LAKE CONDITIONS REPORT

Buffalo River
Watershed

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1. Introduction

The Buffalo River Watershed-Wide Total Maximum Daily Load (TMDL) study is one of two pilot TMDLs currently being conducted in Minnesota. The goal of the watershed-wide design to addressing TMDLs (i.e., the Watershed Approach) is to develop a comprehensive plan for managing surface water quality across the entire watershed, rather than focusing on a single water body at a time. The ultimate goal of the Buffalo River Watershed-Wide TMDL study is to protect waters where conditions are excellent and restore waters that are impaired. As a pilot study, results of the Buffalo River Watershed-Wide TMDL study will also inform the completion of other similar watershed-wide TMDL studies in the Red River Valley. The Buffalo Red-River Watershed District (BRRWD) is the local governmental unit leading the TMDL effort under contract with the Minnesota Pollution Control Agency (MPCA). The BRRWD has been actively working to improve the water quality of lakes and streams within the District for a number of years.

During Phase I of this Watershed-Wide TMDL study, a Watershed Conditions Report (HEI, 2010b) was completed to provide an overview of water quality conditions within the watershed and identify data gaps. The Watershed Conditions Report provided a general description of watershed conditions, but did not provide a detailed analysis and summary of lake water quality within the watershed. The purpose of this report is to parallel some of the information provided in the Watershed Conditions Report and its associated addendum (HEI 2011), focusing the discussion on the study area's lakes. Data included in this report includes a summary of general watershed characteristics, a summary of the area's lakes, a review of current literature dealing with the lakes in the watershed, and an analysis of existing lake water quality data. Although the intent of this report is not to duplicate or supersede the MPCA's formal water quality assessment, which last occurred for this area in the spring of 2011, lake water quality data is summarized using methods consistent with the MPCA's assessment and 303(d) listing criteria (MPCA 2010). The information contained in this report will be used to inform future decisions regarding lake water quality and provide data for the ongoing TMDL study.

2. Buffalo River Watershed

The following section summarizes information presented in the BRRWD's Watershed Management Plan (HEI 2010a) and the Phase I Watershed Conditions Report (HEI 2010b). General Buffalo River Watershed (BRW) characteristics are included in this report to set the stage for discussion about the areas of the watershed that directly impact its lakes and also to provide a broader context of the setting in which these waters exist.

2.1 Physical Setting

The BRW (HUC 09020106), located in northwest Minnesota, comprises an area of 1,100 square miles. Other watersheds bordering it are the Wild Rice River (north), Pelican River (east), and Cormorant Lakes (east). The western and southern boundaries are a subwatershed that drains directly to the Red River of the North, of which the Buffalo River is a tributary.

The BRW lies in portions of Clay, Becker, Wilkin, and Otter Tail Counties. Municipalities within the watershed include Glyndon, Hawley, Lake Park, Audubon, Callaway, Georgetown, Hitterdal, and Barnesville (**Figure 1**). The BRW comprises the majority of the BRRWD, which manages the water resources and holds permitting authority in the area. A small segment of the BRW (in the south-east corner) lies outside of the BRRWD and thus the District has no authority in that area. This will be particularly important if and when impairments are found in the waters that lie in this portion of the watershed. The BRRWD office is located in the south-central portion of the watershed, in Barnesville, MN.

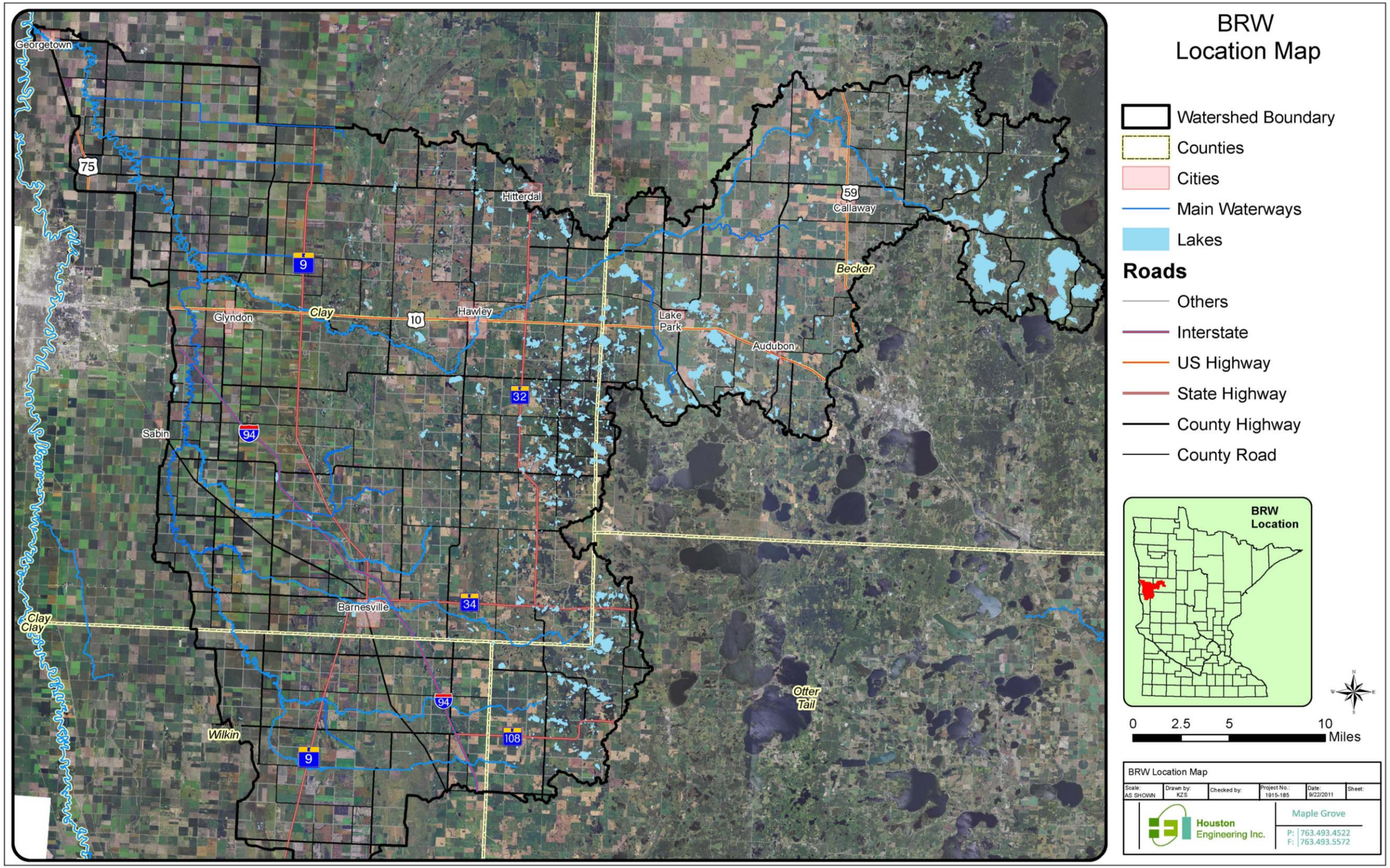

Figure 1. Location of the Buffalo River Watershed.

2.2 Geomorphology

The geology of the BRW is typical of watersheds in the Red River Valley, consisting of lakeshore deposits (outlets, outwash, and peat), glacial lake deposits (Lacustrine), till, alluvium, supraglacial drift complex, and a small amount of ice-contact deposits overlying the bedrock (**Figure 2**). Bedrock in the eastern portion of the watershed is comprised of metamorphic, undifferentiated igneous, and Precambrian rock, while the western portion consists of a small band of Cretaceous, fine-grained sandstone and shell. Clay and silt lake deposits dominate the Lake Agassiz plain bordering much of the South Branch of the Buffalo River and the lower reaches of the Buffalo River. Lakeshore deposits, delta sand, and gravel have formed a transition zone between the lake plain and the glacial moraine areas.

2.3 Topography

The watershed can be characterized by three physiographic regions; extending from the western to eastern boundary: the glacial lake bed deposits, the beach ridge area, and the glacial moraine. Over 12,000 years ago, much of the area was covered by Glacial Lake Agassiz, which was formed by an accumulation of melt waters from the last receding glacier. The western portions of Clay and Wilkin counties are located on this lake bed. The lake bed is characterized by flat, extremely level deposits of lake sediments reaching up to 80 feet deep. The beach ridge area is located along the boundary of old Glacial Lake Agassiz. The level of Lake Agassiz fluctuated through the centuries, with the fluctuations leaving their mark on the land in the form of beaches. The beach ridge physiographic region follows a north-south corridor approximately eight miles wide through the center of the watershed and is located on the east boundary of the lake plain. The glacial moraine area is located east of the beach ridge physiographic region. The soil, rocks and debris deposited by glaciers formed the landscape of this region. The glacial moraine area can be characterized as rolling prairie, with scattered areas of sharply rolling hills interspersed with lakes, ponds, wetlands, and bogs. All in all, elevation across the watershed decreases from east to west, and ultimately drains to the Red River, as can be seen in **Figure 2.**

2.4 Soils

Similar to the three physiographic regions, three distinctive soil groupings occur in the BRW. The soils in the west tend to be clays of low permeability, with poor internal drainage, though very fertile for agriculture. The soils near and within the beach ridge area tend to be clay loams and sandy loams mixed with sands and gravels and include some moderately steep slopes. The soils of the moraine area are mostly clays and silts, and those areas of more irregular topography tend to have a loamy texture that are dark to moderately dark colored and poorly to well-drained. The glacial moraine upland area has nearly level to steep slopes and many wet areas and pocketed depressions.

The soil erodibility factor (K-factor) is a unitless measure of erodibility for a standard condition. The K-factor represents the susceptibility of soil to both the rate of runoff and erosion and range from 0 to 1. Soils resistant to erosion and detachment (clays) have low K-factor values (0.0-0.2), whereas easily detached soils (silts) are most erodible and usually have K-factor values greater than 0.40. According to the Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) data layer, K-factors in the BRW range from 0.02 to 0.64. The majority of the soils in the watershed are moderately susceptible to erosion caused by surface water runoff, as seen in **Figure 2**. These soils are mostly associated with sloping areas within the beach ridge geomorphic region.

Beach ridge areas are also the most susceptible to wind erosion. Wind erodibility within the watershed ranges from 0 to 310 tons per acre per year with the highest values occurring in the western portion of the watershed (**Figure 2**).

2.5 Ecoregions

State water quality standards for lakes are based on the United States Environmental Protection Agency's (USEPA) Level III Ecoregions and whether a lake is defined as shallow (<15 feet maximum depth or > 80% of the lake is classified as littoral) or deep (>15 feet maximum depth). An ecoregion is an area of relative homogeneity characterized by distinctive regional ecological factors such as soils, potential natural vegetation, land use, and topography (MPCA 2011a). The BRW transects three Level III Ecoregions including: the Lake Agassiz Plain (LA), the North Central Hardwood Forests (NCHF), and the North Lakes and Forests (NLF). The majority of the watershed is located in the LA Ecoregion with a lesser area of NCHF. Less than 5% of the watershed is located in the NLF Ecoregion (**Figure 3**).

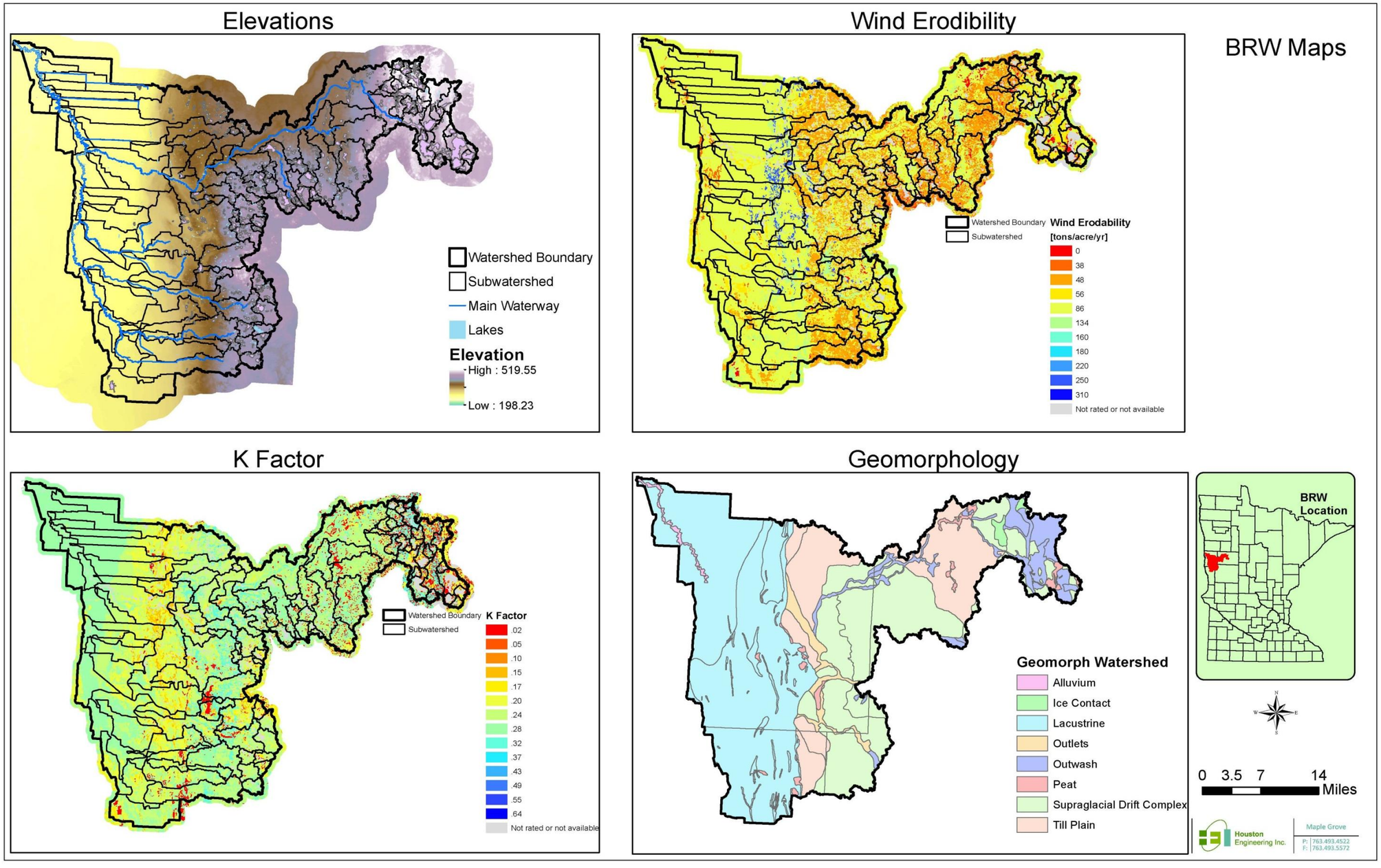

Figure 2. Elevations, wind erodibility, K-factor (soil erodibility), and geomorphology across the Buffalo River Watershed.

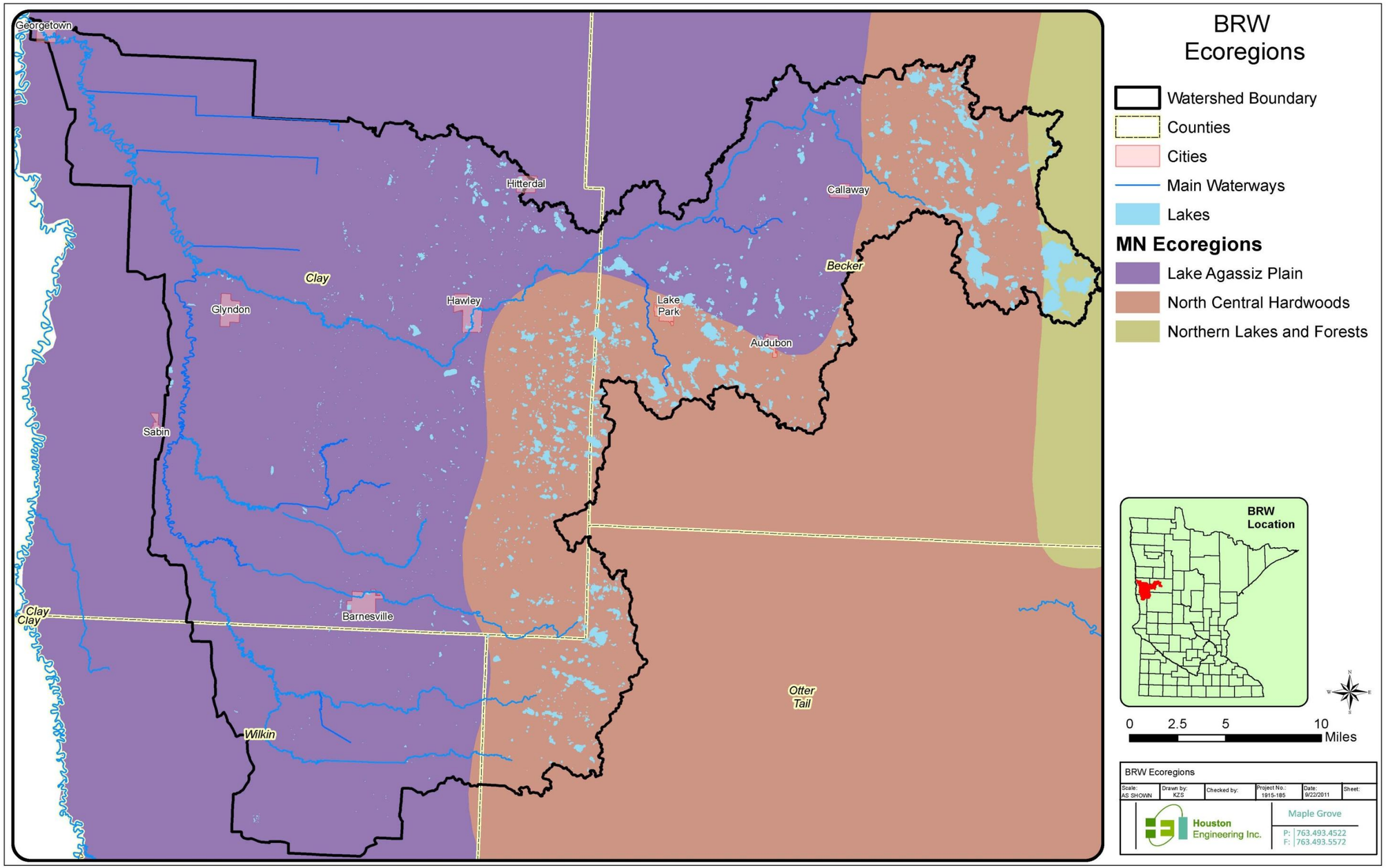

Figure 3. Ecoregions within the Buffalo River Watershed.

2.6 Climate

The Buffalo River is located near the center of the North American continent and has a continental climate, characterized by cold weather and reduced amounts of precipitation. The movement of cold, polar air masses into the area during the winter months resulting in very cold, dry weather. During the spring and summer, warm moist air from the Gulf of Mexico tends to dominate weather patterns. Historic weather data in the area indicate extreme variations in temperature and moderate precipitation. Seasonal temperatures across the area are relatively consistent, while the eastern portion of the watershed generally receives more precipitation.

Historic data from the Minnesota Climatology Group's Detroit Lakes (MN) weather station is summarized in **Table 1**. Recent increases in annual precipitation have resulted in numerous issues in the area, including more frequent flooding and high water problems in many of the area's lakes. Data in **Table 1** highlight this increased precipitation showing average values of the past 5-years as compared to historic averages. Impacts of the high water and floods have caused both financial and emotional damage to citizens within the watershed.

Table 1. Weather data from 1971-2004 and 2005-2010 for Detroit Lakes, MN.

	Detroit Lakes, MN	
Climate Parameter	**(1971-2004)**	**(2005-2010)**
Range of Mean Monthly Temperature(^{o}F)	6 to 69	12 to 70
Mean Annual Temperature (^{o}F)	40	43
Record Low Temperature (^{o}F)	-45	-37
Record High Temperature (^{o}F)	101	98
Mean Annual Precipitation (inches)	25.75	30.34
Mean Snowfall Per Year (inches)	42.51	48.73

2.7 Socio-Economic Considerations

As part of the Watershed-Wide TMDL, the MPCA has developed a socio-economic profile of the BRW. The purpose of this profile is to describe the capacity of the watershed to provide the social, economic and institutional resources needed to support the successful development and implementation of the Watershed-Wide TMDL, including the ability to implement any recommended

practices and the capacity and/or willing to support environmental initiatives (MacGregor 2011). The socio-economic profile is the main source of information for this section.

The BRW consists of primarily rural development with an average population density of 14 people per square mile. Slightly more than half of the area residents live in the six small cities of the watershed, with slightly less than half living in the 36 townships (MacGregor 2011). The rural area population has experienced a decline since the 1960s, due to changes in farming practices and the difficulty of finding employment in small towns. In contrast, population growth is occurring in the eastern portion of the watershed, concentrating in the region around the lakes. This increase is likely due to the increasing popularity of the lakes for vacation and retirement homes.

The median age of the BRW is 42.15 years, which is older than the MN median age of 37 years and the national median age of 36.5 years. The average age of farmers in the watershed is almost 56 years (the two measures are not directly comparable). An aging population of the BRW may indicate a reduced ability to pay for improvements suggested under the TMDL, as other personal costs rise and incomes stagnate or decrease. An aging population also means an aging economy, with little or no growth (MacGregor 2011). It is estimated that about 60 percent of personal income in the BRW comes from labor, with the remaining portion coming from non-labor sources such as payments from dividends, interest, rent and transfer payments from government and business, such as Social Security or disabilities (again, consistent with an aging population).

Civic engagement measures accounted for the by the MPCA show that the citizenry of the BRW are highly committed to their community. United States Census data show a low rate of emigration from the watershed (i.e., the likelihood of people living the same house from one year to the next is very high). Voter turnout rates in the area are consistently higher than the state and national averages with over 95% of registered voters casting ballots in 2008 and approximately 70 percent voting in 2010 (a non-presidential election year). Participation in existing state and regional volunteer monitoring activities was also shown to be high. (MacGregor 2011)

2.8 Land Cover and Land Use

The BRW is largely covered by agricultural land uses, with the majority of the agricultural activity occurring in the western and north-central portions. The types of crops grown in the watershed have changed over the past 90-years, with the most dramatic changes starting around 1970 (**Figure 4**). **Table 2** highlights the changes occurring from 1970 to 2006 (USDA 2007).

Areas in the eastern portion of the watershed are mostly forested, with scattered lakes and wetland areas. Riparian zones also exist along the Buffalo River. As noted earlier, several small municipalities are scattered across the watershed. The land cover across the watershed is presented in **Figure 5.**

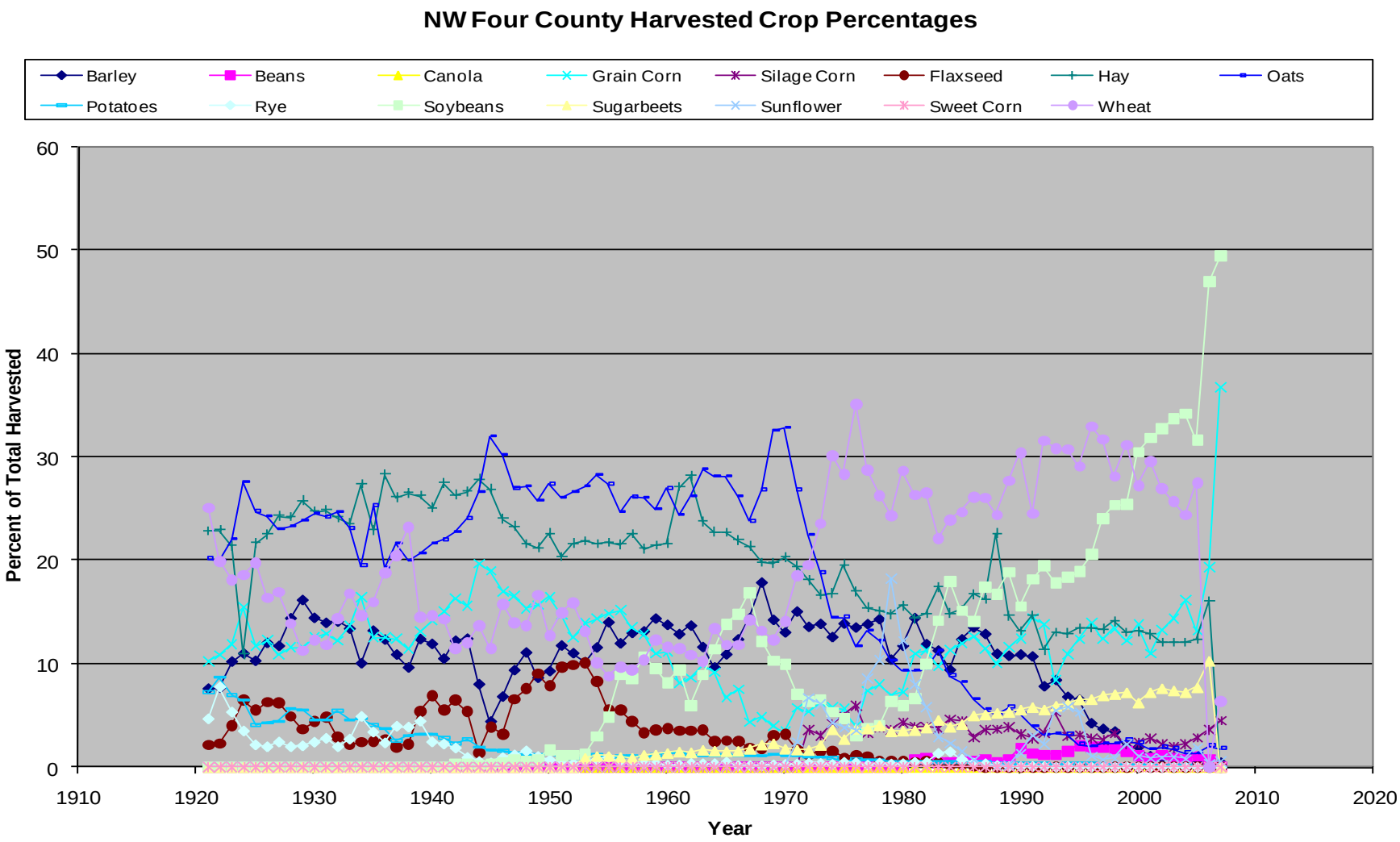

Figure 4. Historical agricultural production in Becker, Clay, Otter Tail, and Wilkin Counties (data combined for all counties).

Table 2. Change in land use in the Buffalo River Watershed.

Land Use	% Watershed Area		Change (%)
	1970	2006	
Soybeans	7.56	26.79	19.23
Wheat	10.72	17.25	6.53
Sugarbeets	1.34	5.97	4.63
Grain Corn	2.62	6.31	3.69
Hay	15.45	15.92	0.47
Sunflower	0	0.12	0.12
Field Peas	0	0.06	0.06
Canola	0	0.05	0.05
Winter Wheat	0.01	0.01	-
Alfalfa	1.61	1.61	-
Barley	9.91	0.06	-9.85
Oats	24.94	0	-24.94
Forest-Deciduous	8.29	8.29	-
Range-Brush	0	0	-
Water	2.84	2.84	-
Wetlands-Mixed	6.99	6.99	-
Residential-Low Density	7.31	7.31	-
Residential-Medium Density	0.39	0.39	-

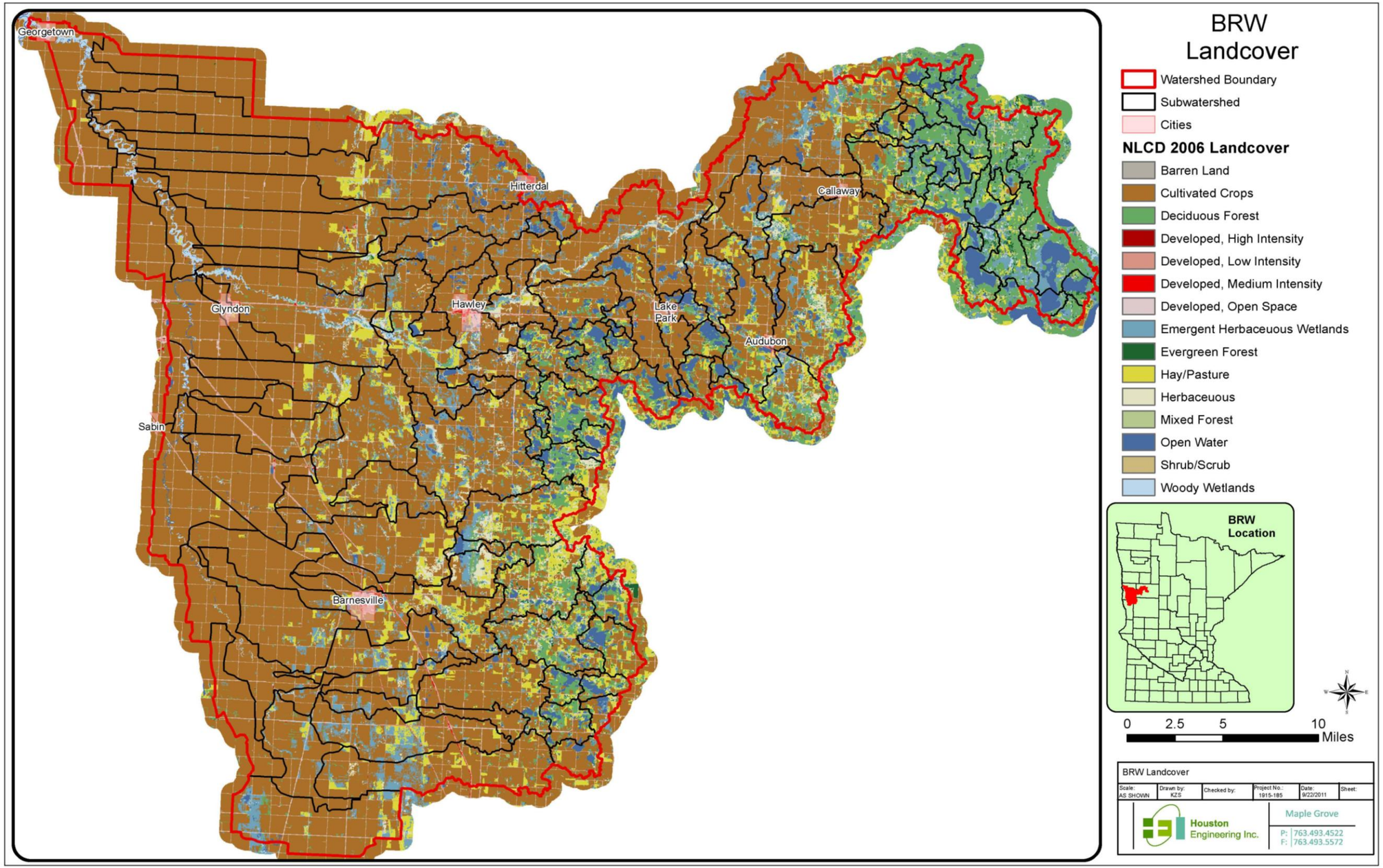

Figure 5. Land cover within the Buffalo River Watershed.

2.10 NPDES Permitted Discharge Facilities

The National Pollutant Discharge Elimination System (NPDES) program is a nationwide federal regulatory program stemming from the Clean Water Act. In Minnesota, this program is implemented by the MPCA. The NPDES program addresses point source discharges, including stormwater and related pollution, from municipal, commercial, industrial, and agricultural sources.

According to the MPCA What's in my Neighborhood Geographic Information Systems (GIS) datalayer (MPCA 2011c), the BRW has 354 active NPDES permits for discharge which can affect water quality. Most permitted facilities are feedlots (203) and construction stormwater permits (115) while fewer permits are for construction stormwater site subdivision (22), wastewater discharge (10) and industrial stormwater (4). Permitted facilities within the watershed are presented in **Figure 6**.

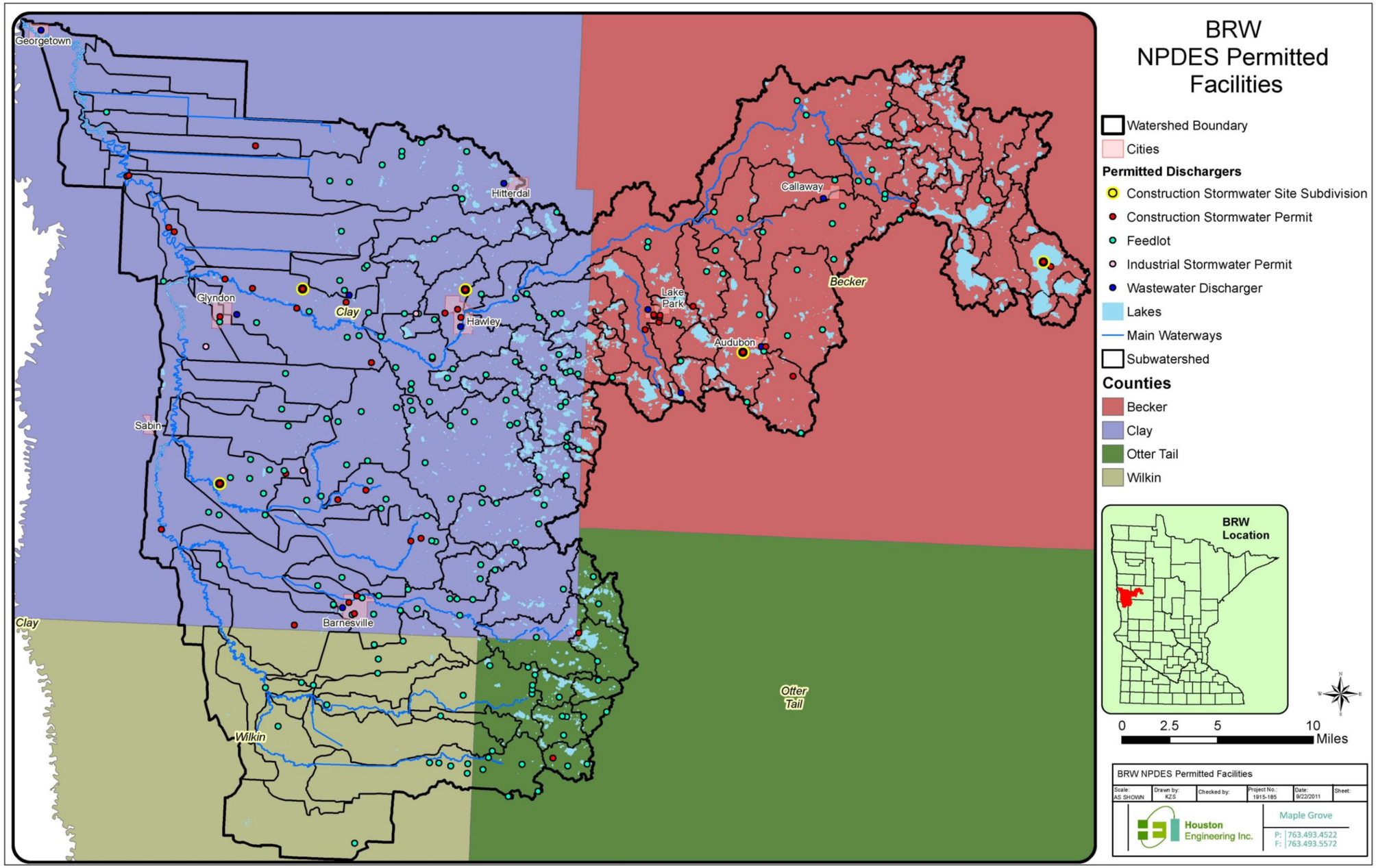

Figure 6. NPDES permitted facilities within the Buffalo River Watershed.

3. BRW Lakes and Reservoirs / Impoundments

3.1 Lakes

The Buffalo River Watershed has numerous lakes and small ponds within its boundaries. The largest lakes (i.e., Tamarack Lake and Rock Lake) lie in the headwaters of the Buffalo River in the far eastern portion of the watershed (see **Figure 1**). A large grouping of small lakes exists in the middle of the watershed, while relatively few lakes exist within the western portion.

According to the MN DNR 24 k GIS data layer, 302 lakes (defined as waterbodies with a surface area greater than 10 acres) and 1,870 smaller ponds exist within the watershed. Approximately 40% of the BRW lakes are considered to be shallow for regulatory purposes (waterbodies with a maximum depth of less than 15 feet or 80% or more littoral area), with the remaining considered deep. One hundred and twelve of the lakes are named, typically because they are used primarily for recreational purposes (especially boating, fishing, or hunting) and/or of special interest to the MN DNR or the general public. Due to the large number of lakes within the watershed, only those lakes with water quality data available will be discussed in detail in this report. Future work under the Watershed-Wide TMDL will address additional lakes within the study area.

3.2 Reservoirs / Impoundments

Several waterbodies in the BRW have been engineered to reduce flooding and control water levels within the watershed. Dams create an artificial ordinary high water level and the ability to retain or release water depending on the needs of area residents. The main reservoirs of the BRW include Stinking Lake Detention, Whisky Creek Tributaries Detention, Stony Creek Detention, and Henry Detention (Spring Creek). Stinking Lake Detention is the only reservoir that has available water quality data. MN DNR water level data is available for both Stinking Lake Detention and Stony Creek Detention.

3.3 Impaired Lakes

The federal Clean Water Act requires states to adopt water quality standards to protect public waters from pollution. These standards dictate the amount of a specific pollutant that can be in a waterbody while still meeting its designated use. In the case of BRW lakes, this use is typically aquatic recreation, including activities such as such as swimming and fishing.

A lake is considered “impaired” when water quality data shows an exceedance of the applicable standards for any pollutant. Impaired waters are placed on the List of Impaired Waters (i.e., 303(d) List), which MPCA files with the USEPA on a biennial basis. After a waterbody is placed on the 303(d) List, a TMDL study must be completed to determine the maximum amount of a pollutant that

the water can receive and still meet the applicable standards. TMDL studies set reduction limits and goals to restore impaired waters and ensure the applicable standards are met.

According to the MPCA's 2010 303(d) List, the BRW has three impaired lakes that require a TMDL (Talac (03-0619), Sand (Stump; 03-0659), Sorenson (03-0625)) and one impaired lake (North Tamarack (03-0241-02)) that does not require a TMDL (**Figure 7)**. A TMDL is not required for North Tamarack due to the nutrient impairment coming from natural resources. All lakes are listed for excess nutrients. Since the 303(d) list was published in 2010, several lakes have been monitored for evidence of impairment. Monitoring results (discussed in detail below) show several lakes are not meeting the applicable standards. As a result of the 2011 water quality assessment in the BRW, MPCA staff have proposed twelve more lakes be considered impaired and be placed on the 2012 303(d) List (**Figure 7**). These lakes are Boyer (03-0579), Forget-me-not (03-0624), Gottenberg (03-0528), Gourd (03-0635), Jacobs (56-1039), Lime (03-0646), Maria (14-0099), Marshall (03-0526), Mission (03-0471), Stakke (03-0631), Stinking Lake Detention (03-0647), and West Labelle (03-0645). Again, all are impaired for excessive nutrients and all proposed lakes require a TMDL to be completed.

3.4 Priority Lakes

As part of their 2010 Watershed Management Plan update, the BRRWD developed a list of Priority Lakes within their boundaries. Lakes within the BRW are an important resource to the local residents, who use them primarily for recreational opportunities, including waterfowl hunting, fishing, swimming, and boating. Maintaining water quality in these lakes is a priority not only for the environmental benefits, but also for their economic value. As previously mentioned, recent years have shown a high potential for residential development around the area's lakes, providing the opportunity for economic growth in these regions.

As part of the prioritization process, lakes in the BRW were screened to develop a group of priority lakes to apply and test the management framework on. Priority lakes were identified using the MN DNR 24K lake database and screened based the following factors: 1) the waterbody had a "p" (public water) designation in the public waters inventory; 2) the waterbody had a listed name; and 3) the waterbody had a surface area greater than or equal to 100 acres. Lakes were then further screened based upon recreational opportunities (primarily fishing) and waterbodies with fish surveys conducted by the MN DNR. A total of thirty-two priority lakes were identified through this screening process **(Table 3**). **Figure 8** displays the priority lakes within the watershed as well as lakes that have water quality data.

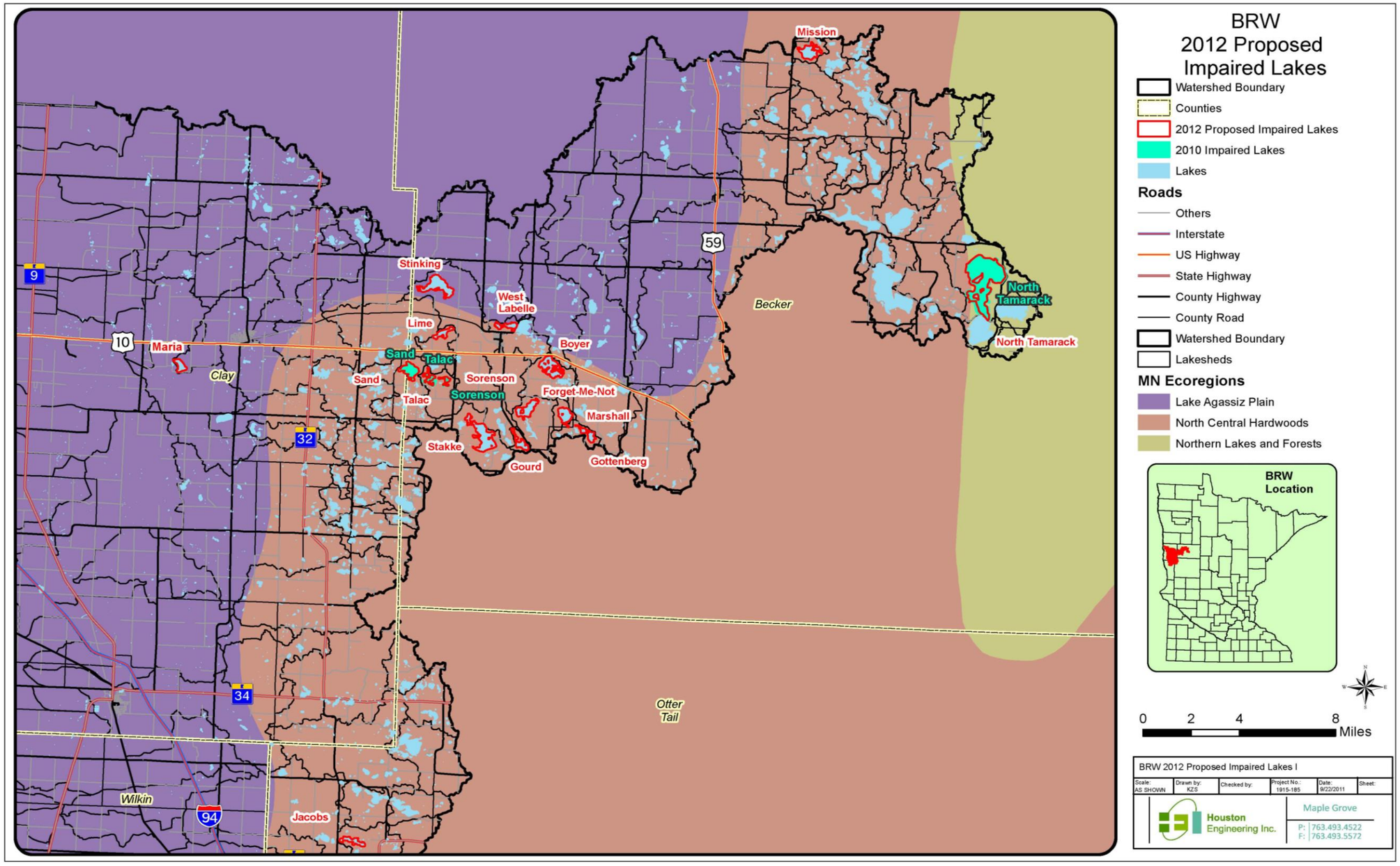

Figure 7. Impaired and proposed impaired lakes within the Buffalo River Watershed.

Table 3. Priority lakes identified by the Buffalo-Red River Watershed District (HEI 2010a).

Lake Name	Lake ID #	County	Planning Region	Quality	Sensitivity to Disturbance	Management Framework Class
Balsam	03029200	Becker	Lakes	Moderate	Moderate	II
Big Sugar Bush	03030400	Becker	Lakes	High	Moderate	I-A
Birch	03035200	Becker	Lakes	Moderate	Low	III
Boyer	03057900	Becker	Mainstem	Moderate	Low	III
Doran	14008900	Clay	Mainstem	Moderate	High	II
East LaBelle	03064800	Becker	Mainstem	High	Moderate	I-A
Fifteen	14003000	Clay	Central	Moderate	Moderate	II
Fish	03031400	Becker	Lakes	High	Low	III
Forget-Me-Not	03062400	Becker	Mainstem	Marginal	Moderate	IV
Gottenberg	03052800	Becker	Mainstem	Moderate	High	II
Gourd	03063500	Becker	Mainstem	Marginal	Moderate	IV
Jacobs	56103900	Otter Tail	Southern	Moderate	Low	III
Lee	14004900	Clay	Mainstem	Moderate	Low	III
Lime	03064600	Becker	Mainstem	Marginal	High	I-A
Little Round	03030200	Becker	Lakes	Moderate	Moderate	II
Little Sugar Bush	03031300	Becker	Lakes	High	Moderate	I-A
Maria	14009900	Clay	Mainstem	Marginal	High	I-A
Marshall	03052600	Becker	Mainstem	Moderate	Moderate	II
Meyer	14007900	Clay	Northern	Marginal	Moderate	IV
Rice	03029100	Becker	Lakes	Moderate	Low	III
Rock	03029300	Becker	Lakes	Moderate	Moderate	II
Sand	03065900	Becker	Mainstem	High	Moderate	I-A
Silver	14010000	Clay	Mainstem	Moderate	Moderate	II
St. Clair	03043000	Becker	Lakes	Moderate	Moderate	II
Stakke	03063100	Becker	Mainstem	Marginal	Moderate	IV
Stinking	03064700	Becker	Mainstem	Marginal	Moderate	IV
Swede Grove	14007800	Clay	Mainstem	Moderate	Moderate	II
Talac	03061900	Becker	Mainstem	Impaired	High	I-B
Tamarack	03024100	Becker	Lakes	Moderate	Moderate	II
Ten	14002100	Clay	Central	High	Moderate	I-A
Three	14001900	Clay	Central	Marginal	High	I-A
Turtle	03065700	Becker	Central	High	Moderate	I-A

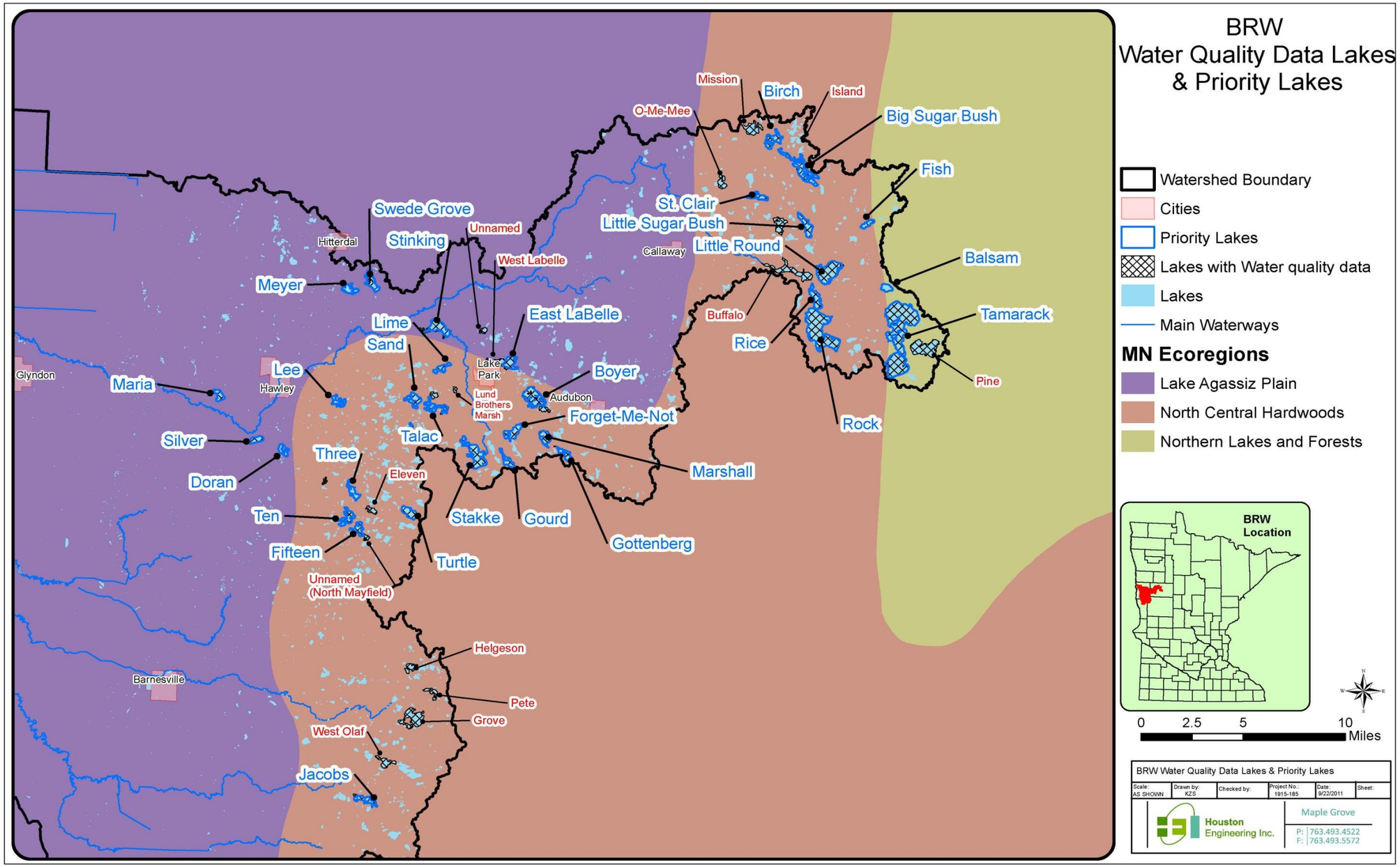

Figure 8. Buffalo River Watershed priority lakes and lakes with water quality data. Note: blue labels indicate priority lakes; red labels indicate lakes with water quality data that are not a priority lake.

The appeal of lakes with good water quality also increases the recreational use of these lakes which can, in turn, decrease lake water quality. To help prevent degradation and protect these lakes, a lake resources management framework was developed for the BRRWD. The management framework was based on two general criteria: current lake quality and sensitivity to change.

The criteria used to establish lake quality were clarity (feet) and impairment status. Clarity data was obtained through the MN DNR LakeFinder web site. The 303(d) listed impaired waters designation came from MPCA records. Lakes were scored individually and given a score of high, moderate, marginal, or impaired.

Lakes were analyzed for their sensitivity to water quality degradation due to increased demands. Sensitivity to change criteria included area (acres), maximum depth (feet), percent littoral area (%), lake access type, and shoreland management classification. Data for the management framework was accessed through the MN DNR LakeFinder web page and from historical records from the MN DNR Detroit Lakes office. Individual criterion value scores were given to each lake and an overall average score was calculated, which gave each lake a score of high, moderate, or low sensitivity.

Four classes were used in the management framework that is described as follows. Individual lake classification for priority lakes can be found in **Table 3**:

- Class I-A – lakes moderately or highly sensitive to disturbance, with high water clarity; also, highly sensitive lakes with marginal water clarity.
- Class I-B – any lakes designated as impaired for stressors other than mercury.
- Class II – lakes moderately or highly sensitive to disturbance, with moderate water clarity.
- Class III – lakes with low sensitivity to disturbance, but with moderate to high water clarity.
- Class IV – lakes with marginal water clarity, having moderate to low sensitivity to disturbance.

The classification framework provides managers a tool for prioritizing how to manage the many lakes within the BRRWD. **Table 4** describes the overall management classification matrix to describe the quality and sensitivity of each lake. Some lakes may need to be restored, while other lakes need to be protected. Management goals for each lake management class are as follows:

- Class I-A and I-B – actively protect the resource to prevent degradation. Pursue lake restoration and lake management efforts, where appropriate.
- Class II – maintain watershed integrity.
- Class III – promote recreational use, with caution.
- Class IV – maintain recreational capacity, consider watershed improvements to improve clarity.

Table 4. Management classification matrix.

		Sensitivity to Disturbance		
		High	**Moderate**	**Low**
Quality	**High**	I-A	I-A	III
	Moderate	II	II	III
	Marginal	I-A	IV	IV
	Impaired	I-B	I-B	I-B

3.5 Sand-Axberg Chain-of-lakes

The Sand-Axberg chain of lakes has been a topic of concern by local citizens and the MPCA for a number of years and is a primary focus of the lakes portion of the Watershed-Wide TMDL study. In the late 1960s, a dike was constructed across the northwest section of Axberg Lake to construct a basin for use in storing the manure of a local poultry farmer (J. Baer Farms). The natural outlet of Axberg Lake was located in the constructed basin and the main portion of the lake was connected to the basin by a culvert inserted through the dike. The main lake basin flowed through the culvert into the constructed basin and discharged through two 12-inch concrete pipes into a wetland system down gradient. Water then traveled north to Lynn-Flint Lake and eventually into Sand (Stump) Lake.

The MPCA was informed by concerned citizens of potential pollution problems existing in the west basin of Axberg Lake and potentially impacting systems downstream. In 1993, water quality samples were taken in the constructed basin and results showed extremely high phosphorus levels (1,280 ppb) in the water column. A sediment study completed in 1997 found visual evidence of poultry manure contaminating the soils and total phosphorus levels as high as 87,000 mg/kg-dry weight.

In 1997, a secondary outlet was constructed in the main (eastern) section of Axberg Lake, allowing water to exit directly from this area and bypass the (western) constructed basin. The culvert between the main lake basin and the constructed basin was plugged. In 1998, the small unnamed lake to the west of Axberg Lake was also rerouted around the constructed basin to reduce the amount of water entering (and contaminated water leaving) that portion of Axberg Lake.

Large amounts of precipitation in 1997 caused extensive flooding that connected closed basins and changed the hydrography of lakes within the Sand-Axberg chain (Paakh, 2011). Prior to 1997, water from Axberg Lake flowed through wetlands into Lynn-Flint Lake to Sand Lake, and from Lee Lake to Talac Lake to Sand Lake. In 1997, Erickson Lake (previously a closed basin) flowed into an unnamed lake into the contaminated west basin, to Sand (Stump) Lake, to Talac Lake and into Yort

(Sand) Lake (previously closed basin). It appears this altered water flow continues to this day (Paakh 2011).

The lakes downstream of Axberg Lake (Sand Lake, in particular) have experienced several toxic blue-green algae blooms that have created offensive odors, displeasing aesthetics, and the potential for fish kills during the winter. Local residents feel conditions in Axberg Lake may have contributed to these problems. The MPCA is working with Baer Farms and local concerned citizens to mitigate the pollution problems within the Sand-Axberg chain-of-lakes. Work completed under this Watershed-Wide TMDL will provide further insight into the issue.

4. Programs, Water Quality Standards, and Other Information Related to Lakes in the BRW

4.1 Programs

4.1.1 Lake Assessment Program

MPCA's Lake Assessment Program (LAP) documents the condition of select lakes across the state. Water quality studies are completed to assess the current lake and watershed conditions for one or more lakes at a time. Detailed reports are developed and data is provided to do one or more of the following: assess trends in a single lake's condition over time, assess the current trophic status of a lake, characterize the trophic status and trends of several lakes in a county or collect additional data to bolster and support current monitoring being conducted by citizens through the Citizen Lake Monitoring Program (CLMP). The MPCA performs LAP projects with a number of partners including lake associations, local units of government, and the MN NDR.

A query of the MPCA's list of completed LAPs found several assessments and reports completed for lakes within the BRW. Lakes with a report include: North Tamarack (03-0241-02), South Tamarack (03-0241-01), Pine (03-0200), Turtle (03-0657), and North Mayfield (14-0029). North Tamarack, South Tamarack, and Pine assessments were completed in 2006 and combined into one LAP report (Anderson 2006). The Turtle Lake report was completed in 1985 as an individual LAP report (Heiskary 1986). The North Mayfield assessment was completed in 2007 as a part of the National Lake Assessment Project (NLAP) and not as a part of the MPCA's LAP (MPCA 2009). The NLAP assessments provide a short summary of information based on one or more samples.

4.1.2 Lake Improvement Districts

A Lake Improvement District (LID) is a local unit of government established by local governing bodies for the purpose of implementing defined lake management projects and for the assessment of the costs (MN DNR 2011a). LIDs have no taxing powers of their own and are limited to the authorities

the parent government (usually the county) gives it. LID statutes and rules can be found at: http://files.dnr.state.mn.us/waters/watermgmt_section/shoreland/lake_improvement_districts_statutes_and_rules.pdf.

The purpose of LIDs, as stated by Minnesota Statute 103B.511, is to "preserve and protect the lakes of the state and to increase and enhance the use and enjoyment of the lakes." A LID can be established to preserve the natural character of lakes and shoreland development, improve water quality and/or provide reasonable assurance of water quantity within a lake. As of 2009, 31 active LIDs exist in Minnesota. The stated management purposes of the active LIDs are as follows: water quality management (8), water level management (8), and aquatic vegetation control (15). Currently, no LIDs exist within the BRW.

4.1.3 Shoreland Management

In recent years, there has been increased demand for development around lakes within the BRW. With this increase in shoreland development, an increase in regulatory management of the activities impacting shoreland has been required to minimize the adverse impacts that development can have on the environment. Increased development along shorelands can lead to increased sediment and nutrient loadings to lakes, which can in turn reduce the water quality. Reduced water quality can affect the biotic communities that inhabit each water body.

The BRRWD supports the protection of shorelines by applying MN DNR Shoreland Rules including Minnesota Rules 6120.3300, Subp. 7 and promoting the use of shoreland best management practices (BMPs) to protect waterbodies from non-point source pollution. The BRRWD also reviews residential development plans and other project plans along lakes and recommends changes to the plans in order to control the water quantity and quality being released into the nearby lakes.

The BRRWD supports programs provided by the Soil and Water Conservation Districts (SWCD) to restore and protect shoreland from erosion. Shoreland protection is listed as practice number 580 in the SWCD's Field Office Technical Guide (see NRCS 2011 for specific information). Components used to inhibit active erosion include critical area plantings, filter strips, riparian buffers, and fencing. The SWCDs provide cost sharing to interested landowners on the installation and maintenance of the designed conservation practice in an effort to reduce the amount of sediment being removed from shorelines, reduce surface water runoff, and reduce nutrients entering a waterbody. The shoreland protection conservation practice must have an effective life of at least 10 years from time of installation and must be properly maintained. Some specific programs through which all the county SWCDs can provide cost sharing are the Reinvest in Minnesota (RIM) Reserve Program and State Cost Share Program.

Becker County SWCD has specific ordinances in regard to lakeshore sites. New developments are required to keep a minimum of 70% of the shore impact zone in a natural state. A redevelopment of nonconforming lots must restore a minimum lake buffer of 15 feet deep by 20 feet wide. Furthermore, in 2009, the Becker SWCD published a lakeshore resource guide for citizens to refer to when protecting or rehabilitating a lakeshore (Becker Co. SWCD 2009).

As a part of their local water management plan, Clay County SWCD has prioritized the protection of shoreland buffers (Clay Co. SWCD 2005). They investigate the enforcement of MN DNR shoreland ordinances that require a buffer on protected waters of the state. The SWCD advocates for the stricter enforcement of shoreland regulations and consider tax incentives for landowners who maintain a 50 foot buffer on public waters.

4.1.4 Management Strategies Identified by the BRRWD

The BRRWD has established water quality goals and policies, as identified in their Watershed Management Plan (HEI 2010a), to maintain and/or improve the water quality of lakes in the District (including those in the BRW). Strategies include establishing programs and activities for addressing lake water quality issues, preparing lake-specific management plans as a tool for managing lakes, establishing numeric lake water quality goals and nutrient loading rates, working to reduce the impact of flooding, and working cohesively with the MPCA to identify impaired waters and complete TMDL studies and projects.

An example of one of these management strategies is the Surface Water Quality Enhancement Program (SQWEP). This program was envisioned by the BRRWD during its recent Watershed Management Plan update and is an example of where the District would like its operations to be in the next 10-years. The goal of the SWQEP is to build upon (and not duplicate) established MPCA lake protection programs (*e.g.,* Citizen lake Monitoring Lake Program, Lake Assessment Program, Clean Water Partnerships, etc.) and provide cost share and technical assistance to:

- Accelerate the completion of Lake Assessment Program studies;
- Initiate studies and develop implementation programs using the various programs of the State; and
- Complete TMDLs working cooperatively with MPCA.

Lake associations and other similar partners could apply to the BRRWD for technical and financial assistance to complete studies that are consistent with the goals and objectives of the District. The BRRWD plans to continue their work on and enhancement of these strategies through the watershed-wide TMDL process and its associated tasks. Utilizing the findings of the TMDL study, the lake management strategies identified by the BRRWD can be more successfully implemented.

4.2 Water Quality Standards

4.2.1 Eutrophication

The main concern for lake water quality in the BRW is eutrophication. Eutrophication is the process by which a water body accumulates nutrients over time. It is a natural process that is accelerated by human impacts on landscapes. In freshwater systems, phosphorus is typically the limiting nutrient, i.e., the nutrient responsible for limiting the amount of primary production (growth of plants and algae) that can occur. As more and more phosphorus accumulates in lakes, excessive phosphorus concentrations promote uncontrolled algal growth leading to a multitude of problems. Problems that can arise due to excessive algal growth include green-colored lakes, odor problems, algal scums covering the surface of the lake, and shading of the water column which inhibits the growth of rooted aquatic plants.

When conditions are right, blue-green algae can become prevalent and cause an increasing amount of water quality problems. Blue-green algae release toxins as they die and can be harmful to humans and terrestrial wildlife. As algae dies and settles to the lake bottom in late summer, bacteria begin to consume the dead algae and reduce the oxygen concentration in the water. The more algae produced during the summer, the more bacterial decomposition that will occur, which can lead to the depletion of the oxygen in the water column. If the concentration of oxygen in the water column becomes low enough, fish kills can occur.

The problems associated with increasing eutrophication include both financial and aesthetics. As eutrophication is accelerated, the waterbody becomes less pleasing for citizens to live around. Reducing the impact humans have on eutrophication can create more appealing aesthetics and a better fishery that can, in turn, provide an increase in the financial value of a lake.

4.2.2 Data Requirements for Assessment

The degree to which eutrophication is occurring is assessed based on three parameters: total phosphorus, corrected chlorophyll-a, and Secchi disk transparency depth. In order to accurately assess a lake for eutrophication, the quality and quantity of available data is important to know. **Table 5** describes the general guidelines set forth by MPCA to assess the quality of available data (MPCA 2010). The “quality” rankings roughly correspond to typical summer monitoring schedules, whereas four total phosphorus samples represent one summer and eight samples represent two summers. In order for the MPCA to assess a lake for inclusion on the 303(d) List, data usually has to be of “excellent” or “good” quality. In addition, all MPCA assessments are based on data collected over the most recent 10-year period.

Table 5. Water quality data requirements for formal water quality assessments (MPCA 2010).

Quality	Available data
Excellent	8 Total Phosphorus, 8 corrected chlorophyll-a, and 8 Secchi disk paired measurements
Good	< 8 but > 4 paired Total Phosphorus, corrected chlorophyll-a, and Secchi disk measurements
Fair	At least 4 Total Phosphorus measurements, some corrected chlorophyll-a and Secchi disk measurements
Poor	Less than 4 Total Phosphorus measurements (often only Secchi data available)

4.2.3 Eutrophication Standards

Eutrophication water quality standards are written to protect lakes as a function of their protected use. The lakes of the BRW are considered Class 2B waters, which are protected for aquatic recreation. The numeric criteria associated with these standards address the averages of water quality data collected within the past 10-years and between June and September. Criteria are written for total phosphorus (TP), chlorophyll-a, and Secchi disk transparency depth. As presented earlier, the ecoregion that a lake lies within dictates the applicable water quality criteria. The depth of the lake (i.e., shallow or deep) is also taken into consideration. The numeric criteria for Class 2B waters (as stated in Minnesota Rule 7050.0222) and "typical" (defined as the interquartile range) summer conditions for reference lakes in the Northern Lakes and Forest (NLF), the North Central Hardwood Forest (NCHF), Northern Glaciated Plains (NGP), and the Western Cornbelt Plains (WCBP) Ecoregions (Heiskary and Wilson 2005) are displayed in **Table 6**. The Lake Agassiz Plain (LA) Ecoregion does not have specific numeric criteria developed but rather lakes within this area are assessed on a case-by-case basis. In practice, when assessing a lake in the LA Ecoregion, the MPCA considers the land use within the lake's total contributing lakeshed and compares that land use to typical values seen in the other ecoregions (as summarized in Heiskary and Wilson 2005). The numeric criteria of whichever ecoregion's land use characteristics most closely match those of the lake in question are then applied for determining impairment. In the lakes of the BRW, this analysis has typically resulted in the NGP/WCBP ecoregions' criteria being used for assessment purposes.

Narrative standards also have an impact on impaired and non-impaired waters. Lakes that have documented proof of toxic algal blooms releasing toxins that have resulted in an animal death or fish kill may be included on the 303(d) List. Available water TP, corrected chlorophyll-a, and/or Secchi depth data (even if it is not "excellent" quality) may be used to determine suitability for impairment.

Table 6. Eutrophication water quality standards for protecting aquatic recreation and typical reference lake summer conditions in selected Ecoregions (Heiskary and Wilson 2005).

Ecoregion	Total Phosphorus (ppb)		Chlorophyll-a (ppb)		Secchi Disk Transparency (m) [2]	
	Standard	Typical ecoregion summer values	Standard	Typical ecoregion summer values	Standard	Typical ecoregion summer values
Northern Lakes and Forest	30	14 - 27	9	< 10	2.0	2.4 - 4.6
North Central Hardwood Forest[1]		23 - 50		5 - 22		1.5 - 3.2
- Deep lakes and reservoirs	40		14		1.4	
- Shallow Lakes	60		20		1.0	
Northern Glaciated Plains[1]		122 - 160		36 - 61		0.4 - 0.8
- Deep lakes and reservoirs	65		22		0.9	
- Shallow Lakes	90		30		0.7	
Western Cornbelt Plains[1]		65 - 150		30 - 80		0.5 - 1.0
- Deep lakes and reservoirs	65		22		0.9	
- Shallow Lakes	90		30		0.7	

[1]: Deep lakes are classified as having a maximum depth greater than 15 feet whereas shallow lakes have a maximum depth less than 15 feet or greater than 80% of the lake is part of the littoral zone.

[2]: Standard for Secchi disk transparency is the minimum transparency value (i.e., values must be greater than the standard)

4.2.4 Other Lake Standards

Total phosphorus, chlorophyll-a, and Secchi disk transparency are commonly analyzed when looking at lakes and lake data because they are the constituents associated with cultural eutrophication. Another constituent of concern when discussing lakes is mercury, as many of Minnesota's lake are considered impaired with the metal (MPCA 2011b). In lakes that have been tested for mercury, fish consumption advisories have been issued by the Minnesota Department of health (MDH).

Mercury is produced in industrial factories, is disbursed through the atmosphere, and deposited via rainfall. Mercury moves readily through the atmosphere and is a bioaccumulative element that magnifies in concentration as it is consumed by biota higher on the food chain. Since humans are on the top of the food chain, this bioaccumulation poses a threat to human life. If humans are chronically exposed to mercury it can lead to permanent neurological damage. Thus, mercury is listed in the state register as a pollutant with human health-based chronic standards.

Minnesota has two water column based chronic standards (one for the Lake Superior basin and one for the rest of the state) and one fish tissue standard. The chronic numeric criteria for the Lake Superior basin is 1.3 ng/L, the chronic numeric criteria is 6.9 ng/L, and the fish tissue standard is 0.2

mg/kg total in edible fish tissue. The fish tissue standard for mercury is the primary reason why the MDH has issued consumption advisories for fish.

In order to be impaired for mercury, five samples within a 3-year period must be sampled within the previous 10-years. If two or more samples exceed the standard in three year period, it is listed as impaired (MPCA 2010). Mercury contamination is a primary concern in some of Minnesota's lakes, but no lakes within the BRW are currently impaired for the pollutant nor are there any known mercury problems within the area.

5. Biologic Resources within the Buffalo River Watershed

5.1 Fish

Angling is a valuable activity that provides recreational opportunities to the residents of and visitors to the BRW. Angling opportunities for sport fish such as largemouth bass (*Micropterous salmoides*), northern pike (*Esox lucius*), and walleye (*Sander vitreus*) and panfish including bluegill (*Lepomis macrochirus*) and black crappie (*Pomoxis nigromaculatus*) exist within the watershed. According to the MN DNR LakeFinder website, 29 of the 51 BRW lakes that have water quality data also have had a fish survey completed by the MN DNR. Several lakes were surveyed as recently as 2009 while other lakes were surveyed last in 1964. Supplemental stocking by the MN DNR has been completed in 12 of the lakes with walleye, bluegill, or channel catfish (*Ictalurus punctatus*). Lake stocking typically occurs because the MN DNR has found some fish populations have low natural recruitment or the quality of the lake's spawning habitat is not adequate to sustain a healthy fishery. Stocking helps to supplement the fishery but does not take the place of natural spawning. The fish resources within the watershed can be found in **Table 7**. BRW lakes without fish data include Balsam, Birch, Doran, Eleven, Gottenberg, Grove, Harrison (Helgeson), Island, Little Round, Lund Brothers Marsh, Maria, Meyer, Mission, O-Me-Mee, Pete, Pine, Sorenson, Swede Grove, Three, North Mayfield, and West Labelle.

5.2 Plant Communities

Several native plant communities and functional landscapes associated with lakes and wetlands exist within the BRW. The Minnesota County Biological Survey (MCBS) completes surveys within individual counties to systematically collect, interpret and find baseline data on the distribution and ecology of rare plants, rare animals, native plant communities, and functional landscapes. Areas within the BRW have been surveyed since 1985, some as recently as 2004. According to the MCBS GIS datalayer, 20 special and/or distinct plant communities associated with lakes and wetlands exist within the watershed. **Table 8** details the special plant communities found within the BRW and the area each community occupies.

Table 7. Fish resources in the Buffalo River Watershed.

	Lake Name, MN DNR lake number, and fish survey year													
	Axberg	**Big Sugar Bush[1]**	**Boyer (sand Beach)[1]**	**Buffalo**	**Canary**	**East Labelle[1]**	**Fifteen[1]**	**Fish[1]**	**Forget-me-not[1]**	**Gourd[1]**	**Jacobs[1]**	**Lee[1]**	**Lime[1]**	**Little Sugar Bush[1]**
	03-0660	**03-0304**	**03-0579**	**03-0350**	**03-0516**	**03-0648**	**14-0030**	**03-0314**	**03-0624**	**03-0635**	**56-1039**	**14-0049**	**03-0646**	**03-0313**
	1964	**2007**	**2008**	**2007**	**1987**	**2008**	**2009**	**1965**	**1964**	**1964**	**1992**	**2005**	**1964**	**2004**
Black bullhead			x	x		x	x	x	x	x			x	x
Black Crappie		x	x	x	x	x	x	x				x		x
Bluegill		x	x	x	x	x	x	x				x		x
Brown bullhead		x	x	x	x		x	x						x
Channel Catfish														
Common Carp														
Green Sunfish	x	x			x				x	x	x			
Hybrid Sunfish		x	x	x	x		x	x			x			x
Largemouth Bass		x	x	x	x	x					x	x		x
Northern Pike		x	x	x	x	x	x	x				x		x
Pumpkinseed		x	x	x		x	x	x	x			x		x
Rock bass				x										
Tullibee (cisco)				x										
Walleye		x	x	x		x	x					x		x
White sucker		x	x	x		x	x		x	x	x	x		x
Yellow Bullhead	x	x	x	x				x			x			x
Yellow Perch		x	x	x	x	x	x		x	x		x		x
Stocking														
Species		Walleye	Walleye			Walleye	Walleye					Walleye		Walleye
Years		2001, 03, 04, 06, 08, 10	2001, 03, 07, 09, 10			2002, 06, 08, 10	2001, 02, 04, 06, 08, 10					2003, 05		2002, 04, 06, 08, 10

[1] Indicates a priority lake identified by the BRRWD

Table 7 (continued). Fish resources in the Buffalo River Watershed.

	Lake Name, MN DNR lake number, and fish survey year														
	Marshall[1] **03-0526** **2004**	**North Tamarack[1]** **03-0241-02** **2008**	**Rice[1]** **03-0291** **1987**	**Rock[1]** **03-0293** **2010**	**Sand (stump)[1]** **03-0659** **2008**	**Sand (Yort)** **03-0618** **1964**	**Silver[1]** **14-0100** **2009**	**South Tamarack[1]** **03-0241-01** **2008**	**St. Clair[1]** **03-0430** **1964**	**Stakke[1]** **03-0631** **1987**	**Stinking[1]** **03-0647** **1964**	**Talac[1]** **03-0619** **1964**	**Ten[1]** **14-0021** **1965**	**Turtle[1]** **03-0657** **2008**	**West Olaf 56-0950** **2007**
Black bullhead	x	x	x	x	x		x	x	x	x	x	x		x	x
Black Crappie		x	x	x	x		x	x	x					x	x
Bluegill	x	x	x	x	x		x	x		x		x		x	x
Brown bullhead	x	x	x	x	x			x	x	x	x			x	
Channel Catfish							x								
Common Carp											x				
Green Sunfish						x						x		x	
Hybrid Sunfish			x											x	x
Largemouth Bass	x	x x	x	x	x		x	x				x		x	x
Northern Pike	x	x	x	x	x		x	x	x		x	x	x	x	x
Pumpkinseed		x	x	x				x			x	x		x	x
Rock bass														x	
Tullibee (cisco)															
Walleye	x	x	x	x	x		x	x			x			x	x
White sucker	x	x	x	x	x	x	x	x	x	x	x	x		x	
Yellow Bullhead		x x		x				x							x
Yellow Perch	x	x	x	x	x		x	x	x	x	x			x	x
Stocking															
Species	Walleye, Black Crappie	Bluegill		Walleye	Walleye		Walleye, Channel Catfish							Walleye	
Years	WAE -2001, 02, 04, 06, 08, 10; BLC-2007	1997		2001, 02, 04, 06, 08, 10	2002, 04, 06, 08, 10		WAE - 2001, 03, 05, 07, 09; CCF - 2001, 03, 07							2001, 03, 07, 09	

[1] Indicates a priority lake identified by the BRRWD

Table 8. Special plant communities / functional landscapes associated with lakes and wetlands in the Buffalo River Watershed.

Plant community / functional landscape	Acres
Calcareous Fen (Northwestern)	2.1
Calcareous Seepage Fen (Northwest) Prairie Subtype	232.7
Cattail Marsh (Northern)	99.1
Emergent Marsh	393.2
Mixed Emergent marsh (Forest)	75.3
Mixed Emergent marsh (Prairie)	370.7
Prairie Wetland Complex	1573.0
Rich Fen (Transition) Sedge Subtype	30.5
Saline Wet Prairie Complex	1957.1
Seepage Meadow / Carr	10.4
Seepage Wetland Complex	490.6
Shrub Swamp - Unknown/Unresolved Subtype	306.2
Shrub Swamp Seepage Subtype	1422.6
Wet Brush Prairie	21.8
Wet Meadow	288.7
Wet Prairie (Central)	7.9
Wet Prairie (Northwest)	4798.3
Wet Prairie (Northwest) Saline Subtype	191.8
Wet Prairie (Northwest) Seepage Subtype	394.1
Willow - Dogwood Shrub Swamp	77.4

5.3 Invasive species

Species that have been introduced into a new location where they do not naturally occur are known as an “exotic” or “non-native” species. If exotic species cause economic or ecological problems, they become known as “invasive.” Invasive aquatic species can have adverse effects on the water quality, recreational usability, and/or biotic trophic structure of a lake. Once invasive species are introduced into a lake, they can rapidly colonize areas that are occupied by native species. Invasive species outcompete native species for the resources necessary to survive and in turn can negatively impact a native population. Once they’ve entered a new aquatic system, invasive species are very difficult, if not impossible, to eradicate.

Common invasive aquatic species include Eurasian Watermilfoil (*Myriophyllum spicatum;* plant), curly-leaf pondweed (*Potamogeton crispus*; plant), zebra mussels (*Dreissena polymorpha*; invertebrate) and common carp (*Cyprinus carpio*; fish). According to the MN DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html) and MN DNR Designation of Infested Waters (MN DNR 2011b), no lakes within the BRW are designated as an infested water body (*i.e.,* having a

colonized invasive species). However, after reviewing the fish surveys completed by MN DNR, common carp exist in Stinking Lake. Common carp are considered a regulated invasive species and are legal to possess, buy and sell, but cannot be released into public waters. The survey confirming common carp in the lake was completed in 1964 and the current status of common carp in the lake is unknown.

5.4 Endangered and threatened species associated with lakes

The MN DNR rare species guide (http://www.dnr.state.mn.us/rsg/filter_search.html#searchform) was queried for all rare and endangered species found within the watershed. Eleven plant and five bird species associated with lakes/wetlands are considered as a special concern, threatened, or endangered species in Minnesota. **Table 9** displays the rare species found within the BRW that are associated with lakes and wetlands.

Table 9. Rare species associated with lakes and wetlands within the Buffalo River Watershed.

Common Name	Scientific Name	Minnesota Status	Federal Status	Species type
Felwort	*Gentianella amarella ssp. acuta*	Special Concern	None	Plant
Few-flowered Spike-rush	*Elocharis quinqueflora*	Special Concern	None	Plant
Hair-like Beak-rush	*Rhynchospora capillacea*	Threatened	None	Plant
Hairy Fimbristylis	*Fimbristylis puberula var. interior*	Endangered	None	Plant
Shortray Fleabane	*Trimorpha lonchophylla*	Special Concern	None	Plant
Small White Lady's-slipper	*Cypripedium candidum*	Special Concern	None	Plant
Sterile Sedge	*Carex sterilis*	Threatened	None	Plant
Twig-rush	*Cladium mariscoides*	Special Concern	None	Plant
Western Prairie Fringed Orchid	*Platanthera praeclara*	Endangered	Threatened	Plant
Whorled Nut-Rush	*Scleria verticillata*	Threatened	None	Plant
Widgeon-grass	*Ruppia maritima*	Special Concern	None	Plant
Marbled Godwit	*Limosa fedoa*	Special Concern	None	Bird
Nelson's sparrow	*Ammodramus nelsoni*	Special Concern	None	Bird
Trumpeter Swan	*Cygnus buccinator*	Threatened	None	Bird
Wilson's phalarope	*Phalaropus tricolor*	Threatened	None	Bird
Yellow Rail	*Coturnicops noveboracensis*	Special Concern	None	Bird

6. BRW Lake Data

The scope of this report is to summarize water quality in every BRW lake that has data available within the past 10-years. Much of the data and information within this report were obtained from MPCA personnel, the MN DNR LakeFinder website (http://www.dnr.state.mn.us/lakefind/index.html), MN DNR Geographic Information Systems (GIS) online data deli (http://deli.dnr.state.mn.us), the MPCA's lake water quality data website (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-data-search.html), and BRRWD-collected information and reports.

6.1 Lake Characteristics

Lake characteristics for all BRW lakes that have had water quality data available within the 10-years are summarized in **Table 10**. Morphometric characteristics including the surface area, maximum depth and percent littoral were collected from the MN DNR LakeFinder website. Percent littoral is defined as the portion of the lake that is 15-feet or less. This is important since that is normally the maximum depth which can sustain rooted aquatic plants (macrophytes). Generally, lakes with a high percentage of littoral area have extensive macrophyte beds. Coincidentally, shallow lakes are defined as lakes as having a maximum depth of less than 15-feet deep or 80% or more of the area is littoral.

Several of the lakes in **Table 10** had no information on the MN DNR LakeFinder website. In those cases, the MN DNR's 24k lakes GIS layer and the MPCA's lake water quality data website were used to fill in data gaps.

Since 1964, fifty-two lakes in the BRW have been sampled for water quality. Most of this sampling was done since 2001. The majority of lakes with water quality data (39 or 75%) are located in the NCHF Ecoregion while the NLF Ecoregion contains the fewest number of lakes (4 or 8%).

Table 10. Lake characteristics for all lakes within the Buffalo River Watershed lakes that have water quality data.

Lake Name	Lake ID	County	Ecoregion[1]	Surface Acres	Max depth (feet)[2]	Percent Littoral (%)	Impaired after 2011 assessment?	Number of Public Accesses	BRRWD Priority Lake?
Anfinson	14-0044-00	Clay	NCHF	24	unknown (shallow)	100	No	unknown	No
Axberg	03-0660-00	Becker	NCHF	43	14.0	100	No	0	No
Balsam	03-0292-00	Becker	NLF	108	7.0	100	No	0	Yes
Big Sugar Bush	03-0304-00	Becker	NCHF	431	42.0	69	No	1	Yes
Birch	03-0352-00	Becker	NCHF	233	25.0	72	No	0	Yes
Boyer	03-0579-00	Becker	NCHF	383	26.0	53	Yes	1	Yes
Buffalo	03-0350-00	Becker	NCHF	412	9.0	47	No	1	No
Canary	03-0516-00	Becker	NCHF	61	25.0	66	No	0	No
Doran	14-0089-00	Clay	LA	112	7.0	100	No	0	Yes
East LaBelle	03-0648-00	Becker	LA	186	19.0	42	No	1	Yes
Eleven	14-0018-00	Clay	NCHF	59	26.0	unknown	No	0	No
Fifteen	14-0030-00	Clay	NCHF	133	22.0	74	No	1	Yes
Fish	03-0314-00	Becker	NCHF	82	59.0	43	No	1	Yes
Forget-Me-Not	03-0624-00	Becker	NCHF	361	7.0	100	Yes	0	Yes
Gottenberg	03-0528-00	Becker	NCHF	114	9.0	100	Yes	n/a	Yes
Gourd	03-0635-00	Becker	NCHF	117	8.0	100	Yes	0	Yes
Grove	56-0952-00	Otter Tail	NCHF	403	18.0	92	No	unknown	No
Harrison (Helgeson)	56-0934-00	Otter Tail	NCHF	108	12.0	100	No	unknown	No
Island	03-0351-00	Becker	NCHF	31	12.0	100	No	unknown	No
Jacobs	56-1039-00	Otter Tail	NCHF	157	17.0	unknown	Yes	0	Yes
Lee	14-0049-00	Clay	NCHF	134	36.0	64	No	1	Yes
Lime	03-0646-00	Becker	NCHF	98	8.0	100	Yes	0	Yes
Little Round	03-0302-00	Becker	NCHF	565	6.0	100	No	n/a	Yes
Little Sugar Bush	03-0313-00	Becker	NCHF	220	29.0	45	No	1	Yes
Lund Brothers Marsh	03-0621-00	Becker	NCHF	28	unknown (shallow)	100	No	unknown	No

[1] NCHF = North Central Hardwood Forest, NLF = Northern Lakes and Forests; LA = Lake Agassiz
[2] Unknown (shallow) = indicates no definite max depth was found but ancillary data showed the lake is considered a shallow lake

Lake Name	Lake ID	County	Ecoregion[1]	Surface Acres	Max depth (feet)[2]	Percent Littoral (%)	Impaired after 2011 assessment?	Number of Public Accesses	BRRWD Priority Lake?
Maria	14-0099-00	Clay	LA	108	9.0	100	Yes	0	Yes
Marshall	03-0526-00	Becker	NCHF	159	21.0	66	Yes	1	Yes
Meyer	14-0079-00	Clay	LA	108	7.0	100	No	0	Yes
Mission	03-0471-00	Becker	NCHF	232	10.0	100	Yes	0	No
O-Me-Mee	03-0428-00	Becker	NCHF	120	10.0	100	No	0	No
Pete	56-0941-00	Otter Tail	NCHF	100	16.0	unknown	No	unknown	No
Pine	03-0200-00	Becker	NLF	533	18.0	89	No	unknown	No
Rice	03-0291-00	Becker	NCHF	177	23.0	74	No	0	Yes
Rock	03-0293-00	Becker	NCHF	1199	18.0	83	No	1	Yes
Sand (Stump)	03-0659-00	Becker	NCHF	200	28.0	52	Yes	1	Yes
Sand (Yort)	03-0618-00	Becker	NCHF	55	9.0	100	No	0	No
Silver	14-0100-00	Clay	LA	109	39.0	33	No	1	Yes
Sorenson	03-0625-00	Becker	NCHF	60	unknown (shallow)	unknown	Yes	unknown	No
St. Clair	03-0430-00	Becker	NCHF	100	29.0	88	No	0	Yes
Stakke	03-0631-00	Becker	NCHF	450	15.0	100	Yes	1	Yes
Stinking	03-0647-00	Becker	LA	370	7.0	100	Yes	0	Yes
Swede Grove	14-0078-00	Clay	LA	120	8.0	100	No	0	Yes
Talac	03-0619-00	Becker	NCHF	98	13.0	100	Yes	0	Yes
Tamarack, North	03-0241-02	Becker	NLF	1431	17.0	97	Yes	4	Yes
Tamarack, South	03-0241-01	Becker	NLF	612	7.5	100	No	n/a	Yes
Ten	14-0021-00	Clay	NCHF	92	17.0	90	No	0	Yes
Three	14-0019-00	Clay	NCHF	105	14.0	100	No	0	Yes
Turtle	03-0657-00	Becker	NCHF	187	73.0	37	No	1	Yes
Unnamed	03-0650-00	Becker	LA	55	unknown (shallow)	unknown	No	unknown	No
Unnamed (North Mayfield)	14-0029-00	Clay	NCHF	33	13.0	100	No	0	No
West Labelle (Duck)	03-0645-00	Becker	LA	192	12.0	100	Yes	unknown	No
West Olaf	56-0950-01	Otter Tail	NCHF	209	61.0	35	No	1	No

[1] NCHF = North Central Hardwood Forest, NLF = Northern Lakes and Forests; LA = Lake Agassiz

[2] Unknown (shallow) = indicates no definite max depth was found but ancillary data showed the lake is considered a shallow lake

6.2 Lake Chemistry Data

Water quality data were provided by MPCA staff for all lakes within the BRW. A total of 52 lakes were found to have at least some TP, chlorophyll-a, and/or Secchi disk transparency data collected. Procedures established by the MPCA to assess lake conditions and determine impairment were used to evaluate and assess the water quality in these lakes (MPCA 2010).

The available water quality data were filtered and summarized to include only samples taken: 1) in the past 10-years (2001-2010), 2) at the surface, 3) from June through September, and 4) not as quality control. After filtering the data, out of the 52 lakes that have data since 1964, 46 had current water quality data available for analysis. Anfinson (14-0044), Lund Brothers Marsh (03-0621), Unnamed (03-0650), and Unnamed (North Mayfield; 14-0029)) Lakes had data that is considered "poor" quality per the MPCA's definition and were, therefore, not included in this analysis. Water quality data were compared to ecoregion standards and typical summer water quality ranges (as defined in Heiskary and Wilson 2005) for each parameter.

Several "priority" lakes (as defined by the BRRWD (HEI 2010a)) have no, or no recent (in the past 10-years), water quality data available. The lakes with no data are Balsam (03-0292), Doran (14-0089), Fish (03-0314), Meyer (14-0079), and Three (14-0019). Axberg (03-0660) had data collected, but only in 1994, 1995, 1997, 1998, and 2000.

For comparison to water quality standards, lakes were separated out by ecoregion and into deep versus shallow depths. Water quality data for deep and shallow lakes within the NCHF Ecoregion are displayed in **Figures 9-11** and **12-14**, respectively. Data for all lakes within the NLF Ecoregion are displayed in **Figures 15-17.** As mentioned previously, the LA Ecoregion does not have numeric water quality criteria developed. The MPCA recommends either using case-by-case standards or using standards of an adjacent Ecoregion (MPCA 2010). When performing the spring 2011 assessment, the MPCA determined that the land use surrounding the three lakes in the LA Ecoregion was most similar to that in the WCBP and NGP Ecoregions. Those ecoregions' numeric criteria were, therefore, applied for this assessment. A similar practice is followed herein, with the WCBP/NGP criteria displayed on the LA Ecoregion lakes' plots. Since the typical summer ecoregion ranges differ for the WCBP and the NGP, the mean lower value and mean upper values are displayed on each plot for each constituent. Data for deep and shallow lakes within the Lake Agassiz Plain Ecoregion are displayed in **Figures 18-20** and **21-23**, respectively. A summary of water quality data for all lakes data can be found in **Appendix A**.

The deep lakes within the NCHF ecoregion show a range of contamination. The data from the four impaired lakes (Boyer, Jacobs, Marshall and Stand (Stump)) confirm the impairment. Boyer and Marshall median values exceed the TP and chlorophyll-a numeric standard, while Jacobs and Sand

(Stump) show the 25th percentile exceeding the TP and Chl-a numeric criteria. All lakes show the 75th percentile of all data fall outside the typical ecoregion summer values. Data from several other lakes (Birch, Lee, and Ten) show the 75th percentile exceeds the standard. The remaining lakes show good water quality as they fall within the typical summer ecoregion ranges and are primarily below the numeric standard.

The shallow lakes within the NCHF ecoregion have eight lakes (Forget-me-not, Gottenberg, Gourd, Lime, Mission, Lee (Talac), Sorenson, and Stakke) listed as impaired. Data support these impairment listings, as high TP and chlorophyll-a concentrations show these three lakes fall outside the typical ecoregion ranges and exceed the water quality standard. Lee (Talac) and Sorenson Lakes show good Secchi disk depths. Other lakes (Harrison and O-Me-Mee) show similar data as the impaired lakes, but were not determined to be impaired by the MPCA. These lakes should continue to be monitored and assessed for possible impairment listing. Although most of the lakes with water quality data collected show an impairment for excess nutrients, a few of the lakes (Buffalo, Island, Little Round, Little Sugar Bush, Pete, and Sand (Yort)) have good water quality and fall below the numeric standards.

The NLF ecoregion has one impaired lake (North Tamarack), which is supported by the available data. Pine and South Tamarack Lakes data show the 75th percentile of all data collected fall within the typical ecoregion summer ranges for TP and Chl-a.

No deep lakes within the LA ecoregion are impaired. The data support this with the majority of chlorophyll-a and TP data falling below the numeric standards and the Secchi disk data showing the 75th percentile of all data are above the numeric standard.

Shallow lakes within the LA ecoregion have two lakes and one reservoir (Maria, West Labelle and Stinking, respectively) listed as impaired for excess nutrients. The data support these listings, as the 25th percentile of chlorophyll-a data for Maria Lake and Stinking Reservoir exceed the numeric standard and all collected data exceed the TP numeric standard. In West Labelle Lake, the 75th percentile and the median value of chlorophyll-a and TP data exceed the numeric standard. Swede Grove Lakes show TP and chlorophyll-a data near the standard and falling within or below the typical summer ecoregion ranges. Secchi disk transparency data show Swede Grove and West Labelle have good water clarity.

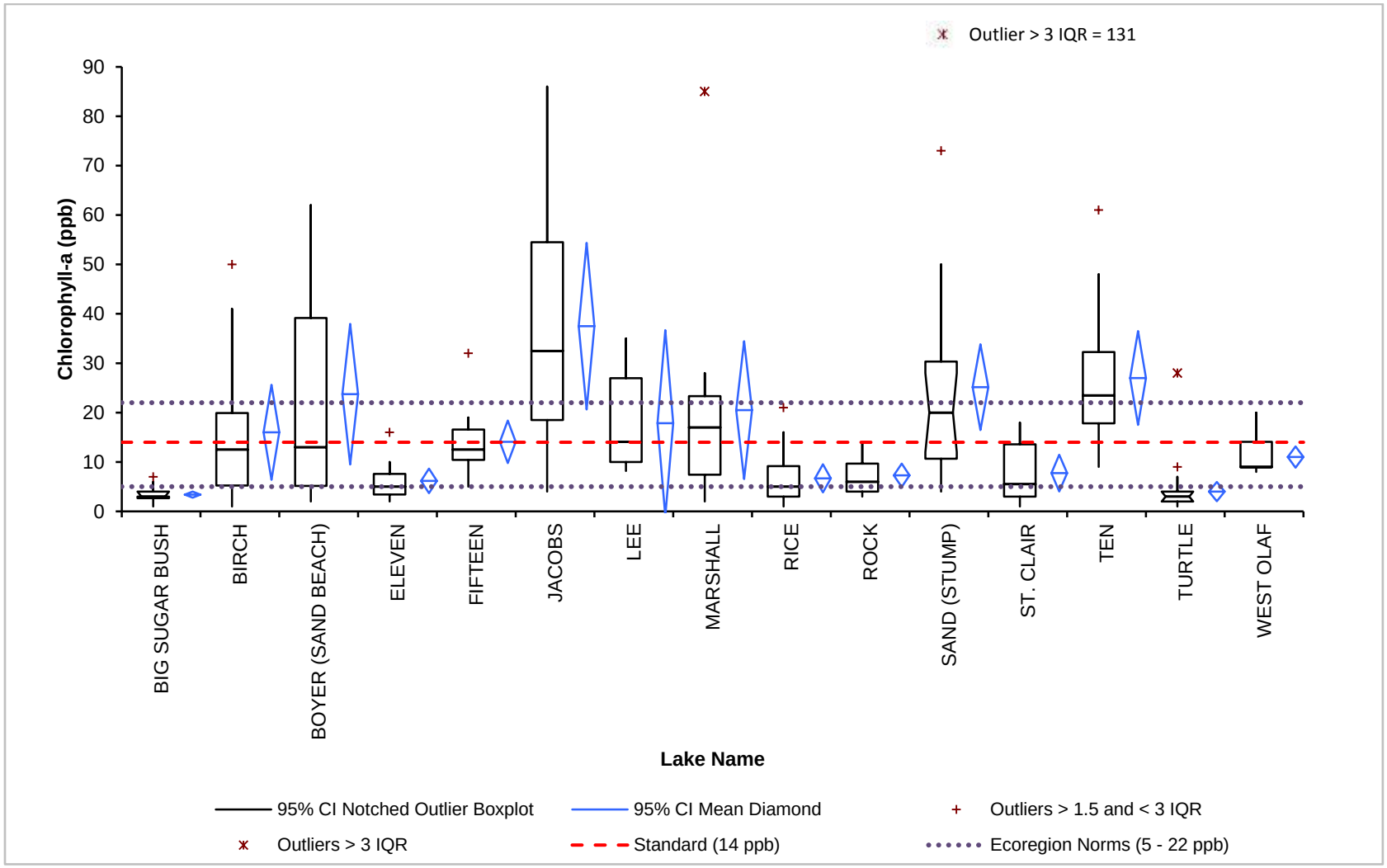

Figure 9. Chlorophyll-a concentrations (ppb) summary for deep lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

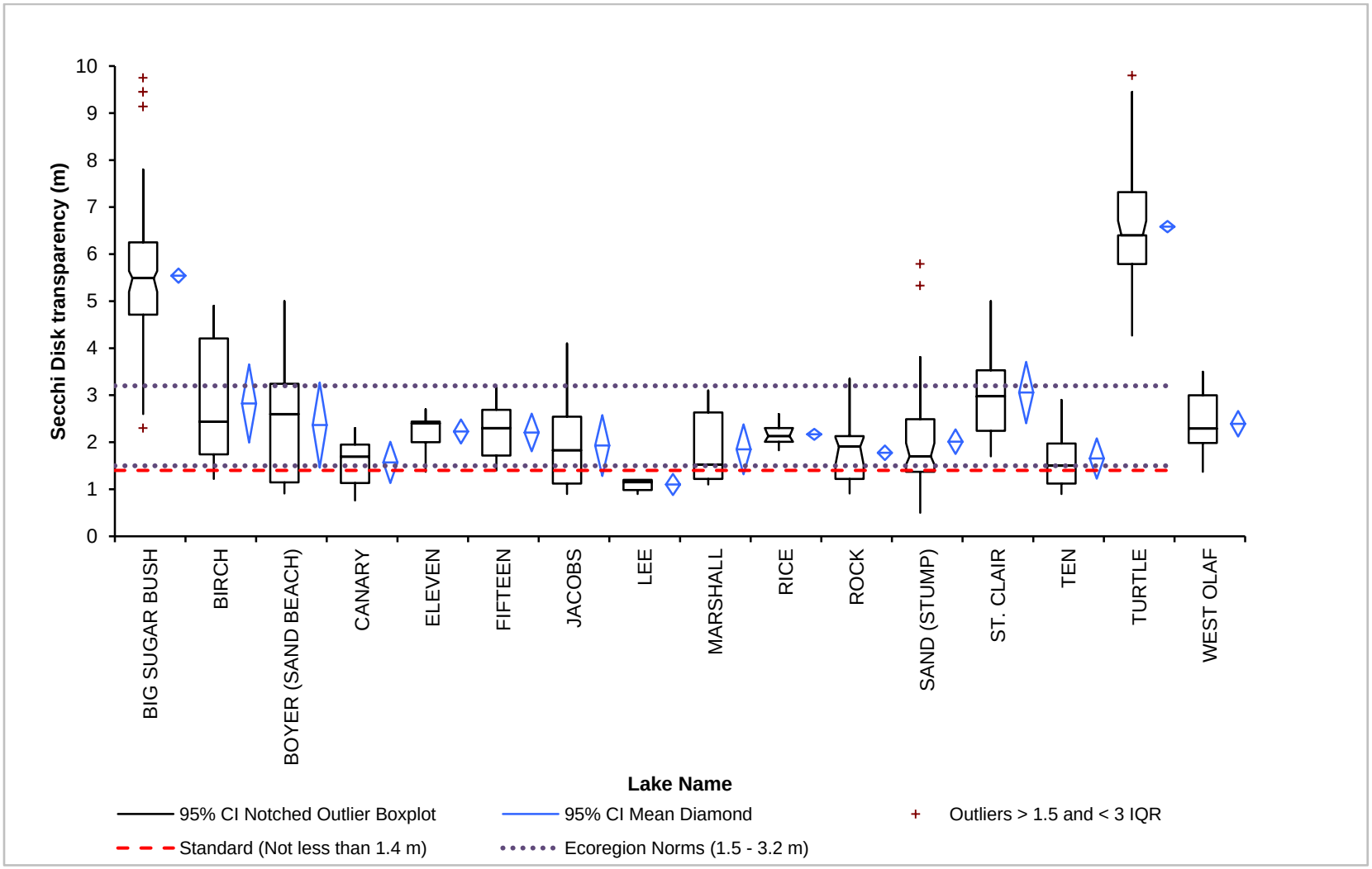

Figure 10. Secchi disk transparency depth (m) summary for deep lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

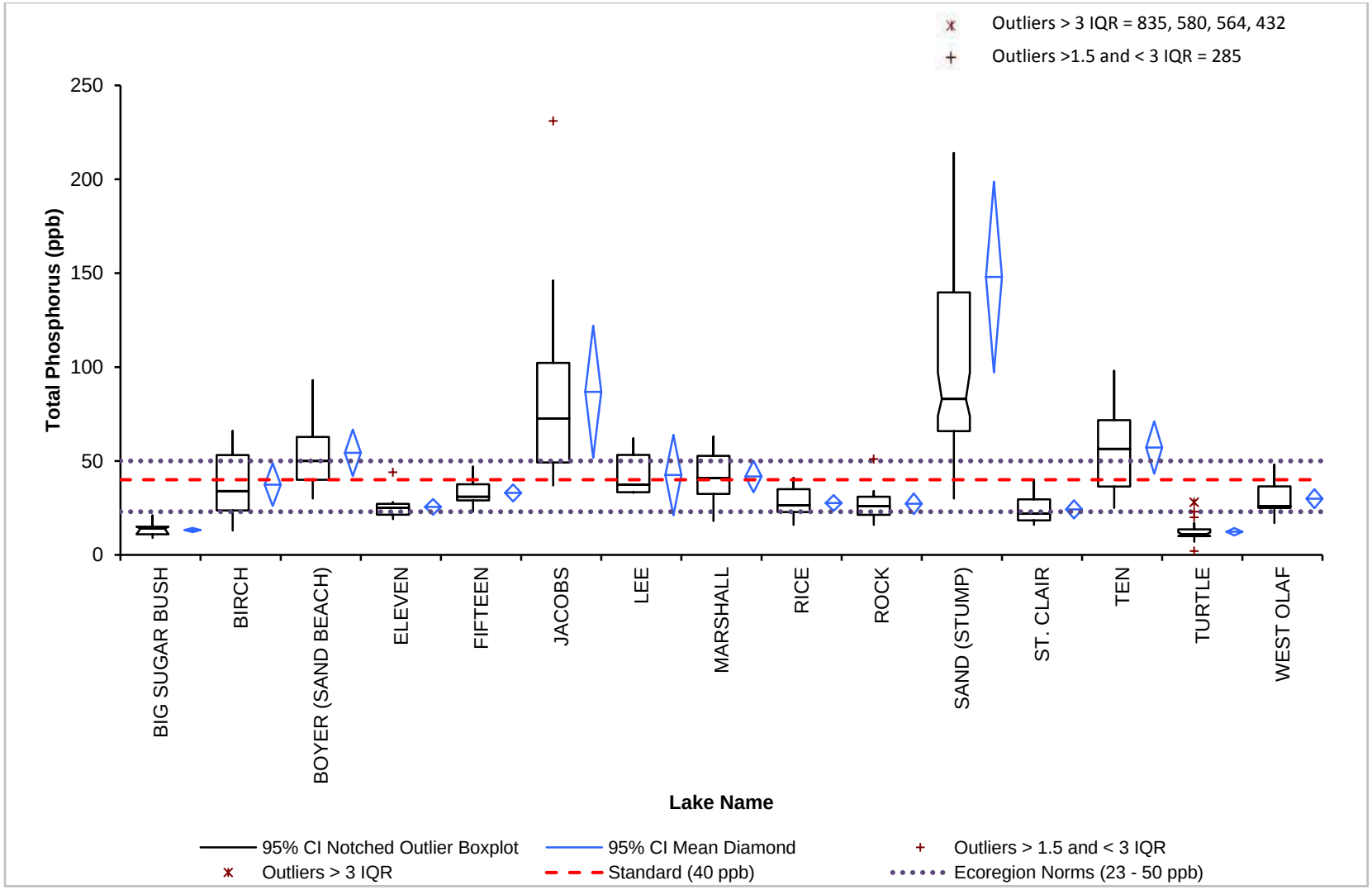

Figure 11. Total phosphorus concentration (ppb) summary for deep lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

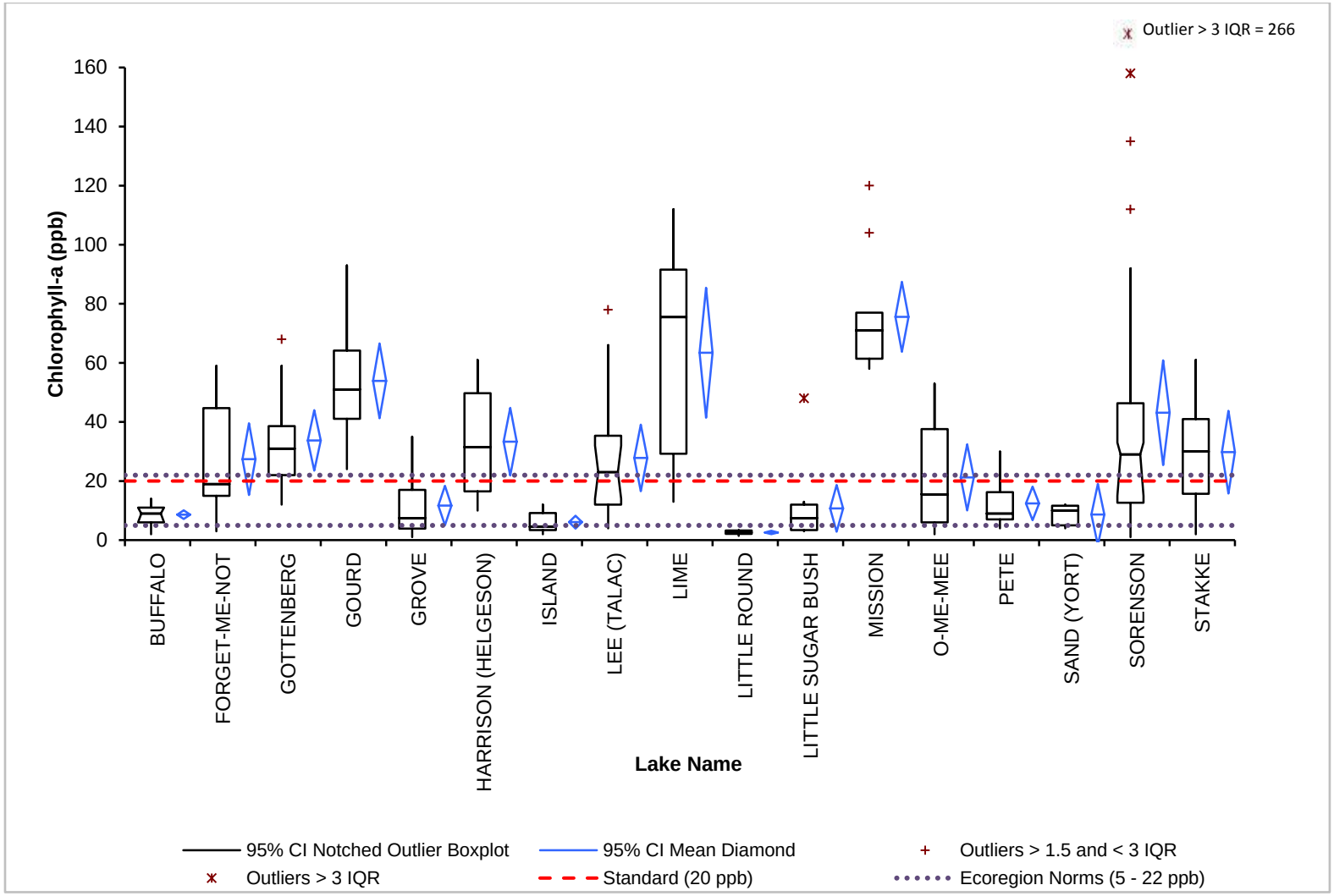

Figure 12. Chlorophyll-a concentration (ppb) summary for shallow lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

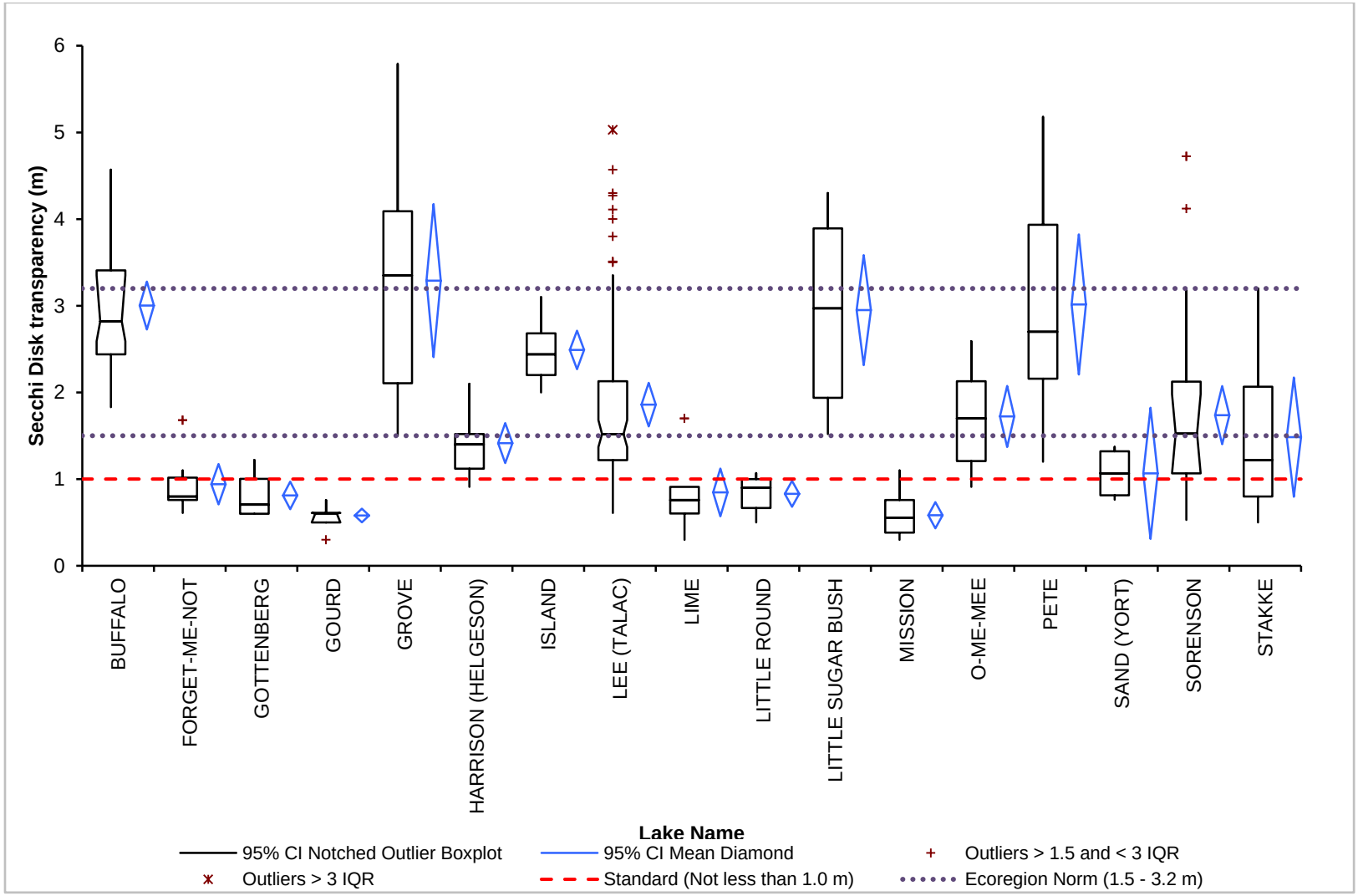

Figure 13. Secchi disk transparency (m) summary for shallow lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

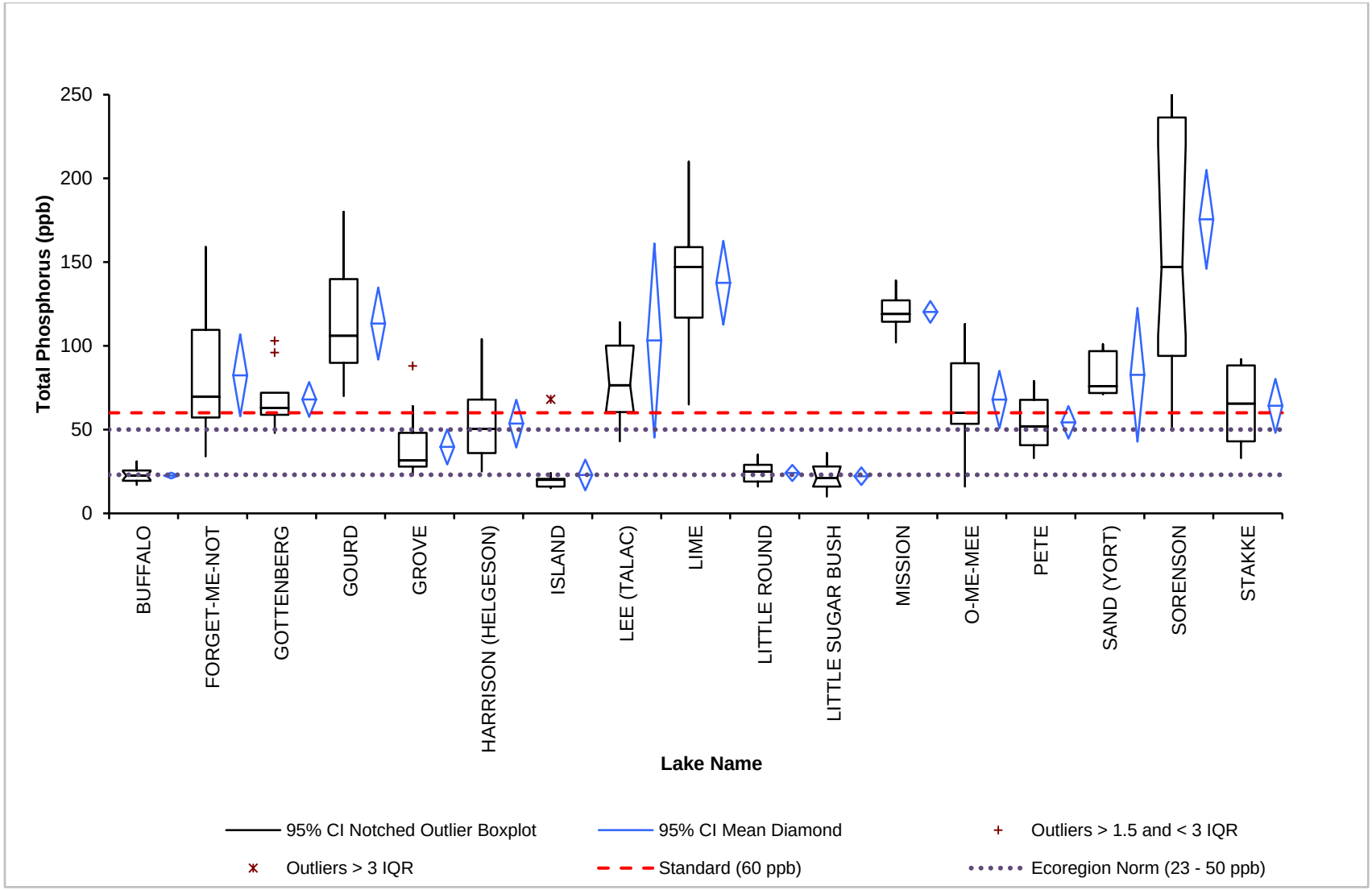

Figure 14. Total phosphorus concentration (ppb) summary for shallow lakes in the North Central Hardwood Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

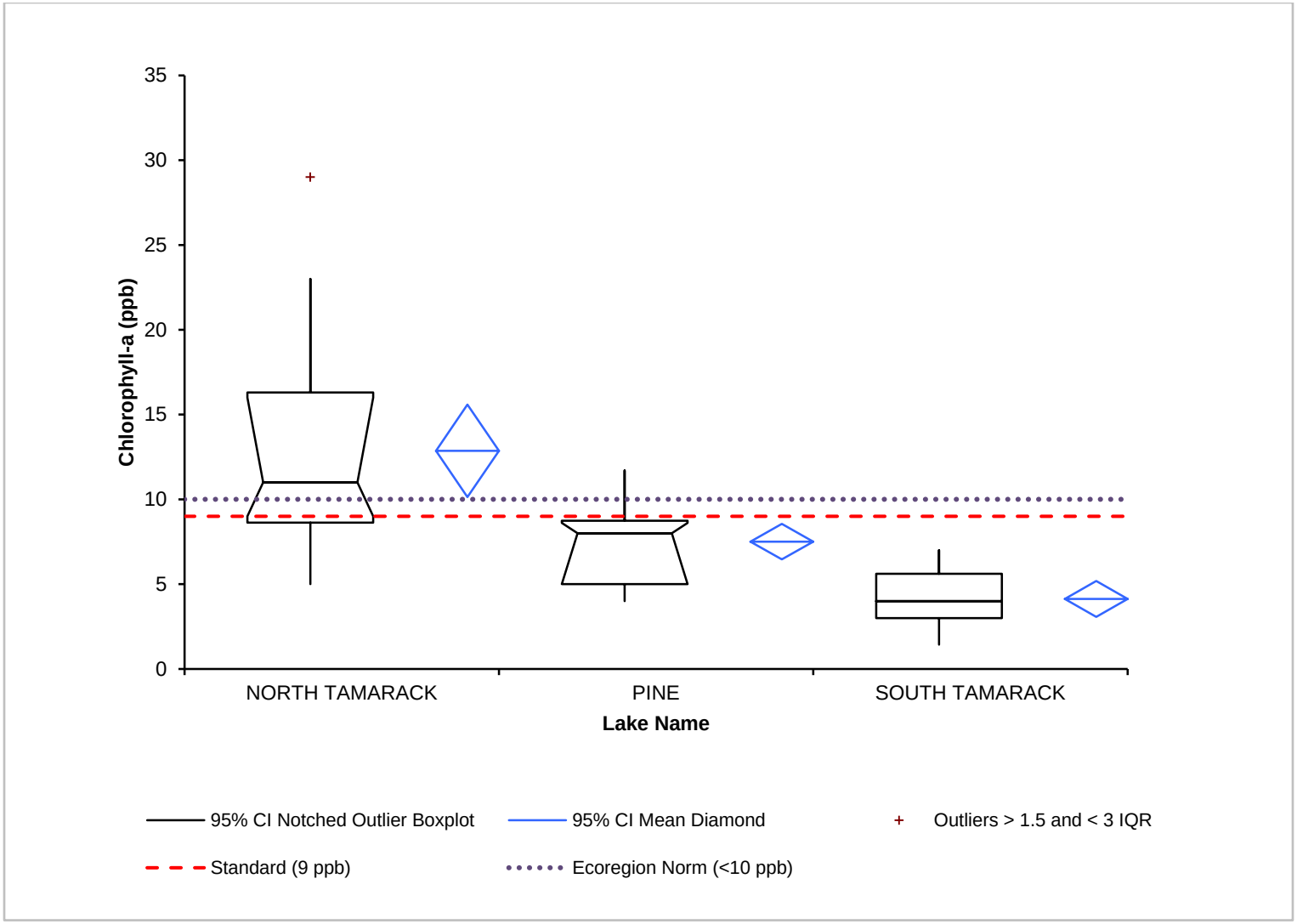

Figure 15. Chlorophyll-a concentration (ppb) summary for lakes in the Northern Lakes and Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

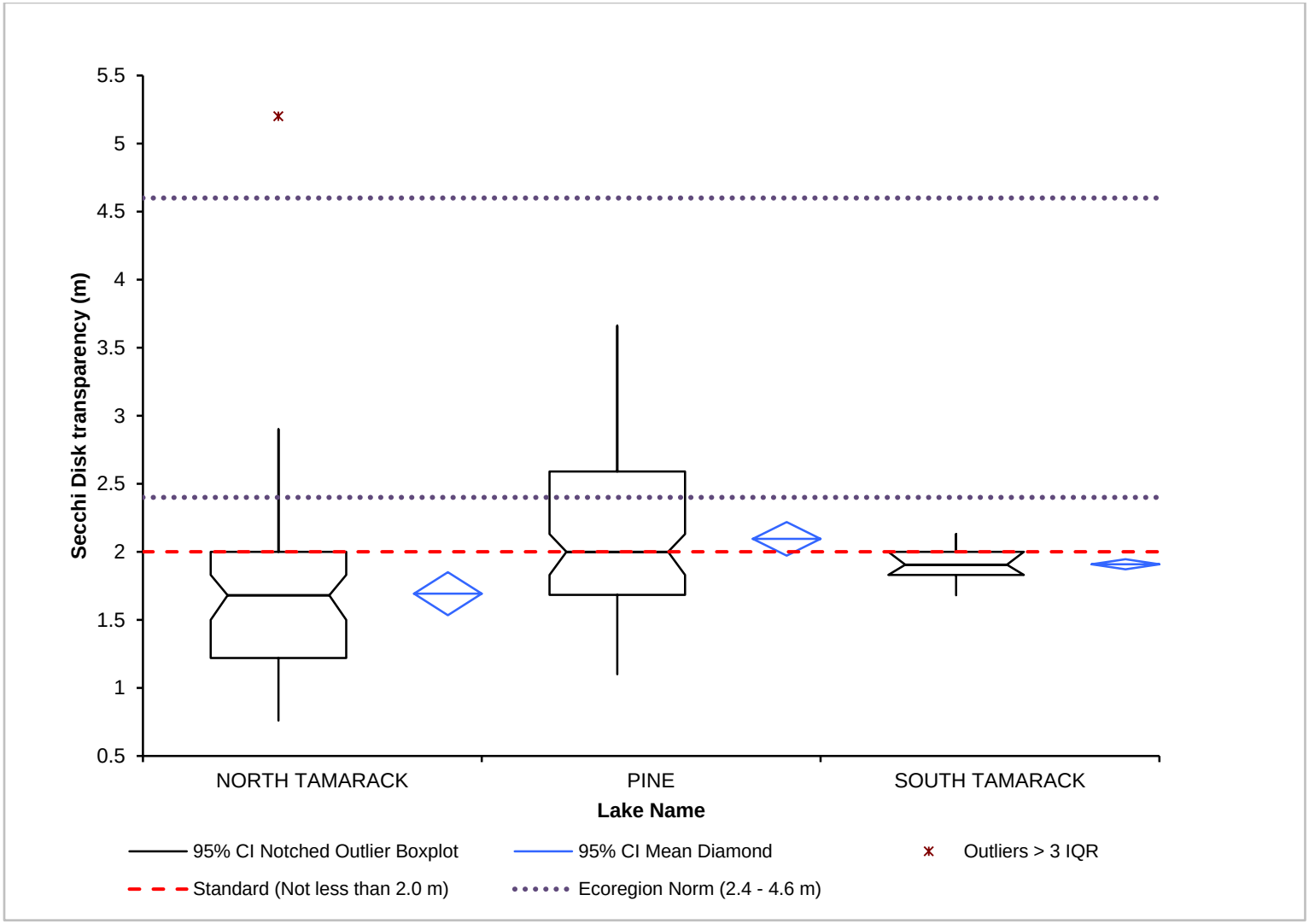

Figure 16. Secchi disk transparency depth (m) summary for lakes in the Northern Lakes and Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

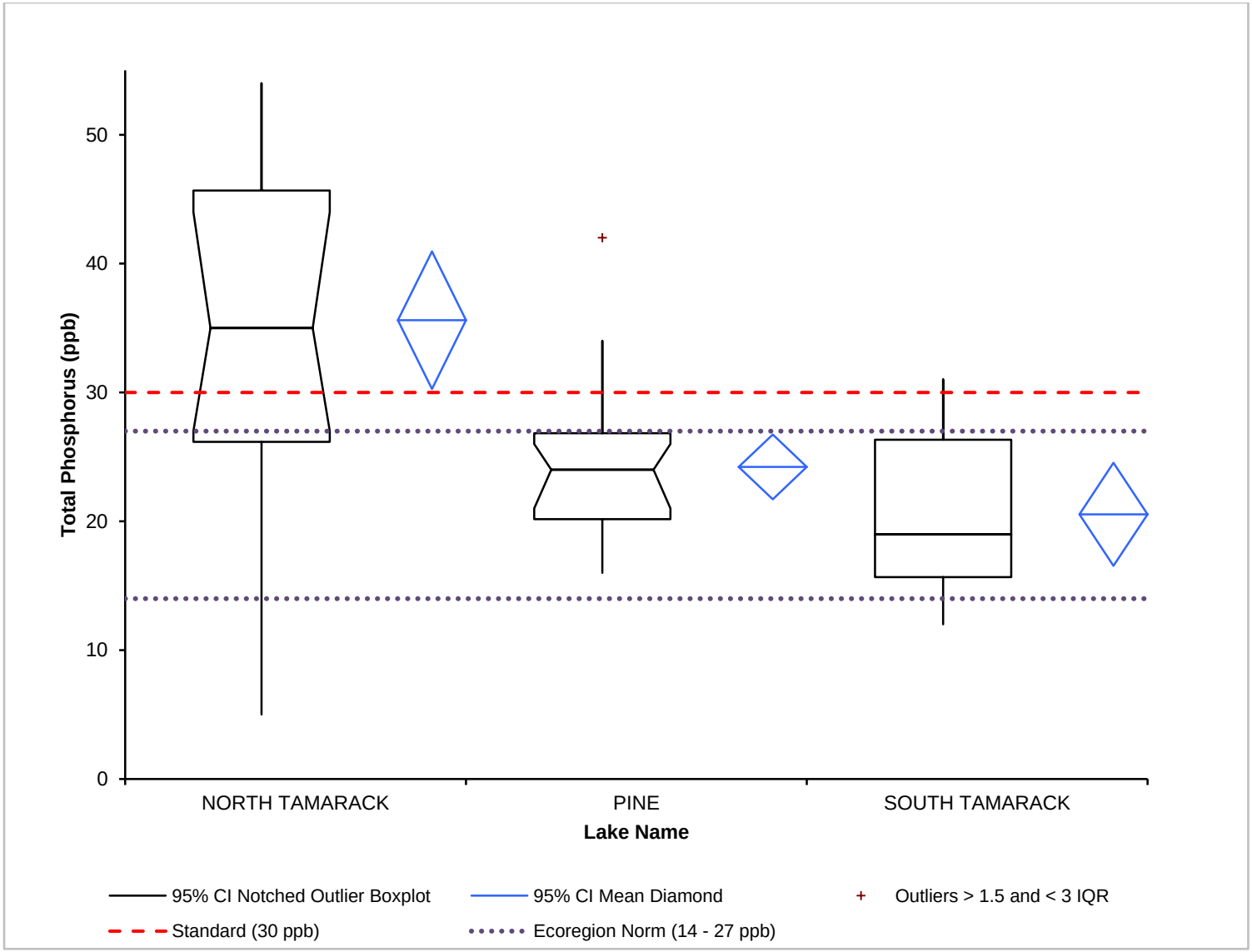

Figure 17. Total phosphorus concentration (ppb) summary for lakes in the Northern Lakes and Forest Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

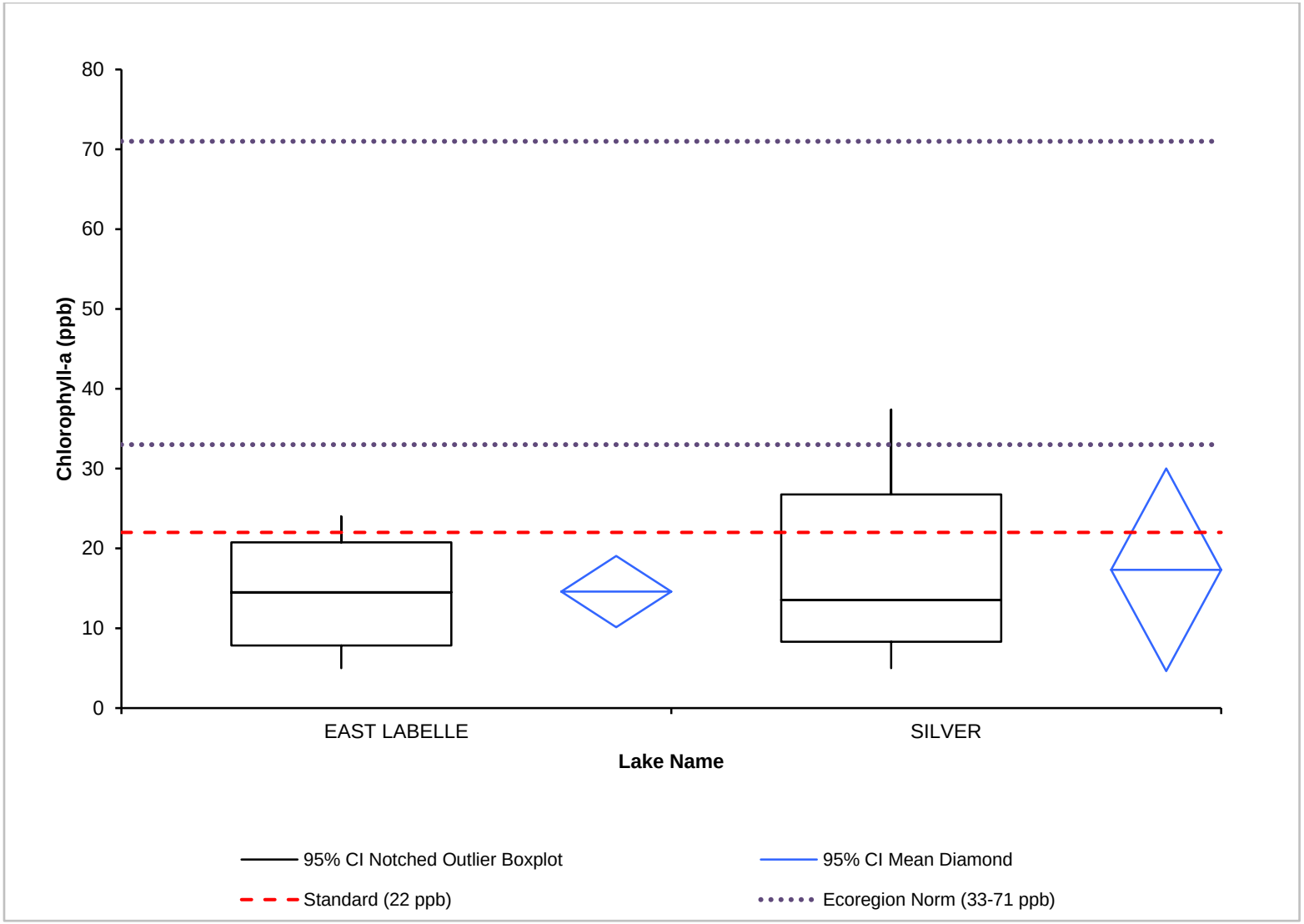

Figure 18. Chlorophyll-a concentrations (ppb) summary for deep lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

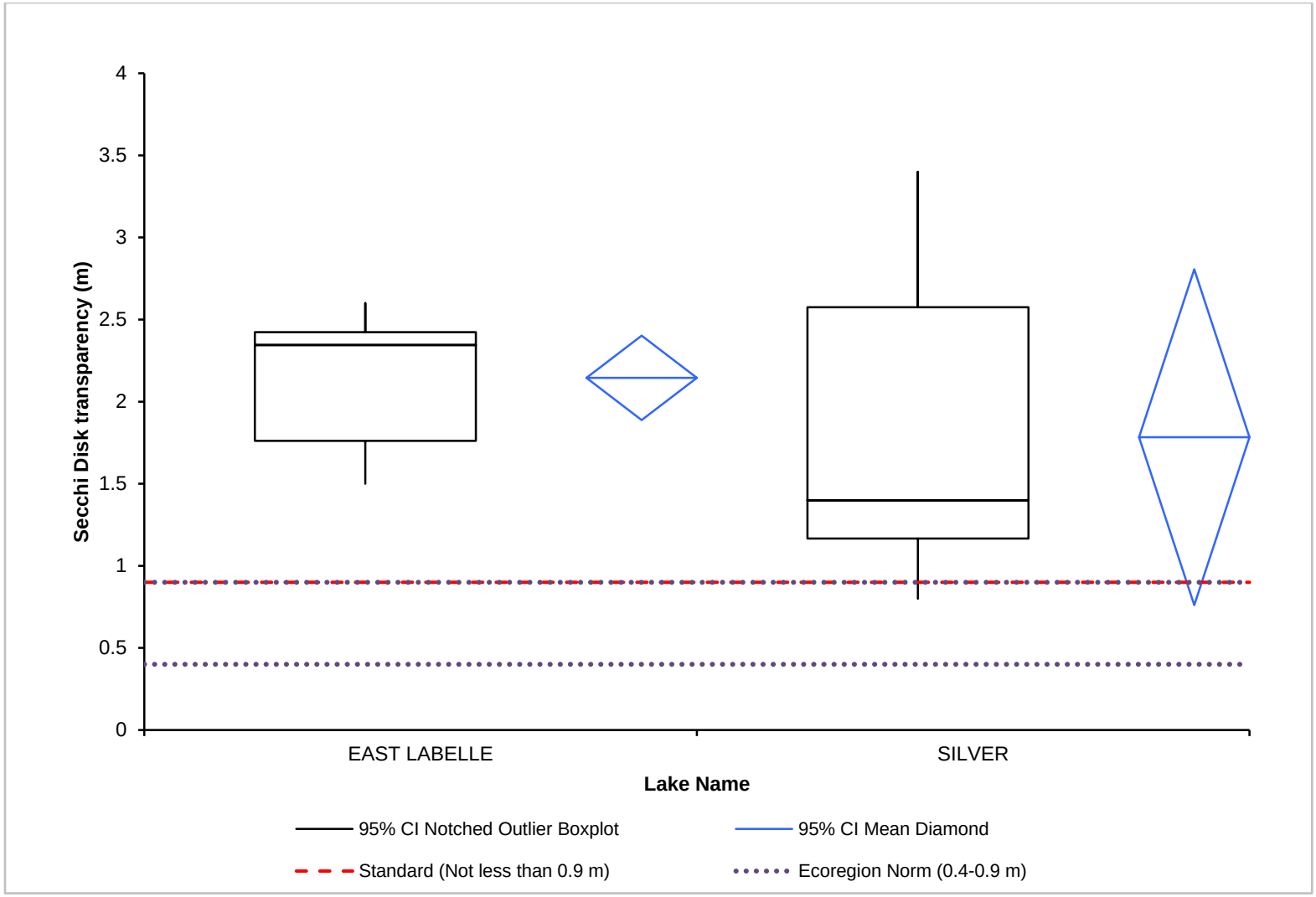

Figure 19. Secchi disk transparency depth (m) summary for deep lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

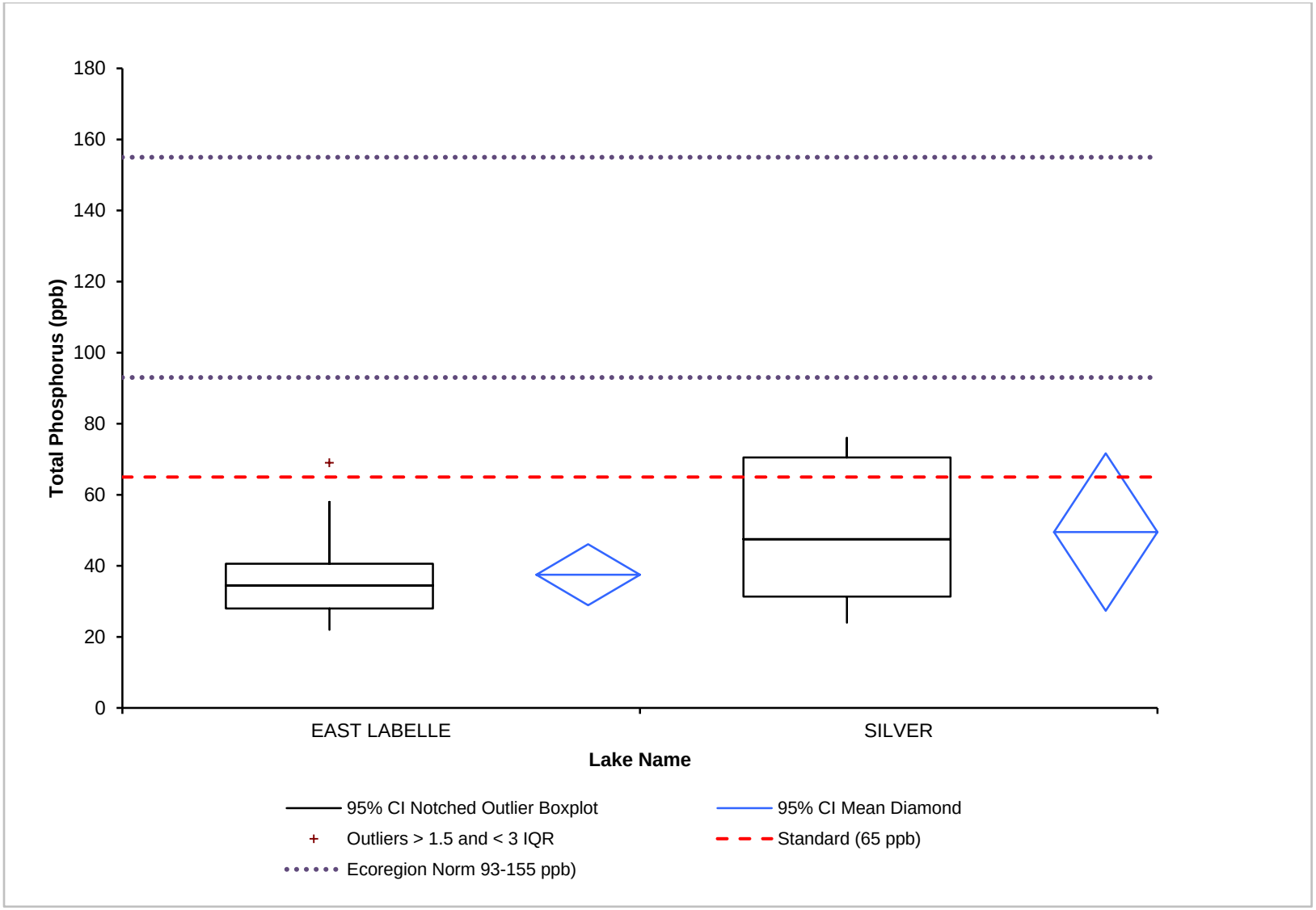

Figure 20. Total phosphorus concentration (ppb) summary for deep lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

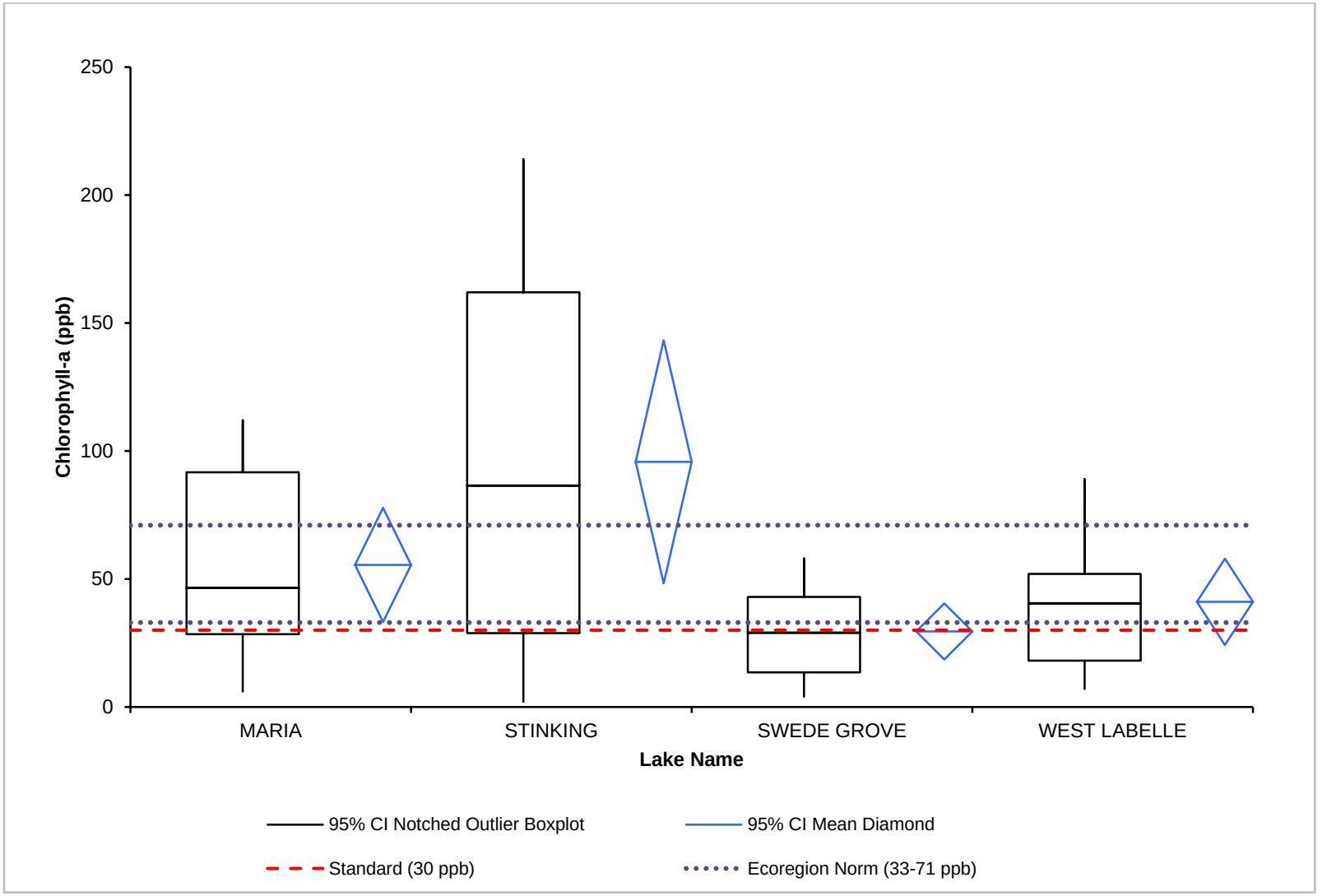

Figure 21. Chlorophyll-a concentration (ppb) summary for shallow lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

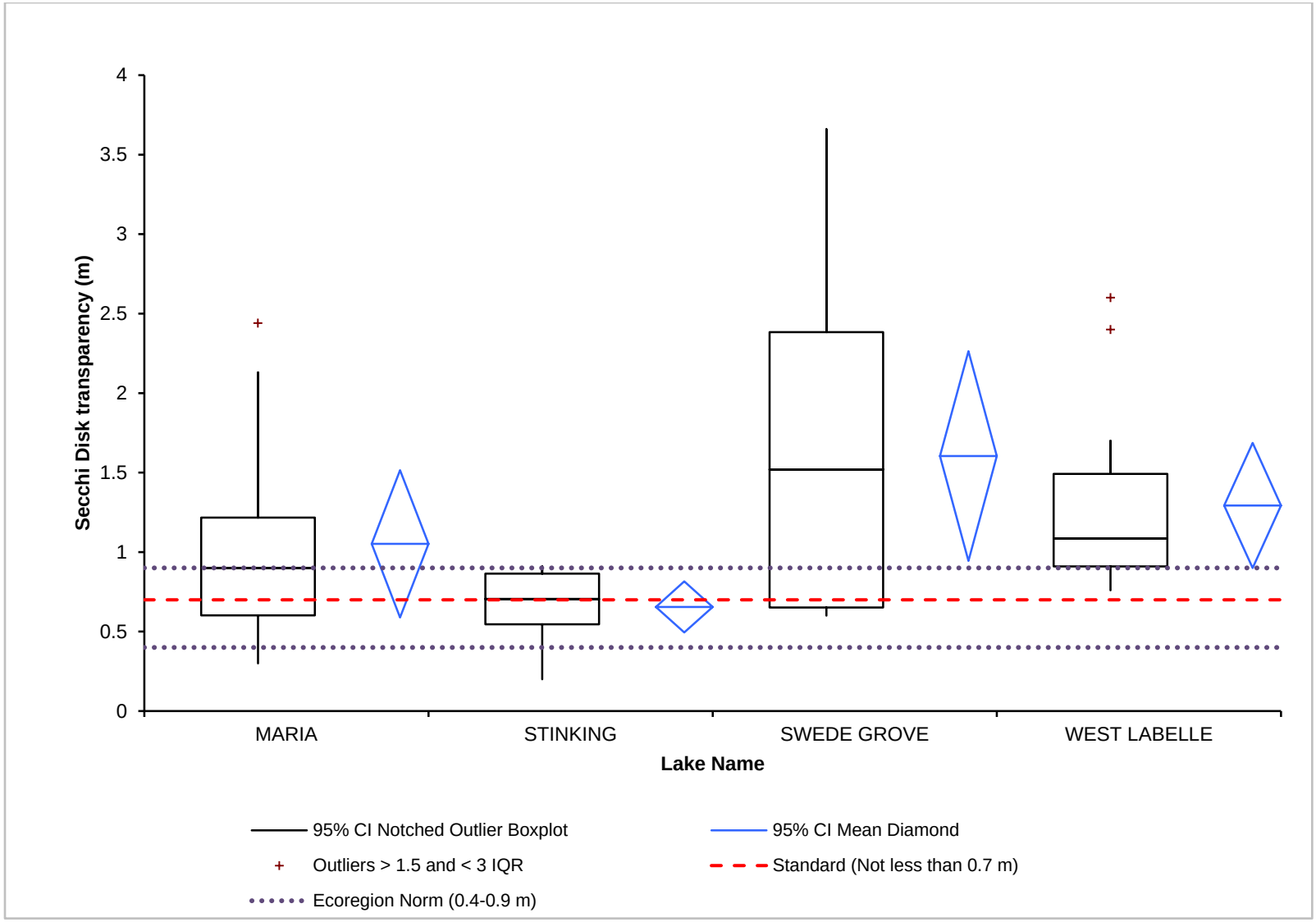

Figure 22. Secchi disk transparency depth (m) summary for shallow lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

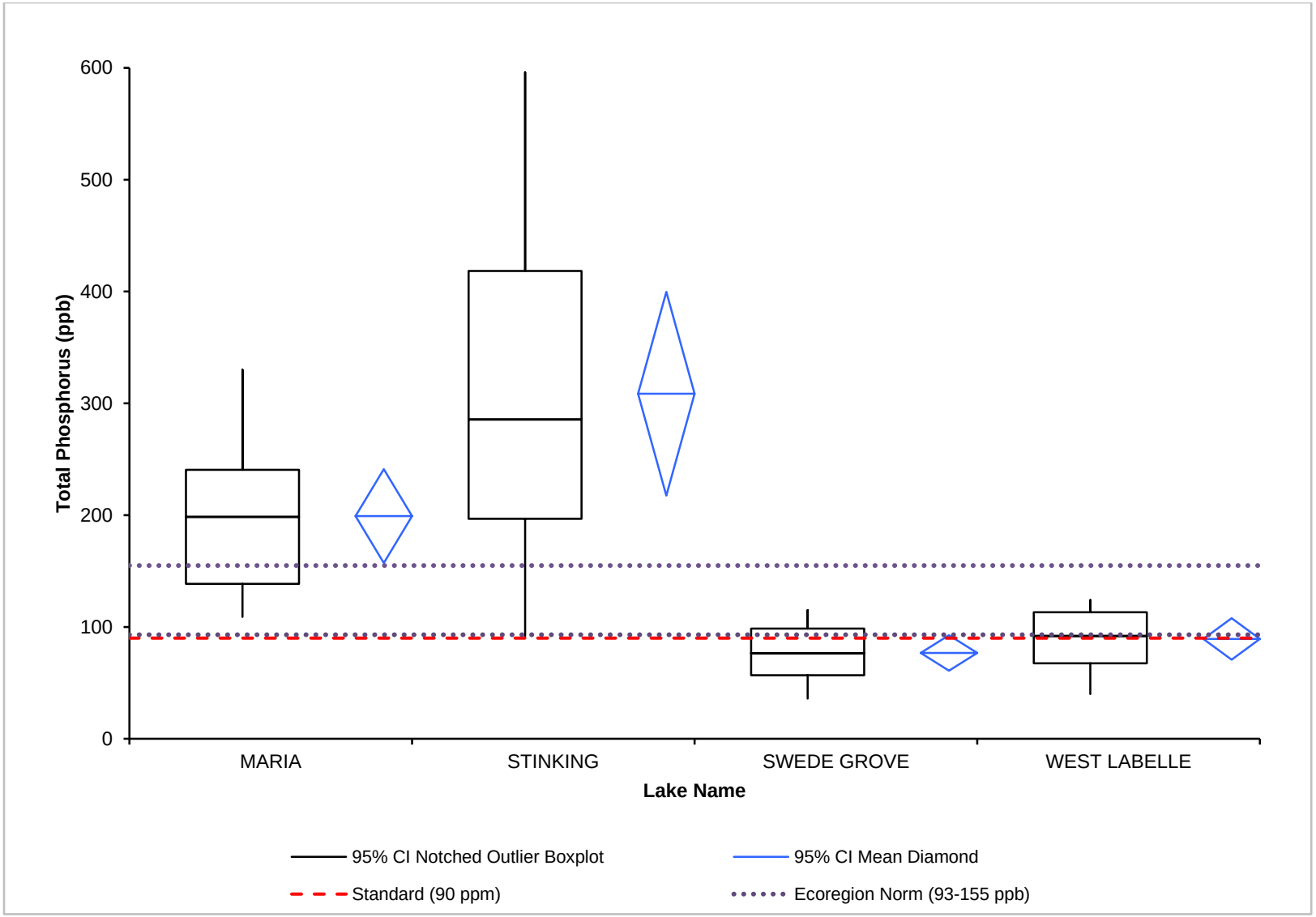

Figure 23. Total phosphorus concentration (ppb) summary for shallow lakes in the Lake Agassiz Ecoregion relative to the Class 2B numeric criteria and Ecoregion norms.

6.3 Trophic Status Index

Trophic status refers to how productive a lake is or the degree of nutrient enrichment in a water body. The trophic status index (TSI) was created by R.E. Carlson (Carlson 1977) as a method to characterize a lake's overall health or productivity. The TSI scale ranges from zero to 100 in which zero indicates an oligotrophic lake with low nutrient concentrations and 100 is a hypereutrophic lake with very high nutrient concentrations. In Minnesota, 65% of all lakes are classified as either eutrophic or hypereutrophic (Heiskary 1985). TSI scores examine the relationship between TP, chlorophyll-a, and Secchi disk transparency and are calculated from the following equations:

Total phosphorus TSI (TSI-P) = 14.42*[ln(TP average)]+4.15
Chlorophyll-a TSI (TSI-C) = 9.81*[ln(Chlorophyll-a average)]+30.6
Secchi disk TSI (TSI-S) = 60 – (14.41*[ln(Secchi average)])
Average TSI = (TSI-P + TSIC + TSIS) / 3

Trophic Status Index values and general associated water quality values are listed in **Table 11**.

Table 11. Trophic status index and description of a typical waterbody.

TSI	Description of waterbody
< 30	Oligotrophic; clear water; high dissolved oxygen through the year in the entire lake
30-40	Oligotrophic; clear water; possible periods of limited dissolved oxygen in deeper portions of the lake
40-50	Moderately clear water; increasing chance of deep portions of the lake having no dissolved oxygen
50-60	Moderately eutrophic; decreased water transparency; possible limited to no dissolved oxygen in deeper portions of the lake; possible aquatic plant problems; supportive of all swimming/aesthetic uses but "threatened"
60-70	Blue-green algae dominance; algal scums possible; extensive aquatic plant problems
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer
> 80	Algal scums present throught summer; summer fish kills; few aquatic plants due to shading of algae; fishery dominated by rough fish

BRW lakes with available water quality data have average TSI values ranging from thirty-nine to seventy-six. **Table 12** displays the TSI-C, TSI-P, TSI-S, and average TSI values for all lakes with water quality within the BRW. Shaded lakes indicate those considered impaired by the MPCA. The majority of the lakes with TSI values in the hypereutrophic category are listed. A considerable number of unlisted lakes may still be considered eutrophic.

Table 12. Trophic Status Index values for all lakes with water quality in the Buffalo River Watershed. Note: Shaded lakes indicate an impaired lake as determined by MPCA.

Lake Name	TSI-C	TSI-P	TSI-S	Average TSI
TURTLE	44	40	33	39
BIG SUGAR BUSH	43	41	35	40
SOUTH TAMARACK	45	48	51	48
ISLAND	48	49	47	48
ST. CLAIR	51	50	44	48
BUFFALO	52	49	44	48
LITTLE SUGAR BUSH	54	49	44	49
ELEVEN	48	51	48	49
PINE	50	50	49	50
RICE	49	52	49	50
LITTLE ROUND	40	50	63	51
ROCK	50	52	52	51
WEST OLAF	54	53	47	52
GROVE	55	57	43	52
BIRCH	58	56	45	53
FIFTEEN	57	55	49	53
PETE	55	62	44	54
EAST LABELLE	57	56	49	54
NORTH TAMARACK	56	56	52	55
MARSHALL	60	58	51	56
SILVER	59	60	52	57
BOYER (SAND BEACH)	62	62	48	57
LEE	59	58	59	59
O-ME-MEE	61	65	52	59
TEN	63	62	53	59
SAND (YORT)	52	68	59	60
HARRISON (HELGESON)	65	62	55	61
STAKKE	64	64	54	61
SWEDE GROVE	64	67	53	61
JACOBS	66	69	51	62
LEE (TALAC)	63	71	51	62
SAND (STUMP)	62	76	50	63
FORGET-ME-NOT	63	68	61	64
WEST LABELLE	67	69	56	64
GOTTENBERG	65	65	63	64
SORENSON	68	79	52	66
LIME	71	75	62	70
MARIA	70	80	59	70
GOURD	70	72	68	70
MISSION	73	73	68	71
STINKING	75	87	66	76

6.4 Lake Level Elevations

Several lakes within the BRW have historic lake level data available through the MN DNR LakeFinder website. Twenty lakes and reservoirs have at least one lake level recorded. Eleven lakes had one to three elevations recorded, while seven lakes and two reservoirs had a continuous lake level record. The lakes with continuous data are Balsam, Big Sugar Bush, Rock, Talac, North Tamarack, South Tamarack, and Turtle; the reservoirs are Stony Creek Detention and Stinking Lake Detention. Available lake level data are summarized in **Table 13**.

Table 13. Lake level elevation data for lakes within the Buffalo River Watershed.

Lake Name	Years with Data	Elevation data (feet above msl)			Historical Fluctuation (feet)	Mean Annual Fluctuation (feet)
		Average	Minimum	Maximum		
Balsam	1978 - 1993	1452.2	1451.1	1455.1	4.0	1.0
Big Sugar Bush	1993 - 2010	1491.9	1489.1	1493.8	4.8	0.9
Boyer	1995, 2000	1316.5	1313.3	1319.7	6.3	n/a
East Labelle	2000	1310.2	1310.2	1310.2	0.0	0.0
Fifteen	1964, 1999	1321.6	1321.3	1322.0	0.7	n/a
Jacobs	1997, 2010, 2011	1309.7	1305.0	1312.7	7.7	n/a
Little Sugar Bush	1985, 1992	1459.2	1459.0	1459.5	0.6	n/a
Maria	1997	1110.0	1110.0	1110.0	n/a	n/a
Rice	2006	1438.8	1438.8	1438.8	n/a	n/a
Rock	1995 - 2010	1440.0	1438.3	1441.7	3.4	1.3
Sand (stump)	2009	1313.3	1313.3	1313.3	n/a	n/a
Sorenson	2009	1313.3	1313.3	1313.3	n/a	n/a
Stinking	1991 - 1993	1210.4	1206.8	1218.1	11.3	3.8
Stony Creek Detention	1990 - 1993	1134.6	1133.0	1137.4	4.4	2.1
Swede Grove	2004	1238.5	1238.5	1238.5	n/a	n/a
Talac	1992 - 2010	1311.5	1305.0	1314.7	9.7	1.1
Tamarack (North)	1975 - 1993	1445.3	1443.3	1447.0	3.7	1.0
Tamarack (South)	1975 - 1993	1443.8	1441.1	1446.2	5.1	1.1
Ten	2003	1306.1	1306.1	1306.1	n/a	n/a
Turtle	1997 - 2010	1362.9	1361.1	1366.3	5.3	1.0

Most natural lakes have lake a mean annual fluctuation around 1.0 foot while the reservoirs (Stinking and Stony Creek Detention) have much larger fluctuations. This is likely due to the reservoirs being managed for flood control with water levels manipulated by humans.

7. Conclusions

The BRW contains many lakes, of which 46 have recent water quality data available. Four lakes are currently listed on the 2010 - 303(d) impaired waters list and MPCA is recommending four more lakes for impairment on the 2012 impairment list. The data contained within this report summarizes the available data, in accordance with MPCA's impairment assessment procedures (MPCA 2010), and will be used to inform future activities within the BRRWD. This report summarized the data that the MPCA's professional judgment team used to recommend lakes to be listed on the 303(d) list of impaired waters.

Several data gaps were found during this review. First, the BRRWD "priority" lake list was first established in 2007. The lakes on the "priority" list and the methods used to create the list should be reviewed and updated based upon the current relevant data. Four BRRWD "priority" lakes (Balsam, Doran, Fish, and Meyer Lake), as well as Axberg Lake, have no recent (2001-2010) water quality data available. Given the priority of these lakes (either as defined by the BRRWD or the MPCA), monitoring should be completed to assess their current status. In addition, Sorenson and Axberg Lakes were not originally placed on the BRRWD's "priority" lake list. Sorenson Lake is currently listed on the 303(d) list of impaired waters and Axberg Lake has been the subject of concern by local residents. Both of these lakes should be designated as "priority" lakes to match up with the BRRWD's water quality goals and to support the TMDL work currently being done within the watershed. Secondly, very few lakes had lake level data. Increasing the amount of lake level data available in the area's waters will better inform the BRRWD with future decision-making about its lake resources. Lastly, several lakes are located within the BRW but are outside the legal boundary of the BRRWD. Lakes that are located in areas like this provide a challenge for managers to promote water quality objectives established by the BRRWD as they have no enforcement authority.

After completing this assessment, several lakes show potential impairments (based only on the available water quality data) but are not currently listed by the MPCA. These lakes include Harrison (Helgeson), Lee, and Ten. These lakes have sufficient water quality data and show elevated levels of TP and chlorophyll-a. The majority of these lakes also have average TSI values greater or equal to than 59, indicating blue-green algal scums are likely to occur at some point during the summer. In addition, Silver, Lee and Stakke lakes have elevated TP and chlorophyll-a levels, but currently have insufficient water quality data available for assessment. These lakes should have more data collected to supplement the existing data and to accurately assess the impairment status of each waterbody in the future.

The information in this report will be used to assist with the watershed-wide TMDL and to guide the BRRWD's future planning. Outcomes of these efforts will enable the BRRWD to better focus its

resources on specific lakes (and their associated lakesheds) that are susceptible to high nutrient loads and to best target BMPs in priority management areas.

8. Works Cited

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9. Appendices

Appendix A. Summary of Water Quality data.

Lake Name	Lake ID #	Year	Chlorophyll a, corrected for pheophytin (ppb)		Depth, Secchi disk depth (m)		Phosphorus (ppb)	
			Average	Count	Average	Count	Average	Count
ANFINSON	14-0044-00	2006					108.00	1
		All years					**108.00**	**1**
BIG SUGAR BUSH	03-0304-00	2001	2.50	2	4.75	7	13.50	2
		2002			5.37	32		
		2003	3.00	7	6.19	33	14.86	7
		2004			6.33	20		
		2005			6.35	14		
		2006			5.02	16		
		2007	4.25	4	5.76	23	11.75	4
		2008	4.00	4	6.42	28	12.25	4
		2009	3.25	8	5.19	23	13.00	8
		2010			4.42	45		
		All years	**3.40**	**25**	**5.54**	**241**	**13.24**	**25**
BIRCH	03-0352-00	2009	9.67	6	3.23	6	34.00	6
		2010	22.33	6	2.41	6	40.83	6
		All years	**16.00**	**12**	**2.82**	**12**	**37.42**	**12**
BOYER (SAND BEACH)	03-0579-00	2008	30.50	6	2.00	6	56.00	6
		2009	15.60	5	2.80	5	52.40	5
		All years	**23.73**	**11**	**2.37**	**11**	**54.36**	**11**

BUFFALO	03-0350-00	2001	8.00	1	2.92	7	17.00	1
		2002			3.35	7		
		2005	8.60	5			22.00	5
		2006	11.00	1			27.00	1
		2007	10.00	1			20.00	1
		2008	6.80	5	2.85	6	24.67	6
		2009	9.67	6	2.85	6	21.50	6
		All years	**8.63**	**19**	**3.00**	**26**	22.55	**20**
CANARY	03-0516-00	2007			1.53	4		
		2008			0.76	1		
		2010			1.90	3		
		All years			**1.57**	**8**		
EAST LABELLE	03-0648-00	2009	11.17	6	2.23	6	35.67	6
		2010	18.00	6	2.06	6	39.33	6
		All years	**14.58**	**12**	**2.15**	**12**	**37.50**	**12**
ELEVEN	14-0018-00	2009	4.67	6	2.28	5	25.50	6
		2010	7.67	6	2.19	6	25.67	6
		All years	**6.17**	**12**	**2.23**	**11**	**25.58**	**12**
FIFTEEN	14-0030-00	2009	15.83	6	2.08	5	34.00	6
		2010	12.33	6	2.31	6	32.00	6
		All years	**14.08**	**12**	**2.21**	**11**	**33.00**	**12**
FORGET-ME-NOT	03-0624-00	2009	17.67	6	0.87	6	66.33	6
		2010	37.17	6	1.02	6	98.50	6
		All years	**27.42**	**12**	**0.94**	**12**	**82.42**	**12**
GOTTENBERG	03-0528-00	2009	24.33	6	0.63	6	61.33	6
		2010	43.17	6	0.99	6	74.67	6
		All years	**33.75**	**12**	**0.81**	**12**	**68.00**	**12**
GOURD	03-0635-00	2009	48.33	6	0.50	6	89.67	6
		2010	59.50	6	0.66	6	137.00	6
		All years	**53.92**	**12**	**0.58**	**12**	**113.33**	**12**

GROVE	56-0952-00	2009	15.67	6	2.46	5	47.17	6
		2010	8.75	8	3.81	8	34.13	8
		All years	**11.71**	**14**	**3.29**	**13**	**39.71**	**14**
HARRISON (HELGESON)	56-0934-00	2009	20.00	6	1.50	5	42.50	6
		2010	46.67	6	1.35	6	64.67	6
		All years	**33.33**	**12**	**1.42**	**11**	**53.58**	**12**
ISLAND	03-0351-00	2009	4.67	6	2.42	6	17.00	6
		2010	7.50	6	2.57	6	28.83	6
		All years	**6.08**	**12**	**2.49**	**12**	**22.92**	**12**
JACOBS	56-1039-00	2009	27.83	6	2.02	5	60.33	6
		2010	47.17	6	1.85	6	113.33	6
		All years	**37.50**	**12**	**1.93**	**11**	**86.83**	**12**
LEE	14-0049-00	2010	17.85	4	1.10	4	42.50	4
		All years	**17.85**	**4**	**1.10**	**4**	**42.50**	**4**
TALAC (LEE)	03-0619-00	2001			1.94	11		
		2002	13.00	4	1.84	10	160.00	7
		2003	32.00	3	1.35	12	75.67	3
		2004	16.50	2	1.87	4	47.00	2
		2005			2.29	7		
		2006	40.75	4	1.50	7	84.25	4
		2007			1.31	5		
		2008	32.25	4	2.65	7	71.50	4
		2010			2.16	7		
		All years	**27.82**	**17**	**1.86**	**70**	**103.20**	**20**
LIME	03-0646-00	2009	58.50	6	0.93	6	114.50	6
		2010	68.33	6	0.76	6	160.83	6
		All years	**63.42**	**12**	**0.85**	**12**	**137.67**	**12**

LITTLE ROUND	03-0302-00	2003			1.07	1	17.00	1
		2009	2.91	4	0.85	4	29.50	4
		2010	2.29	4	0.75	4	20.50	4
		All years	**2.60**	**8**	**0.83**	**9**	**24.11**	**9**
LITTLE SUGAR BUSH	03-0313-00	2009	6.83	6	3.08	6	19.50	6
		2010	14.67	6	2.82	6	24.83	6
		All years	**10.75**	**12**	**2.95**	**12**	**22.17**	**12**
LUND BROTHERS MARSH	03-0621-00	2003			0.30	1	133.00	1
		All years			**0.30**	**1**	**133.00**	**1**
MARIA	14-0099-00	2009	62.17	6	0.76	5	188.83	6
		2010	48.83	6	1.30	6	209.50	6
		All years	**55.50**	**12**	**1.05**	**11**	**199.17**	**12**
MARSHALL	03-0526-00	2008	28.33	6	1.65	5	45.00	6
		2009	12.67	6	2.02	6	38.50	6
		All years	**20.50**	**12**	**1.85**	**11**	**41.75**	**12**
MISSION	03-0471-00	2009	83.50	6	0.53	6	127.00	6
		2010	67.67	6	0.63	6	113.50	6
		All years	**75.58**	**12**	**0.58**	**12**	**120.25**	**12**
NORTH TAMARACK	03-0241-02	2005	12.41	5	1.37	3	46.00	7
		2007	17.25	4	1.28	16	33.00	4
		2008	11.25	4	1.67	16	33.25	4
		2009	12.50	4	1.67	16	30.75	4
		2010	11.00	4	2.16	18	27.25	4
		All years	**12.86**	**21**	**1.69**	**69**	**35.61**	**23**
O-ME-MEE	03-0428-00	2009	10.17	6	1.53	6	59.83	6
		2010	32.33	6	1.91	6	76.00	6
		All years	**21.25**	**12**	**1.72**	**12**	**67.92**	**12**

PETE	56-0941-00	2009	11.33	6	2.46	5	57.50	6
		2010	13.50	6	3.48	6	51.17	6
		All years	**12.42**	**12**	**3.02**	**11**	**54.33**	**12**
PINE	03-0200-00	2005	7.33	5	2.10	3	26.29	7
		2007	8.50	4	1.71	17	28.50	4
		2008	7.00	4	2.20	17	20.00	4
		2009	6.50	4	2.71	16	23.00	4
		2010	8.25	4	1.81	18	21.75	4
		All years	**7.51**	**21**	**2.10**	**71**	**24.22**	**23**
RICE	03-0291-00	2002	4.75	8	2.03	7	31.13	8
		2008	18.50	2	2.44	1	35.00	2
		2009	5.33	6	2.28	6	20.50	6
		All years	**6.69**	**16**	**2.17**	**14**	**27.63**	**16**
ROCK	03-0293-00	2001			1.85	6		
		2002			0.99	2		
		2004			1.95	4		
		2005			1.64	4		
		2006			1.68	3		
		2007	8.50	2	1.37	5	31.50	2
		2008	8.50	6	1.76	9	27.67	6
		2009	5.40	5	1.99	8	25.00	5
		2010			2.12	5		
		All years	**7.31**	**13**	**1.78**	**46**	**27.23**	**13**

SAND (STUMP)	03-0659-00	2002	6.50	8	2.13	9	163.79	14
		2003	22.50	6	1.68	5	195.56	9
		2004	24.25	4	2.24	6	107.40	5
		2005	32.00	4	2.08	6	199.20	5
		2006	36.25	4	1.89	6	71.25	4
		2007	23.33	3	1.56	9	73.67	3
		2008	50.75	4	2.24	16	104.75	4
		All years	**25.15**	**33**	**2.01**	**57**	**147.98**	**44**
SAND (YORT)	03-0618-00	2002	8.67	3	1.07	3	82.67	3
		All years	**8.67**	**3**	**1.07**	**3**	**82.67**	**3**
SILVER	14-0100-00	2008	9.00	2	2.45	2	28.00	2
		2010	21.48	4	1.45	4	60.25	4
		All years	**17.32**	**6**	**1.78**	**6**	49.50	**6**
SORENSON	03-0625-00	2002	11.38	8	1.40	10	201.36	11
		2003	54.50	6	2.13	8	164.22	9
		2004	58.29	7	1.33	7	143.00	8
		2005	61.50	8	2.19	7	183.44	9
		2006	28.00	4	2.06	3	142.50	4
		2008	41.50	4	1.48	4	210.25	4
		All years	**43.14**	**37**	**1.74**	**39**	**175.53**	**45**
SOUTH TAMARACK	03-0241-01	2005	4.18	3	1.70	1	29.25	4
		2008	4.00	1	1.68	1	16.00	1
		2009	4.50	4	1.88	16	15.25	4
		2010	3.75	4	1.96	18	18.25	4
		All years	**4.13**	**12**	**1.91**	**36**	**20.54**	**13**
ST. CLAIR	03-0430-00	2009	7.83	6	3.12	6	24.00	6
		2010	7.67	6	3.00	6	24.50	6
		All years	**7.75**	**12**	**3.06**	**12**	**24.25**	**12**

STAKKE	03-0631-00	2003					59.00	1
		2008	24.50	4	1.72	4	48.25	4
		2009	34.00	5	1.30	5	78.00	5
		All years	**29.78**	**9**	**1.48**	**9**	**64.20**	**10**
STINKING	03-0647-00	2009	65.33	6	0.55	6	340.83	6
		2010	126.17	6	0.76	6	276.33	6
		All years	**95.75**	**12**	**0.66**	**12**	**308.58**	**12**
SWEDE GROVE	14-0078-00	2009	28.00	6	1.00	5	76.00	6
		2010	31.00	6	2.11	6	77.50	6
		All years	**29.50**	**12**	**1.60**	**11**	**76.75**	**12**
TEN	14-0021-00	2009	29.00	6	1.38	5	62.50	6
		2010	25.00	6	1.88	6	51.83	6
		All years	**ye**	**12**	**1.65**	**11**	**57.17**	**12**
TURTLE	03-0657-00	2001	2.25	4	6.29	32	18.50	4
		2002			6.61	31		
		2003			5.82	32		
		2004			7.22	32		
		2005	3.88	8	6.26	46	12.00	8
		2006	11.00	3	6.53	33	9.67	3
		2007	3.67	3	6.82	36	10.00	3
		2008	2.67	3	6.84	33	10.00	3
		2009	2.33	3	6.77	33	11.00	3
		2010	3.25	4	6.79	36	13.25	4
		All years	**4.00**	**28**	**6.59**	**344**	**12.32**	**28**
UNNAMED	03-0650-00	2003			0.76	1	142.00	1
		All years			**0.76**	**1**	**142.00**	**1**

UNNAMED (NORTH MAYFIELD)	14-0029-00	2007			2.50	1		
		All years			**2.50**	**1**		
WEST LABELLE	03-0645-00	2009	22.67	6	1.70	6	80.00	6
		2010	59.50	6	0.89	6	98.50	6
		All years	**41.08**	**12**	**1.29**	**12**	**89.25**	**12**
WEST OLAF	56-0950-01	2005	9.25	4	2.83	7	24.25	4
		2006	8.50	2	2.07	5	31.00	3
		2009	10.25	4	2.70	3	25.25	4
		2010	14.75	4	1.79	4	39.50	4
		All years	**11.00**	**14**	**2.39**	**19**	**29.93**	**15**