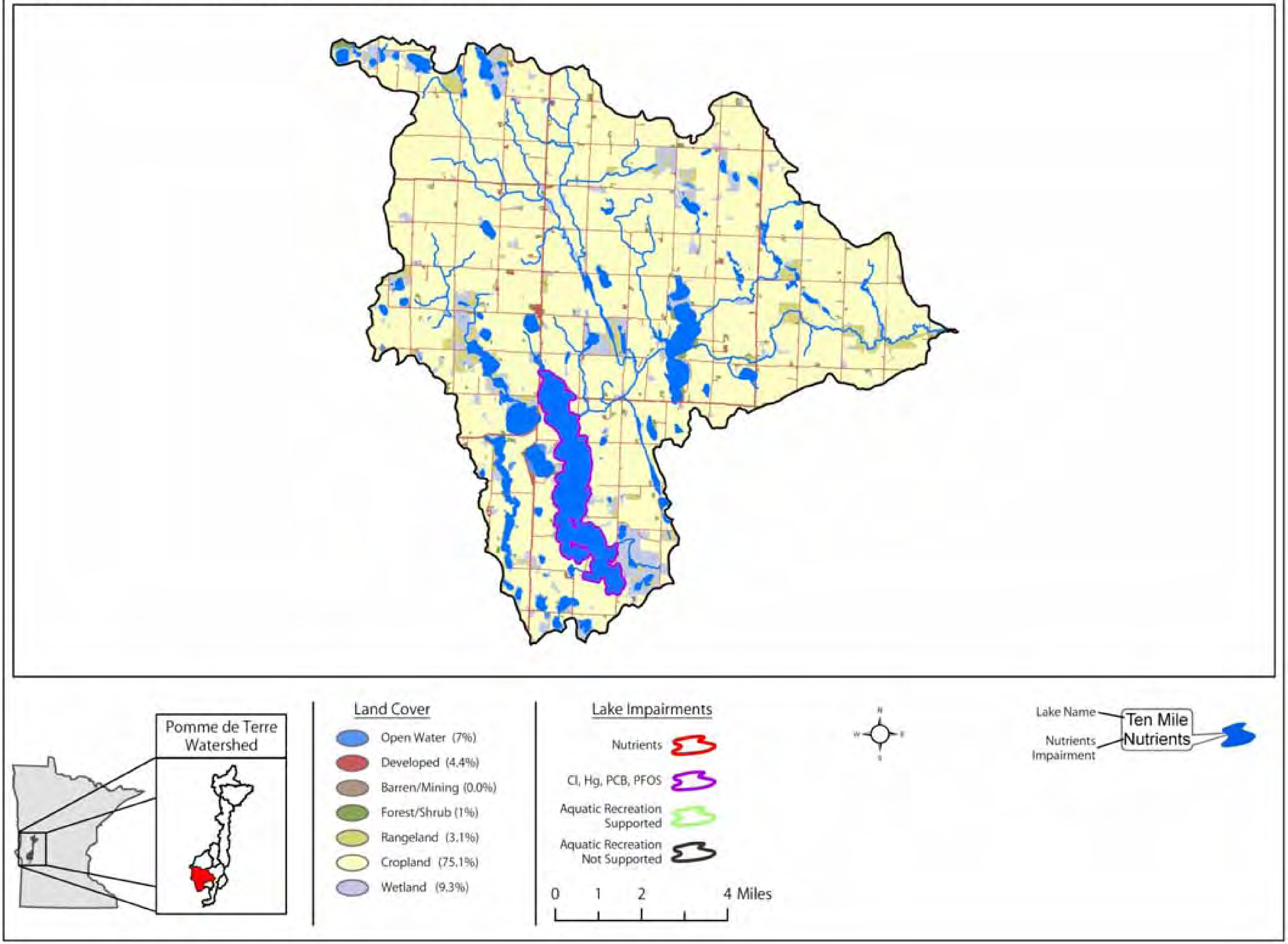


Hattie Lake was modeled using NGP ecoregion-based inputs. MINLEAP predicted in-lake P, Chl-a, and Secchi that were not significantly different than observed. Hattie most likely receives excessive nutrient loading from both external (watershed) and internal sources (Table 26).

Table 26. MINLEAP Model Results for Hattie Lake.

Parameter	2003-2009 Observed	MINLEAP Predicted
TP (µg/L)	305	226 (±93)
Chl-*a* (µg /L)	79	181.3 (±126.4)
Secchi (m)	0.7	0.4 (±.2)
P loading rate (kg/yr)	-	2739
P retention (%)	-	0.87
P inflow conc. (µg/L)	-	1746
Water Load (m/yr)	-	0.86
Outflow volume (hm^3/yr)	-	1.57
Residence time (yrs)	-	1.8
Vighi & Chiaudani	-	38.6

Drywood Creek Watershed Unit - HUC 07020002060



Drywood Creek Watershed – No Aquatic Recreation Lakes

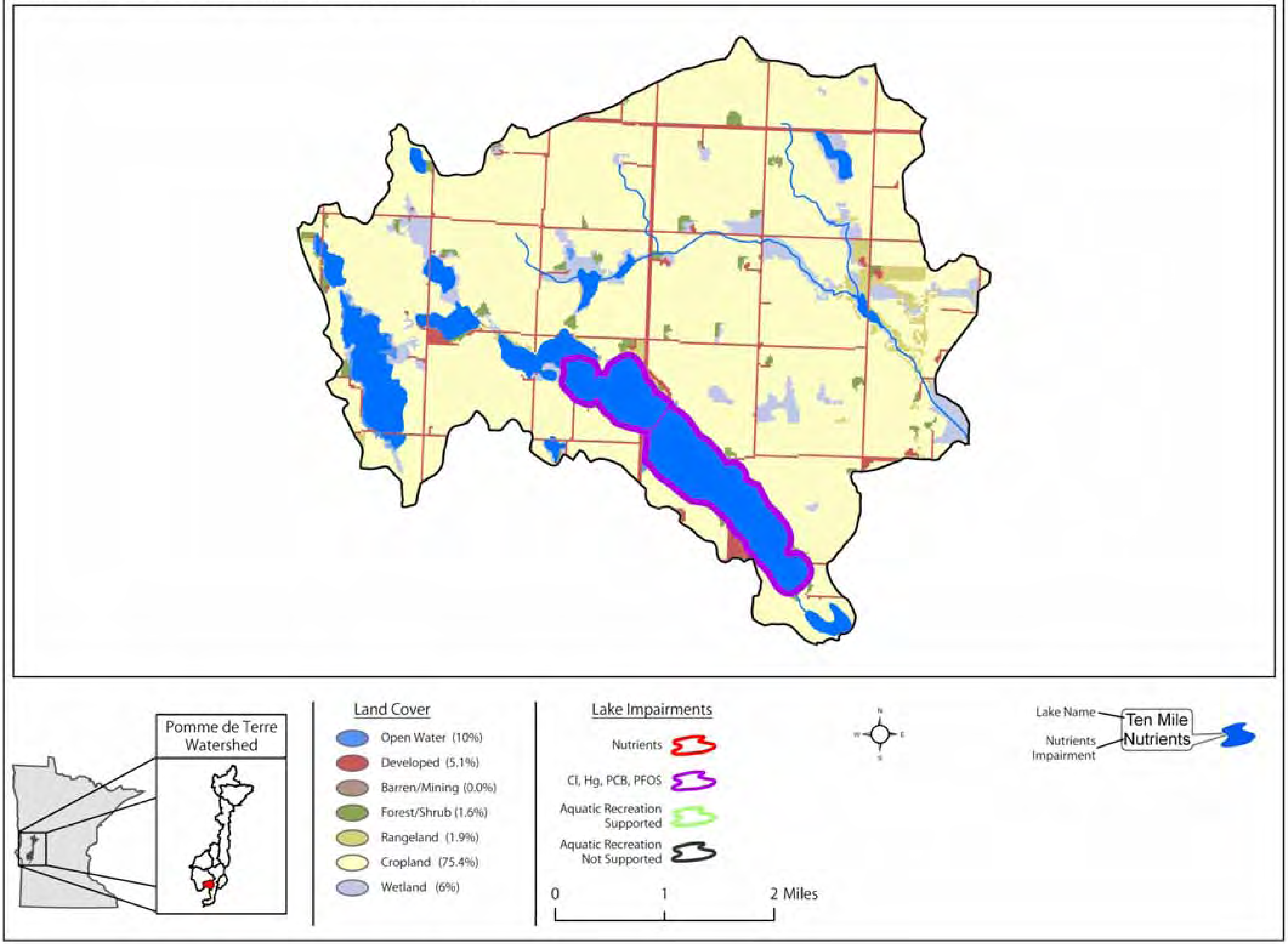
Artichoke Lake is a large 788-hectare (1,946 acre), shallow, productive lake located in eastern Big Stone County. Artichoke was used as an ecoregion reference lake in the mid-1980s because it was thought to be fairly typical and had a moderate-sized watershed (21:1 watershed: lake ratio), with minimal feedlots in contrast to many other lakes in the Northern Glaciated Plains (NGP) ecoregion. As a result, water quality and other information were gathered by MPCA. Artichoke Lake currently has assessment level data; however, water chemistry values were highly variable. Since Artichoke Lake is part of the Sustaining Lake in a Changing Environment (SLICE) project, another year of data will be collected and aid in making assessment decisions. More information on Artichoke Lake through the SLICE project can be found at the following link:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/sentinel-lakes.html

The U.S. Environmental Protection Agency lead a survey of the nation's lakes in conjunction with the states in 2007. A total of 909 lakes were included in this survey. Drywood Lake was selected as one of the lakes for this study. More information regarding Drywood Lake and National Lakes Assessment Project (NLAP) can be found at the following link:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/national-lakes-assessment-project-nlap.html

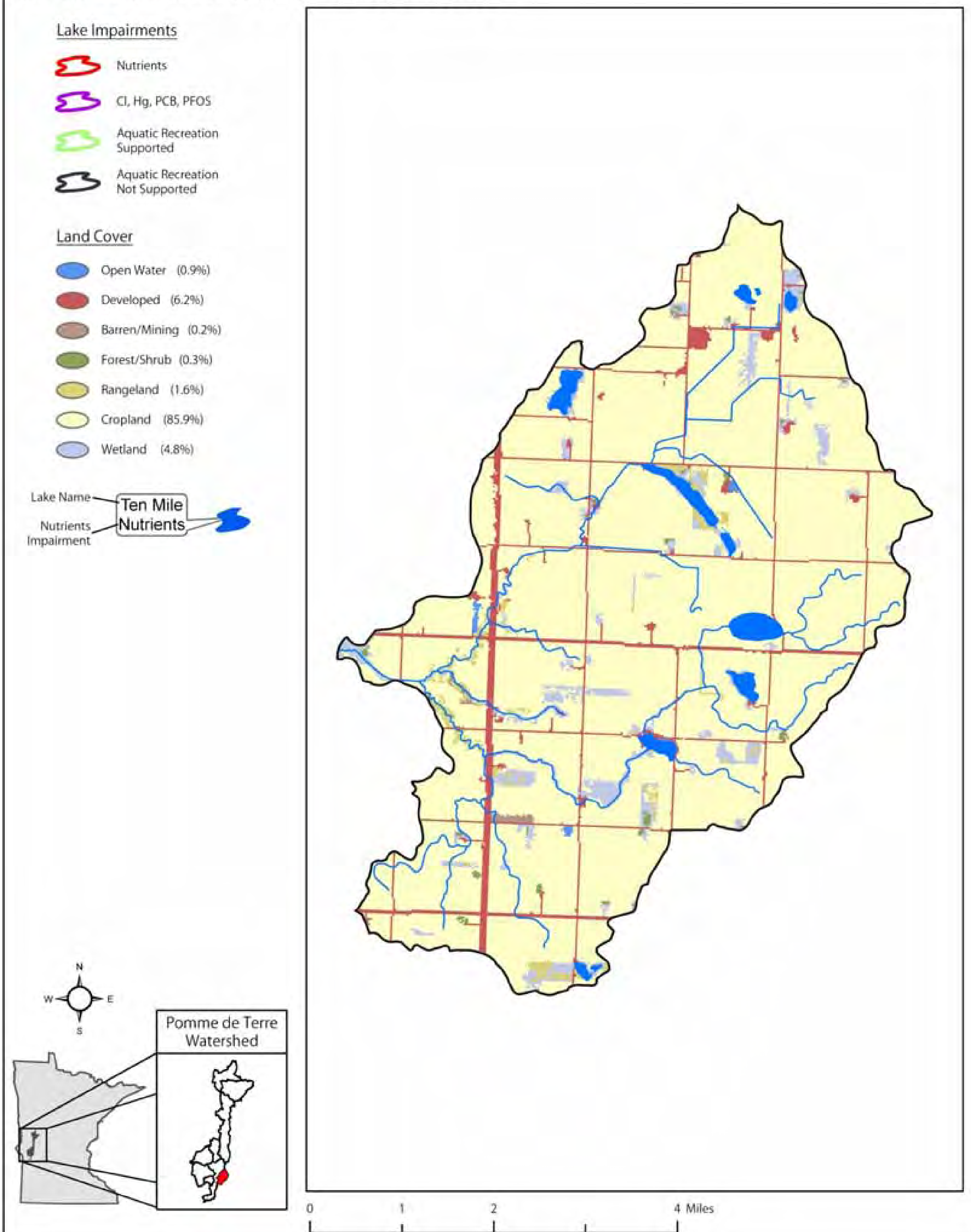
Lake Oliver Watershed Unit - HUC 07020002080



Lake Oliver Watershed – No Aquatic Recreation Lakes

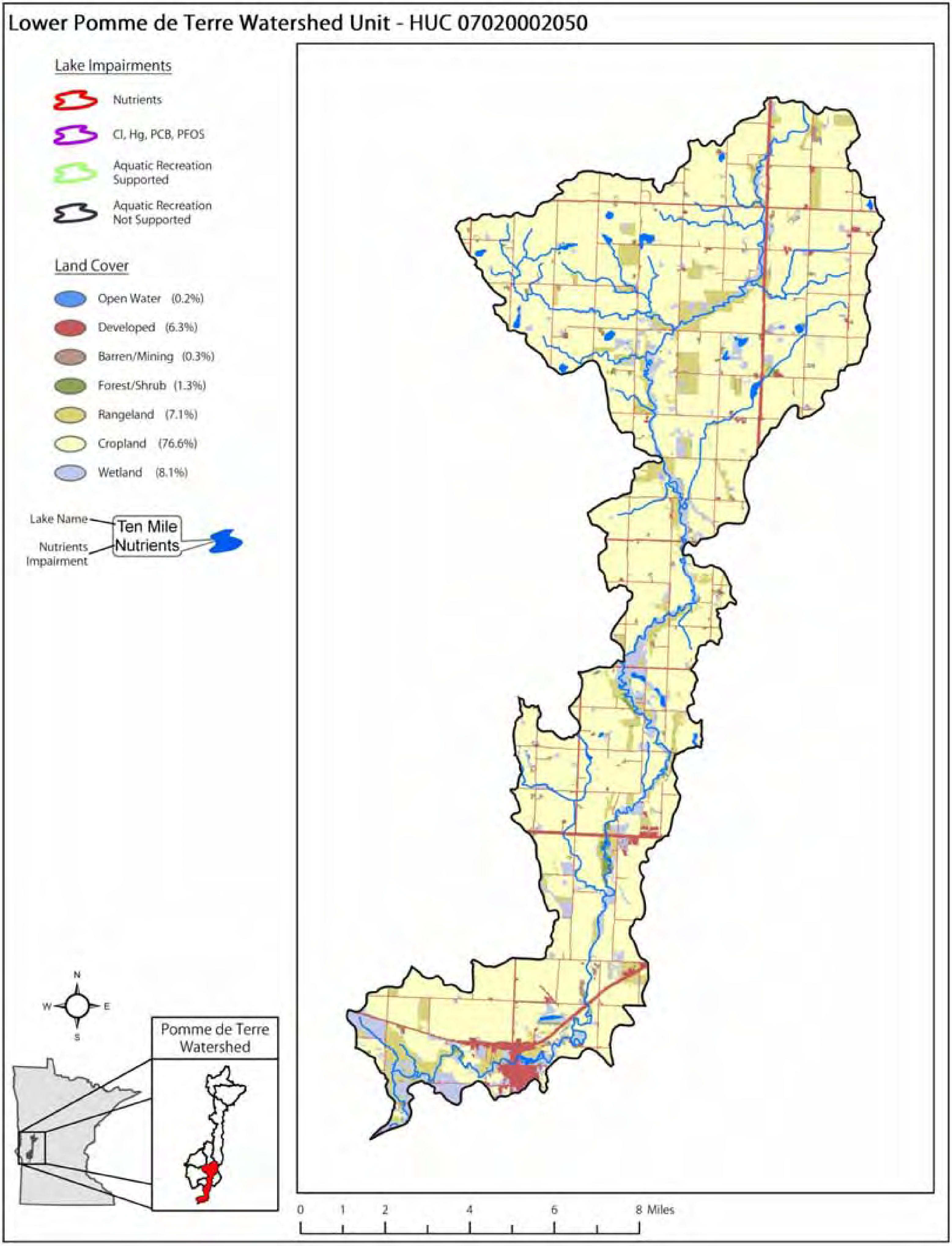
Lake Oliver (07020002080) HUC-11 watershed is the smallest HUC-11 covering two percent of the Pomme de Terre River watershed. This 5,168 hectare (12,771 acre) watershed has five lakes and land use is primarily cropland (75%). Assessment data for aquatic recreation have not been fully collected to assess any lakes at this time. Lake Oliver has been assessed for aquatic consumption and found to be not supporting.

Fairfield-Tara Watershed Unit - HUC 07020002070



Fairfield-Tara Watershed – No Aquatic Recreation Lakes

Fairfield-Tara (07020002070) HUC-11 watershed is small, covering three percent of the Pomme de Terre River watershed. This 7,558 hectare (18,677 acre) watershed has one lake and land use is primarily cropland (86%). Assessment data for aquatic recreation have not collected at this time.


Lower Pomme de Terre Watershed Unit - HUC 07020002050
Lake Impairments
Nutrients
Cl, Hg, PCB, PFOS
Aquatic Recreation Supported
Aquatic Recreation Not Supported
Land Cover
Open Water (0.2%)
Developed (6.3%)
Barren/Mining (0.3%)
Forest/Shrub (1.3%)
Rangeland (7.1%)
Cropland (76.6%)
Wetland (8.1%)
Lake Name
Ten Mile
Nutrients
Nutrients Impairment
N
W
E
S
Pomme de Terre Watershed
0
1
2
4
6
8 Miles

Lower Pomme de Terre Watershed – No Aquatic Recreation Lakes

The Lower Pomme de Terre (07020002050) HUC-11 watershed covers 12 percent of the Pomme de Terre River watershed. This 27,290 hectare (67,435 acre) watershed has two lakes and land use is primarily cropland (77%). Assessment data for aquatic recreation have not collected at this time.

Conclusion

The complexity of the Pomme de Terre River watershed explains the wide spectrum of water quality observed within its lakes. Geology, land use, lake morphology, and watershed size must all be considered in order to fully understand water quality for individual water bodies. General patterns in good and poor water quality can be explained for regions with these similar characteristics. The Pomme de Terre River Watershed has 217 lakes, most of which are located in the northern headwaters of the watershed. Throughout the watershed the majority of large and or deep lakes have been sampled. All water quality data from these activities are compared to state water quality standards to determine if a given lake is fully supporting or not supporting standards set for recreational use (e.g., swimming, wading, etc.). Eleven lakes have been fully assessed against water quality standards set for aquatic recreation and the findings indicate that seven fully support aquatic recreational uses and four do not. Nineteen lakes have some water quality data, but the datasets are insufficient data to allow assessment.

Lakes clustered in the northern headwaters of the Pomme de Terre River watershed tend to have good water quality. The majority of assessed lakes were found to be fully supporting and are located within the Pelican Creek and the northern portion of the Upper Pomme de Terre HUC-11 watersheds. Geology and lake morphology are the main drivers of water quality in this area. Sandy out wash soils were deposited in the headwaters allowing for high ground water inflow. In addition, lake basins in the headwaters are typically deep and allow for stratification and the storage of P in sediments. Lakes are in close proximity and have small catchments in the headwaters area, which reduces the potential that pollutants form runoff will flow into the lake. The highest percentages of forest and shrub land within the Pomme de Terre River watershed are located in the headwaters. These land use types reduce and filter overland flow improving water quality entering lakes and streams.

Midway through the watershed, a transition in geology, lake morphology, and land use causes lake water quality to diminish. Assessed lakes in the southern portion of the Upper Pomme de Terre and Little Muddy Creek HUC-11 watersheds were found to be non supporting. Very few lake basins are located in the mid- to southern portions of the watershed. Lake basins are shallow due to flat topography or formed by impoundments on the Pomme de Terre River. Flat topography and few lake basins result in large individual lake catchments. Lake impoundments on the Pomme de Terre River also have large watersheds which include the entire watershed area drained north of the impoundment. The transition to clay loam soils reduces infiltration and promotes increased runoff. Land use is dominated by cropland because soils are ideal for growing crops. The combination of poor infiltration, cropland dominated land use, and large watershed area results in poor lake water quality.

Understanding the dynamics of how water travels through the Pomme de Terre River watershed is difficult because individual bodies of water cycle pollutants differently. Sources of non point source pollutants are difficult to quantify; however, trends in water quality can be distinguished in areas with similar characteristics. In the Pomme de Terre River watershed the northern headwaters behave differently than the mid- to southern portion of the watershed, and this explains why water quality is typically good in the northern headwaters and diminishes moving south.

Appendix

HUC 11 NAME	LAKE ID	LAKE NAME	AREA acres	DEPTH feet	TP Mean	Chl-a Mean	Secchi Mean	Impairment Status	RS Trend	CLMP Trend
Drywood Creek	06-0002	Artichoke	1924	13	247.7	23.5	0.8	IF		
	06-0004	Unnamed	14						DT	
	06-0014	Unnamed	10							
	06-0019	Unnamed	35						NT	
	06-0020	Long	182						NT	
	06-0070	Unnamed	42							
	75-0183	Drywood	49						NT	
	75-0286	Unnamed	22						DT	
	75-0365	Unnamed	12							
	76-0136	Unnamed	23						DT	
	76-0149	South Drywood	231	4					NT	
	76-0167	Unnamed	11							
	76-0169	North Drywood	389		508.8	7.8	0.9	IF	NT	
Fairfield-Tara	75-0095	Unnamed	48						DT	
Lake Oliver	76-0146	Oliver	484	12					NT	
	76-0146-01	Oliver (east portion)	324	12	354.3	109.0	2.3	IF	NT	
	76-0146-02	Oliver (west portion)	153	18						
	76-0160	Large Henry	34	4					DT	
	76-0161	Unnamed	21						IT	
Little Muddy Creek	75-0165	Unnamed	43						NT	
	75-0192	Clear	141						DT	
	75-0196	Unnamed	33						NT	
	75-0200	Hattie	454	8	303.6	78.5	0.7	NS	IT	
	75-0201	Flax	61						DT	
	75-0203	Gorder	496	4					NT	
	75-0207	Unnamed	38						NT	
	75-0209	Unnamed	58						DT	
	75-0230	Unnamed	108						NT	
	75-0231	Unnamed	34							
	75-0232	Unnamed	37							
Lower Pomme de Terre	76-0128	Unnamed	18							
	76-0129	Appleton Mill Pond	32						NT	
Muddy Creek	75-0161	Harstad Slough	163						DT	
	75-0212	Unnamed	27						NT	

Pelican Creek	21-0353	Anka	131	10	32.6	14.1	0.5	IF	NT	
	21-0355	Ina	218	48					NT	
	21-0361	Unnamed	37						NT	
	21-0363	Unnamed	30						NT	
	21-0367	Unnamed	94						NT	
	21-0369	Unnamed	20						DT	
	21-0370	Unnamed	25						DT	
	21-0375	Christina	3955	14.5	74.7	33.3	0.6	NS		IT
	26-0002	Pelican	3735	21	42.0	20.5	0.8	IF		IT
	26-0065	Unnamed	69						NT	
	26-0072	Unnamed	29						NT	
	26-0074	Unnamed	11							
	26-0076	Little	58	8					DT	
	26-0077	Melby	55						NT	
	26-0078	Ask	63						NT	
	26-0080	Burns	39						DT	
	26-0085	Unnamed	16							
	26-0153	Briggs	34						IT	
	26-0164	Unnamed	16							
	26-0165	Unnamed	17							
	26-0367	Unnamed	20							
	56-0148	Millpond	51						NT	
	56-0149	Sampson	178	16					NT	
	56-0150	Unnamed	14							
	56-0151	Toms	111						NT	
	56-0158	Unnamed	18						NT	
	56-0159	Long	38						NT	
	56-0160	Spitzer	16	33	24.3	6.7	2.8	IF	NT	
	56-0232	Unnamed	40						NT	
	56-0234	Unnamed	29						NT	
	56-0248	Unnamed	50						IT	
	56-0251	Torgerson	141				4.1	IF	NT	
	56-0252	Middle	208	56			3.9	IF	NT	
	56-0253	Eagle	898	46	11.4	3.0	6.2	FS	NT	IT
	56-0255	Hancock	202	23						
	56-0257	Unnamed	24						NT	
	56-0259	Unnamed	131						DT	
	56-0261	Unnamed	48						IT	
	56-0263	Unnamed	71						NT	
	56-0264	Unnamed	33						NT	
	56-0267	Unnamed	64						NT	
	56-0272	Unnamed	18						NT	

	56-0370	Jolly Ann	295						NT	
	56-0393	Johnson	335	6	31.3	11.3	3.8	IF	NT	
	56-0396	Lacey	92						DT	
	56-0401	Unnamed	53						NT	
	56-0402	Vinge	192						NT	
	56-0405	Blacken	81						NT	
	56-0407	Unnamed	15							
	56-0408	Sewell	332	52	28.5	10.5	2.4	IF	NT	
	56-0414	Unnamed	22						DT	
	56-0415	Unnamed	18						DT	
	56-0416	Beebe	71						NT	
	56-0558	Formoe	205						NT	
	56-0559	Clear	390	29	37.4	13.0	2.3	FS	NT	DT
	56-0560	Unnamed	30						DT	
	56-0561	Sand	64						NT	
	56-0596	Unnamed	53						NT	
	56-0600	Unnamed	47						NT	
	56-1083	Unnamed	48						NT	
	56-1357	Unnamed	25						NT	
Upper Pomme de Terre	26-0013	Unnamed	17						DT	
	26-0017	Unnamed	18						DT	
	26-0029	Unnamed	24						DT	
	26-0030	Turtle	61						NT	
	26-0031	Round	38						NT	
	26-0032	Spring	77						IT	
	26-0033	Retzlaff	35						NT	
	26-0042	Unnamed	12						NT	
	26-0048	Lower Elk	32						NT	
	26-0050	Kenny	26						NT	
	26-0051	Lee	67						NT	
	26-0053	Lee	26						NT	
	26-0054	Unnamed	39						DT	
	26-0055	Thorstad	44						DT	
	26-0056	Lee	11							
	26-0066	Shady Grove	67						IT	
	26-0084	Unnamed	31						NT	
	26-0088	Sand	20						NT	
	26-0095	Barrett	523	25	70.8	33.0	1.8	IF	NT	NT
	26-0096	Unnamed	25						DT	
	26-0097	Pomme de Terre	1775	23	36.1	12.9	1.1	IF	NT	NT
	26-0111	Patchen	254	6					NT	

26-0114	Shauer	99						IT	
26-0117	Cormorant	695						DT	
26-0118	Janstad	25						NT	
26-0120	Horseshoe	78						NT	
26-0162	Duck	50						NT	
26-0163	Unnamed	64						NT	
26-0167	Mill Pond	108						NT	
26-0180	Unnamed	13							
26-0308	Schmall Marsh	32						NT	
26-0398	Unnamed	55							
56-0295	Hollo	82						IT	
56-0379	North Turtle	1542	19	83.3	31.8	2.0	NS	NT	
56-0380	Unnamed	90						NT	
56-0390	Long	373	88	22.5	6.7	3.1	FS	NT	
56-0391	Johannes	121						NT	
56-0392	Unnamed	45						DT	
56-0394	Unnamed	45						NT	
56-0395	Sommer	129	7					NT	
56-0420	Unnamed	32						NT	
56-0421	Hanson	48						NT	
56-0423	German	74						NT	
56-0424	Unnamed	13							
56-0427	Dane	104						NT	
56-0428	Long	201	24					NT	
56-0429	Unnamed	14							
56-0430	Fiske	243	26					NT	
56-0432	Unnamed	42						NT	
56-0433	Tamarack	203	5					NT	
56-0434	Unnamed	19						NT	
56-0435	Volen	75						NT	
56-0436	Unnamed	38						NT	
56-0437	Stalker	1337	95	20.0	6.8	3.1	FS	NT	NT
56-0438	Unnamed	30						NT	
56-0439	Unnamed	34						NT	
56-0440	Steenerson	48						NT	
56-0441	Back	88						NT	
56-0455	Horseshoe	108						NT	
56-0456	Unnamed	40						NT	
56-0465	Unnamed	25						NT	
56-0470	Unnamed	10							
56-0562	Long	95						NT	

56-0564	Jotan	71						NT	
56-0585	Unnamed	96						NT	
56-0587	Mud	53						NT	
56-0588	Unnamed	55						NT	
56-0589	Mineral	639	8.5	60.3	14.0	1.5	IF	NT	
56-0590	Unnamed	27						NT	
56-0591	Unnamed	41						NT	
56-0592	Unnamed	30						NT	
56-0595	Unnamed	25						NT	
56-0601	Unnamed	39						DT	
56-0603	Tumuli	91						NT	
56-0604	North Ten Mile	642	14	24.8	5.1	1.2	IF	NT	
56-0611	Alkali	91						NT	
56-0612	Unnamed	76						NT	
56-0613	Ten Mile	1408	50	22.7	8.0	2.3	FS	NT	NT
56-0615	Hansel	116						NT	
56-0616	Unnamed	32						IT	
56-0620	Rose	108						NT	
56-0625	Unnamed	19							
56-0630	Unnamed	102						NT	
56-0631	Rosvold	74						IT	
56-0634	Unnamed	22						NT	
56-0637	Bahle	72						NT	
56-0639	Indian	104	37			2.1	IF	NT	NT
56-0642	Unnamed	51						NT	
56-0643	Unnamed	22						NT	
56-0644	Unnamed	21						NT	
56-0645	Unnamed	43						NT	
56-0647	Unnamed	35						NT	
56-0648	Unnamed	11							
56-0650	Unnamed	11							
56-0651	Larson	47				0.8	IF	NT	NT
56-0655	Bromseth	56						DT	
56-0656	Fossan	68	25					NT	
56-0780	Chautauqua	228	14.5					NT	
56-0781	Swan	725	44	24.5	5.7	3.9	FS	NT	IT
56-0795	Unnamed	52						DT	
56-0849	Unnamed	27						NT	
56-1118	Unnamed	27						NT	
56-1420	Unnamed	13							
56-1431	Unnamed	28						NT	

56-1452	Unnamed	13							
75-0011	Unnamed	18							
75-0012	Unnamed	13						NT	
75-0029	Foss	26						DT	
75-0061	North Pomme de Terre	433	3	57.3	16.3	0.7	IF	NT	
75-0062	Winters Slough	11							
75-0074	Middle Pomme de Terre	197	4	61.0	25.0	0.7	IF	NT	
75-0075	Perkins	505	10	112.3	14.9	0.7	NS	NT	NT
75-0088	Unnamed	36						NT	
75-0096	Pomme de Terre Reservoir	59						NT	
75-0097	Crystal	187	4.5	214.3	3.3	1.1	IF	NT	
75-0100	Coleman Slough	16							
75-0113	South Wintermute	105						NT	
75-0145	Unnamed	22						NT	
75-0146	Unnamed	16							
75-0164	Silver	101						IT	
75-0315	Unnamed	15							
75-0337	Unnamed	19							

FS- Full Support, NS- Non Supporting, IF- Insuficent Data, DT- Downward Trend, IT- Improving Trend

References

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnology and Oceanography 22:361-369.

'Closest Station' Climate Data Retrieval, October 2008 – September 2009. State Climatology Office, Minnesota Department of Natural Resources. 2010.

Feist, M.D. 2008. Snake River Watershed Monitoring and Assessment Report. MPCA. St. Paul MN

Heiskary, S.A. and C.B. Wilson. 2005. "Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria." 3rd Ed." MPCA. St. Paul MN 150 pp.

Water Year Precipitation Departure from Normal, October 2008 – September 2009. Map. State Climatology Office, Minnesota Department of Natural Resources. 2010.

Wilson, C.B. and W.W. Walker 1989. Development of lake assessment methods based upon the aquatic ecoregion concept. Lake and Reserv. Manage. 5(2):11-22.