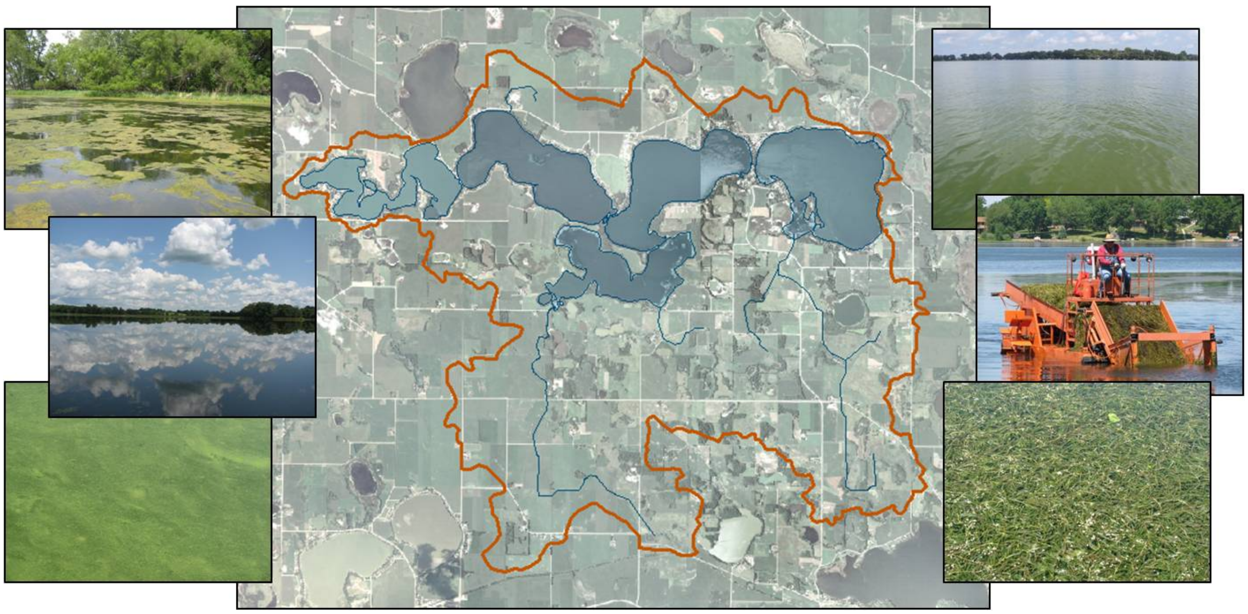
Upper Cannon Lakes
Excess Nutrient
Total Maximum Daily Load Study:
Jefferson-German Lake Chain



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<table>
<tr><th colspan="3">TMDL Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th>Summary</th><th>TMDL Page #</th></tr>
<tr><td>Location</td><td>The Jefferson German Lake Chain watershed is located in south eastern Le Sueur county and north eastern Blue Earth County in south central Minnesota. The lake chain is comprised of deep and shallow lakes and is in the Cannon River Watershed which represents a major tributary to the Mississippi River.</td><td>17</td></tr>
<tr><td>303(d) Listing Information</td><td>Five basins in the lake chain all listed in 2008:
· West Jefferson Lake (40009202)
· Middle Jefferson Lake (40009204)
· Swedes Bay (40009203)
· East Jefferson Lake (40009201)
· German Lake (40006300)
Affected Designated Use: Aquatic Recreation
Pollutant or Stressor: Nutrients/Eutrophication
Target Start/Completion Date: 2016/2020</td><td>30</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td>The applicable water quality standards are those for Class 2B waters and for lake eutrophication for the North Central Hardwood Forest ecoregion, as follows:
<table>
<tr><th>Total Phosphorus (µg/L)</th><th>Chlorophyll-a (µg/L)</th><th>Secchi Depth (meters)</th></tr>
<tr><td>Deep lakes:
40</td><td>14</td><td>1.4</td></tr>
<tr><td>Shallow lakes:
60</td><td>20</td><td>1.0</td></tr>
</table></td><td>30</td></tr>
<tr><td>Loading Capacity</td><td>Based on the numerical goals above and using the BATHTUB model, the phosphorus (P) loading capacities - or Total Maximum Daily Loads (TMDLs) - in kilograms(kg) per year and per day were determined as follows:
<table>
<tr><th rowspan="2">Lake</th><th colspan="2">Total Maximum Daily Load (TMDL)</th></tr>
<tr><th>(kg P / yr)</th><th>(kg P / day)</th></tr>
<tr><td>West Jefferson</td><td>140</td><td>0.3855</td></tr>
<tr><td>Middle Jefferson</td><td>254</td><td>0.6940</td></tr>
<tr><td>Swedes Bay</td><td>286</td><td>0.7802</td></tr>
<tr><td>East Jefferson</td><td>534</td><td>1.4650</td></tr>
<tr><td>German Lake</td><td>583</td><td>1.5970</td></tr>
</table></td><td>72-76</td></tr>
</table>

	The TMDLs were determined as annual loads; daily loads were calculated as averages, *i.e.*, as annual loads divided by 365.25 (average number of days per year).	
TMDL Allocations	See tables below	77-78
Margin of Safety	The numeric target for Total Phosphorus is 36 ug/L, and 54 ug/L, respectively. This reflects a 10% Margin of Safety in concentration terms.	76-77
Seasonal Variation	MPCA's eutrophication standard is compared to the growing season (June through September) average.	35
Reasonable Assurance	· Availability of reliable means of addressing pollutant loads (i.e. best management practices); · A means of prioritizing and focusing management; · Development of a strategy for implementation; · Availability of funding to execute projects; · A system of tracking progress and monitoring water quality response; · Interested and engaged Lake Association	83-85
Monitoring	The Minnesota Pollution Control Agency began a four-year Intensive Watershed Monitoring program in the Cannon River drainage in 2011. This is part of a 10-year cycle of monitoring, assessment, analysis, modeling, planning, and implementation that will be on-going throughout the State of Minnesota now and in the future. Additional monitoring programs involving state and local partnerships will also be developed.	86
Implementation	A general list of implementation activities has been included within the TMDL. A more detailed implementation plan will be included in the Cannon River Watershed Report by approximately 2016.	80-82
Public Participation	This report includes a list of all meetings and events related to public and technical team involvement with the TMDL.	87

TMDL Allocations (77-78):

Lake	Waste Load Allocations (WLAs) (kg P / yr)	kg P/day
West Jefferson	0.05	0.00014
Middle Jefferson	0.20	0.00045
Swedes Bay	0.40	0.00120
East Jefferson	0.10	0.00032
German Lake	0.40	0.00095

Lake	Load Allocations (LAs) (kg P / yr)	(kg P / day)
West Jefferson	140	0.3834
Middle Jefferson	254	0.6951
Swedes Bay	286	0.7809
East Jefferson	534	1.4630
German Lake	583	1.5950

Executive Summary

In 2008, the Minnesota Pollution Control Agency (MPCA) listed the Jefferson-German Lake Chain (JGC) as impaired for aquatic recreation due to excess nutrients under section 303(d) of the Clean Water Act. Excessive phosphorus loading is the main cause of the impairment. The goals of the JGC Excess Nutrients Total Maximum Daily Load (TMDL) study are to describe the nature and extent of the lake chain's phosphorus impairment and determine source load allocations that consider major sources. Resources are currently being allocated to the Cannon River watershed (the major watershed that the JGC lies in) to complete a comprehensive assessment, conduct stressor identification focused on biological impairments, construct a watershed model and complete additional TMDLs as necessary. These components of MPCA's watershed approach, particularly the modeling, will allow for simulation of various management scenarios aimed at pollutant load reductions.

The JGC is a five basin lake system comprised of German Lake (40-0063-00), East Jefferson Lake (40-0092-01), Middle Jefferson Lake (40-0092-04), Swedes Bay (40-0092-03) and West Jefferson Lake (40-0092-02). It is located in the upper portion of the Cannon River watershed within Le Sueur County. The JGC watershed comprises a total area of 15,167 acres within the North-Central Hardwood Forest ecoregion and is dominated by mostly agricultural land-use. At 3,157 acres, the JGC basins themselves represent the largest waterbody in south central Minnesota.

This lake has been the subject of past investigations. Concerned citizens began tracking secchi transparency in 1973 and the first comprehensive study of the lake was begun by the MPCA in 1990. That MPCA study identified German Lake as being eutrophic and the lake basins that make up Jefferson Lake as being hypereutrophic. German lake was found to be more eutrophic than 56% percent of lakes within the North Central Hardwood Forests (NCHF) eco-region while the Jefferson lake basins were more eutrophic than 80% of lakes within the NCHF.

The focus and primary intent of this project is to better characterize phosphorus levels, probable sources, and estimate reductions required to meet the TMDL water quality goal. Watershed wide phosphorus loading was estimated to assess the magnitude of nonpoint and point sources and establish a cause-effect linkage of loading sources and subsequent in-lake phosphorus concentrations. Samples were collected for the TMDL study between April and October 2009 and 2010 (note that only June-September results were used for TMDL calculation). Ten monitoring stations were located throughout the watershed and lake. The resulting data illustrates a declining trend in water quality through the season due to watershed and internal phosphorus loading. The current total phosphorus load to West Jefferson is 397 kg/yr; Middle Jefferson is 1340 kg/yr; Swedes Bay is 3566 kg/yr; East Jefferson is 1700 kg/yr; and German is 1477 kg/yr. A total phosphorus load of 140 kg/yr in West Jefferson; 534 kg/yr in East Jefferson; and 583 kg/yr in German would be required to reach the water quality goal of 36 µg/l; the goal includes a 10 percent margin of safety. A total phosphorus load of 254 kg/yr in Middle Jefferson and 286 kg/yr in Swedes Bay would be required to reach the water quality goal of 54 µg/l; the goal includes a 10 percent margin of safety. Over time, reductions in external loading should lead to reductions in internal loading.

ACKNOWLEDGEMENTS

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	Abbreviations and Acronyms
BMP	Best Management Practice
CWA	Clean Water Act
cfs	Cubic Feet per Second
CLP	Curly-leaf Pondweed
EPA	Environmental Protection Agency
GL	German Lake
GIS	Geographic Information Systems
JGC	Jefferson-German Lake Chain
LA	Load Allocation
MDNR	Minnesota Department of Natural Resources
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
NCHF	North Central Hardwood Forest (eco-region)
NO_2+NO_3	Nitrite + Nitrate Nitrogen
NPDES	National Pollutant Discharge Elimination System
PO_4	Ortho-phosphorus
ppm	Part per million
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Protection Plan
RC	Reserve Capacity
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Sediment
mg/L	Milligrams per liter
µg/L	Micrograms per liter
WLA	Waste Load Allocation
WRC	Water Resources Center (Minnesota State University, Mankato)

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Section 1.0 Background Information

1.1 Site Description

The Jefferson-German Chain (JGC) consists of five interconnected lake basins that comprise a total surface area of 3,157 acres, making it the largest lake system in south central Minnesota. Despite the relatively large size of this chain of lakes, the watershed that drains into the JGC is relatively small (15,167 acres) and is dominated by agricultural land use. The watershed to lake surface area ratio of the JGC is 5:1 (Table 1.1 A.). The combination of a small watershed-to lake ratio and the thermal stratification of the JGC gives this waterbody a better than average chance for restoration.

The JGC is a relatively shallow lake ecosystem with 81% of the Jefferson Lake basins (comprised of West Jefferson, Middle Jefferson, East Jefferson, and Swedes Bay) and 58% of German Lake falling within the littoral zone (Mueller and Klement, 2006). Due to a large wind fetch and shallow morphometry, the JGC is susceptible to internal nutrient loading via sediment re-suspension. Furthermore, an aquatic plant survey conducted in 2009 identified curly leaf pondweed as being extremely abundant throughout the littoral zone of the JGC.

Table 1.1 A. Examples of surface area to watershed area ratios for Cannon River watershed lakes and reservoirs.

Lake Name	Lake or Reservoir*	Cannon River Flowage?	Surface Area** (acres)	Watershed Area*** (acres)	Ratio
French (66-0038-00)	Lake	No	879	4,400	5.0
Shields (66-0055-00)	Lake	Yes	932	7,053	7.5
Rice (66-0048-00)	Reservoir	Yes	314	12,839	40.8
Volney (40-0003-00)	Lake	No	277	2,017	7.3
Jefferson German Chain (multiple lake IDs)	Lakes	No	3,157	15,167	4.8

* Determined by presence or absence of artificial control structure at outlet.
**From draft 2012 303(d) lakes shapefile.
***Delineated by Cannon River Watershed Partnership at request of Rice County in 2002.

1.2 Purpose

German Lake (40-0063-00), East Jefferson Lake (40-0092-01), Middle Jefferson Lake (40-0092-04), Swedes Bay (40-0092-03) and West Jefferson Lake (40-0092-02) are listed on the MPCA's 2008 303(d) list for aquatic recreation based on nutrient/eutrophication. The target start and completion dates were set at 2016 and 2020, respectively. The goal of this TMDL analysis is to quantify the nutrient reduction that will be required to meet the water quality standards established for lakes in the NCHF eco-region.

Furthermore, this study identified the largest sources of nutrients (phosphorus) to the JGC and complements existing studies to provide reduction strategies for source areas in accordance with section 303(d) of the Clean Water Act.

1.3 History

Historically, most of the JGC watershed was covered with hardwoods, however, upon settlement the land was cleared for agricultural use. The water quality of this chain has been degraded over a period of decades which led to the first studies being done in 1973 when concerned citizens began tracking secchi transparency. The first comprehensive study of the lake was began by the MPCA in 1990 and it identified German Lake as being eutrophic and the lake basins that make up Jefferson Lake as being hypereutrophic. German lake was found to be more eutrophic than 56% percent of lakes within the North Central Hardwood Forests (NCHF) eco-region while the Jefferson lake basins were more eutrophic than 80% of lakes within the NCHF.

In 1993 Le Sueur County conducted an intense, comprehensive Phase I Diagnostic and Feasibility study of the lake and watershed. The project objectives were to quantify runoff and nutrient loading from the local watersheds, assess the cause-effect relationships relating watershed land use practices and stream runoff characteristics, provide water budgets and mass nutrient balances for the lake system, and determine methods for improving the water quality of the lake chain. Based upon the results of this study, an implementation plan was set into place to reduce nutrient loading which developed into the Jefferson-German Lakes Water Quality Improvement Project.

The implementation phase, or Phase II, ran from 1995-2004. The implementation goals throughout that nine year period were: to reduce pollutant loading through the implementation of best management practices, increase public awareness of water quality issues, improve coordination of watershed activities, and to evaluate the project’s effectiveness. Some activities accomplished with implementation dollars were: hiring of a watershed specialist; 167 non-compliant individual sewage treatment systems were upgraded, and two feedlot improvement projects.

1.4 Landscape and Setting

Watershed, Lake and Inflow/Outflow Description:

The Jefferson-German watershed is located in south eastern Le Sueur County and north eastern Blue Earth County in south-central Minnesota. This chain of five lakes is part of the Cannon River watershed, which is part of the Lower Mississippi River Basin in Minnesota.

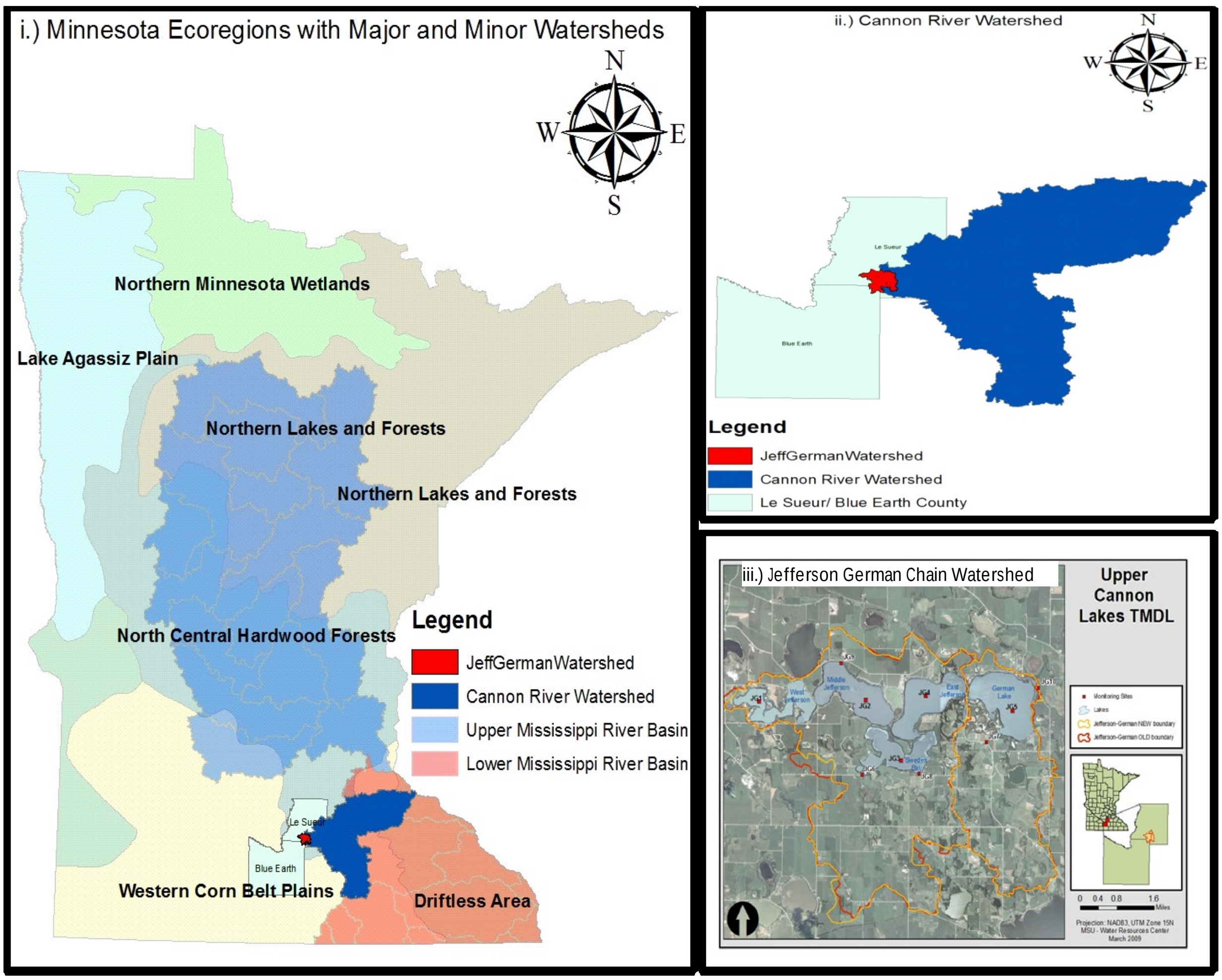

Figure 1.4 A. Geographical location of the Lower Mississippi River Basin (i), Cannon River Watershed showing location of the Jefferson German Lake Chain (ii) and Jefferson German Lake Chain Watershed (iii).

Minnesota is divided into seven ecoregions based on vegetation, soil type, geology, and climate. The JGC is located in the North Central Hardwood Forest ecoregion; however the JGC watershed is very close to the border of the Western Corn Belt ecoregion (Figure 1.4 A, i). Land use within the watershed features characteristics common to both ecoregions. All land use data is based on the 2009 NASS land use statistics, which is the most current version available during the creation of the TMDL.

The JGC watershed is 15,171 acres, (including the surface area of lakes). Cultivated land use practices account for 52% of the total area within this watershed (Figure 1.4 B). The specific land use characteristics for the JGC watershed are summarized in Table 1.4 A. The landscape is comprised of rolling to steeply sloping hills interspersed with poorly draining swales and sloughs (Mueller and Klement, 2006). Historically, most of the watershed was covered with hardwoods. However upon settlement much of the land was cleared for agricultural use (Mueller and Klement, 2006).

The JGC watershed can be separated into sub-watersheds by lake basin; each of the five lakes within the JGC has their own sub-watershed (Figure 1.4 C). Additionally, each of the four TMDL monitored stream sites that flow into the JGC has a defined sub-watershed (Figure 1.4 D). Each of these sub-watersheds has different land use practices. Due to these differences, some sub-watersheds have historically contributed a disproportionate amount of nutrients to the JGC. Results from a 1994 Diagnostic and Feasibility study led by Le Sueur County suggest that surface inflows at monitoring locations on the north side of Middle Jefferson (JG9) and the southern side of Swedes Bay (JG6) (Figure 1.4 D) have historically contributed the greatest proportion of nutrients to the JGC. Several BMP's have been implemented in an effort to control nutrient loading from these locations; however, according to the current study, the ditch at site JG9 has continued to contribute a disproportionally high amount of nutrients.

Table 1.4 A. Summary of Land use Classifications for the JGC Watershed.

Land use Classification	Total Acreage	Percent of Total
Corn	2171.61	14.32
Sorghum	0.77	0.01
Soybean	2386.04	15.73
Sweet Corn	6.16	0.04
Barley	0.77	0.01
Spring Wheat	9.28	0.06
Winter Wheat	3.08	0.02
Oats	5.41	0.04
Alfalfa	51.86	0.34
Other Hays	11.56	0.08
Peas	15.45	0.10
Grass/Pasture Ag	656.87	4.33
Woodland	3.86	0.03
Wetland	4.63	0.03

Water (Includes Lakes)	3349.12	22.08
Developed/Roads	1098.56	7.24
Developed-Low Intensity	163.73	1.08
Developed-Medium Intensity	6.18	0.04
Barren	2.31	0.02
Deciduous Forest	1273.78	8.40
Evergreen Forest	5.41	0.04
Mixed Forest	0.77	0.01
Shrubland	37.76	0.25
Grassland herbaceous	395.98	2.61
Pasture/Hay	2674.44	17.63
Woody Wetlands	188.42	1.24
Herbaceous Wetlands	643.3	4.24
Total Acreage	**15167.11**	**100.00**

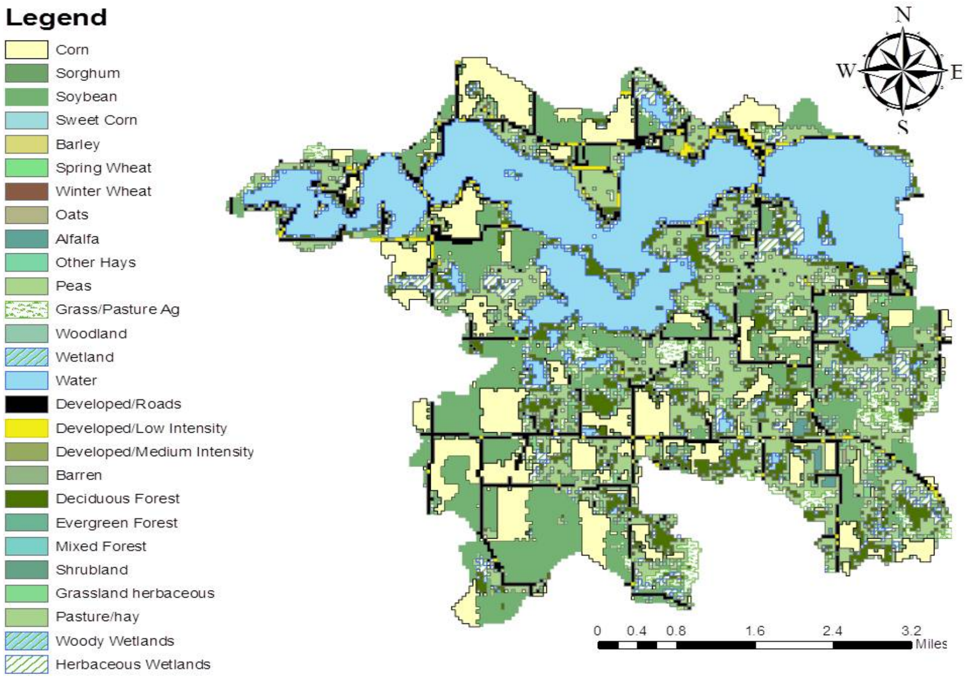

Figure 1.4 B. Land use in the Jefferson German watershed is comprised mostly of agriculture (corn, soybean, sweet corn, alfalfa, dry beans, and peas). The land uses within the watershed were determined using the 2009 National Agriculture Statistic Service's land use layer.

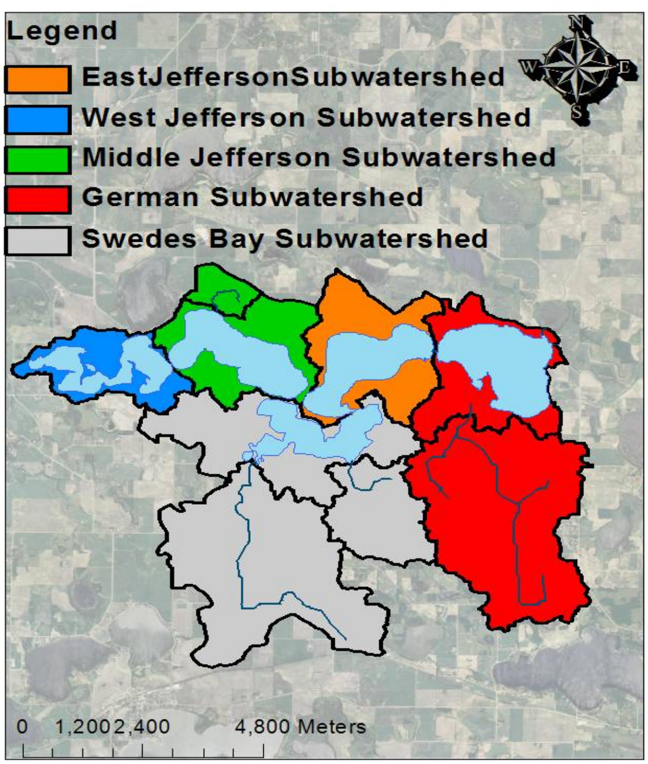

Figure 1.4 C. The Jefferson German Chain consists of five lake basins with associated watershed.

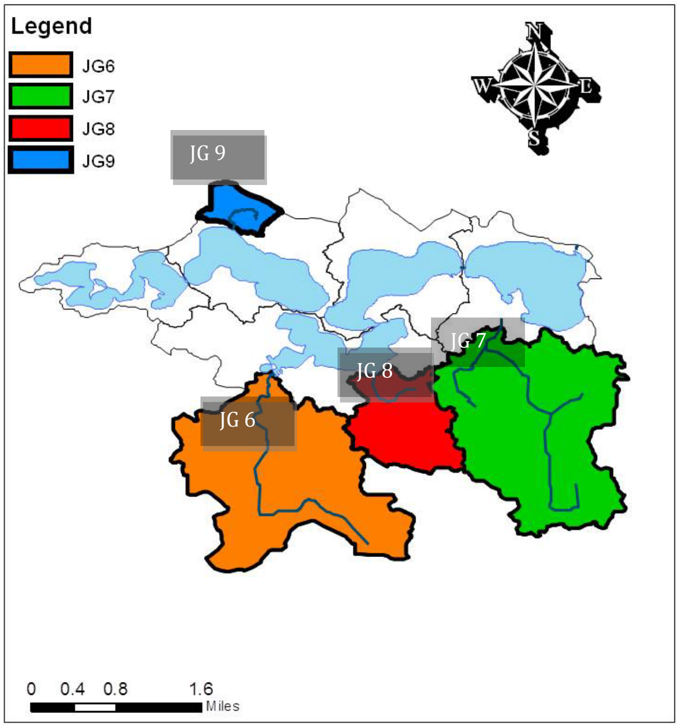

Figure 1.4 D. Location of four surface water inflow sites and their sub-watersheds (J6-J9).

1.5 Jefferson German Lake Chain Hydrology

The Jefferson German Chain flows in an easterly direction from West Jefferson Lake through Middle and East Jefferson and German Lake, with Swede's Bay flowing into East Jefferson Lake along the way. This describes the long-term average flow; because the lakes normally stand at a common elevation (approximately 1,017 feet above mean sea level), it is possible for the flow to reverse between the lakes at times. All of the outflow from the JGC exits through German Lake, which is where the outflow was monitored during the project (site JG10). It was not practical to measure the lake-to-lake flows within the chain in the project, but significant tributaries were monitored at sites JG6, JG7, JG8, and JG9 (Figure 1.5 A.).

Water budgets were constructed for the lake chain for the monitored years 2009 – 2010. The local precipitation averaged about 39 inches/yr for the period. In the vicinity of the JGC, lake evaporation is nearly equal to precipitation on average, and this equality was assumed in the water budget constructions. This assumption implies that net runoff from the lake surfaces is zero.

The 2009 – 2010 average flows measured at sites JG6, JG7, JG8, and JG9, when divided by the corresponding drainage areas, yielded runoff depths in the range 4.1 – 8.4 inches/yr. The total of the average flows at these four stations was 2,902 acre-feet/yr. This was actually larger than the average flow measured at site JG10 (1,907 acre-feet/yr), even though the JG10 flow included these tributary flows, as well as flows from the unmonitored areas.

To complete the JGC water budgets, two things were necessary: (1) an estimate of flow from the lakes' unmonitored, or local, watersheds, and (2) an adjustment to the flow at JG10 to accommodate the upstream flows. Flow from the local watersheds was estimated by applying a runoff depth of 1.9 inches/yr to their areas. This low runoff depth was actually based on the measured flow at site JG10 and the 12,075-acre JGC watershed *land area* (*i.e.*, overall watershed area minus the total area of the lakes themselves – excluded because they contribute zero runoff). The resulting water balance for the lake chain required a flow at JG10 equal to 3,317 acre-feet/yr, about 14% greater than the sum of the flows for sites JG6, JG7, JG8, and JG9. With the JG10 flow adjustment made, the average runoff from the JGC watershed (land area-based) was 3.3 inches/yr.

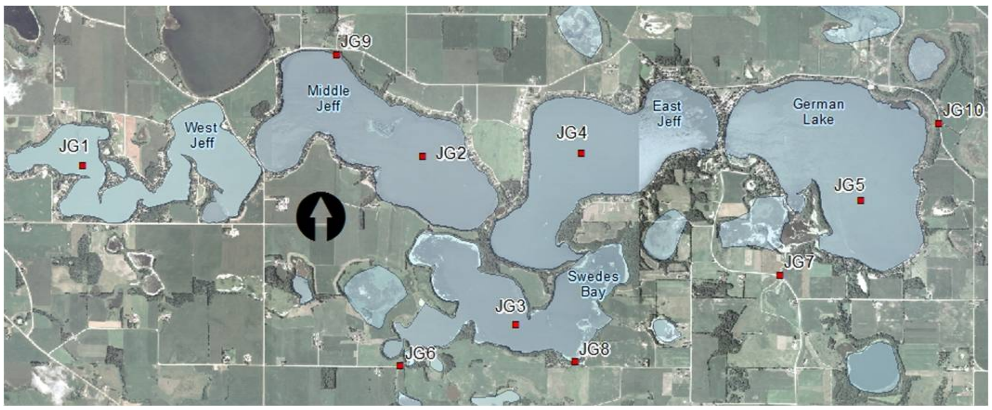

Figure 1.5 A. Location of all ten monitoring locations (JG1-JG10) in the Jefferson German chain of lakes.

1.6 Lake and Watershed Characteristics

The JGC consists of five lakes with a combined surface area of 3,096.89 acres. Land use in the Jefferson German watershed is comprised mostly of cultivated land use practices. A large percentage of the forests and wetland acreage within the watershed have been cleared for agricultural production.

West Jefferson Lake:

West Jefferson Lake has a surface area of 439 acres and a maximum depth of 7.4 meters (24 feet). Approximately 80% of West Jefferson Lake is within the littoral zone (less than 15 feet deep). Historically, West Jefferson Lake has begun to stratify at the end of May and remained stratified through August.

The West Jefferson Lake watershed is small; even with West Jefferson Lake included the total watershed acreage is 1,036 acres. Subtracting the lake acreage from the total watershed acreage yields 597 acres of land that drain into West Jefferson Lake. The three most common land uses within the watershed (excluding West Jefferson Lake itself) are cultivated land, pasture/hay, and developed land. Wetlands, forests, and grasslands encompass less than 10% of the entire watershed (Table 1.6 A.). At 439 acres, West Jefferson Lake itself also comprises a significant proportion of the watershed. The watershed-to-lake ratio for West Jefferson Lake is 2.4:1.

Middle Jefferson Lake:

Middle Jefferson Lake has a large surface area with a total acreage of 664 acres. The lake is extremely shallow for its size with a maximum depth of 2.5 meters (8 feet). 100% of the surface area is within the littoral zone; therefore, the entire basin is capable of supporting macrophyte growth. The large size, shallow morphometry, and large fetch typically prevent stratification except during periods of extreme calm. A weak thermal stratification is sometimes induced by the dense stands of curly-leaf pondweed that shade water near the bottom of the lake, creating cooler water below the surface.

Middle Jefferson Lake's watershed is very small in comparison to the size of Middle Jefferson Lake. With Middle Jefferson Lake included, the Middle Jefferson Lake watershed is 1,765 acres; the watershed to lake ratio is less than 3:1. Subtracting the Middle Jefferson Lake acreage from the total watershed acreage yields 1,101 acres of land that drain into Middle Jefferson Lake. The predominant land uses within the watershed (excluding Middle Jefferson Lake) are cultivated land, developed land, and pasture/hay. Forests, wetlands, and grasslands comprise only 10% of the entire watershed (Table 1.6 A.).

Swedes Bay:

Swedes Bay is a fairly large lake basin with a surface area of 492 acres; however it has a maximum depth of only 1.8 meters (6 feet). Similar to Middle Jefferson Lake, 100% of Swedes Bay is within the littoral zone; therefore, the entire basin is capable of supporting macrophyte growth. The large size and shallow morphometry of this lake basin prevent stratification except during periods of extreme calm when CLP stands are in full bloom. Stratification at this time is very weak and often interrupted by the slightest of winds. Swedes Bay has the largest watershed of any of the 5 lake basins on the JGC at 5,946 acres (Swedes Bay included). Subtracting the Swedes Bay acreage from the total watershed acreage yields 5,453 acres of land that drain into Swedes Bay. The three most common land use practices within the watershed (not including Swedes Bay) are cultivated land, pasture/hay, and developed land (Table 1.6 A.). The watershed to lake ratio of Swedes Bay is approximately 12:1, much larger than any other lake basin on the JGC. At 492 acres, Swedes Bay itself accounts for about 8% of the total watershed area; in comparison, West Jefferson Lake a similar sized waterbody accounts for 42% of its watershed. Approximately 18% of Swedes Bay's watershed is comprised of forests, grasslands and wetlands. The presence of these land uses has historically helped to improve water quality in Swedes Bay.

East Jefferson Lake:

East Jefferson Lake is 646 acres with a maximum depth of 11.3 meters (37 feet.) East Jefferson Lake is the second deepest lake on the JGC, only 53% of the surface area is within the littoral zone. Macrophyte growth is therefore restricted in a large percentage of the surface area. East Jefferson Lake typically begins to thermally stratify at the end of May and remains stratified through August. East Jefferson Lake's watershed is small at 1,684 acres (Including East Jefferson Lake), yielding a watershed to lake ratio of 2.6:1. East Jefferson Lake itself accounts for 38% of the total watershed area. Subtracting the East Jefferson Lake acreage from the total watershed acreage yields 1,037 acres of land that drain into East Jefferson Lake. The three most common land uses within the watershed (not including East Jefferson Lake) are cultivated land, pasture/hay, and developed land. Forests, wetlands, and grasslands make up 22.8% of the watershed (Table 1.6 A.); the presence of these land uses has likely helped to improve water quality in East Jefferson Lake.

German Lake:

German Lake is a large lake basin with a total acreage of 855 acres and a maximum depth of 51 feet. In comparison to the lake basins that comprise Jefferson Lake, a greater proportion of German Lake is deeper than 20 feet; only 58% of German Lake is within the littoral zone. The German Lake watershed is large at 4,740 acres (including German Lake). However, because German Lake is also large, the watershed to lake ratio is only 5.5:1. Subtracting the German Lake acreage from the total watershed acreage yields 3,885 acres of land that drain into German Lake. The predominant land uses within the watershed include pasture/hay, cultivated land, and forested land (Table 1.6 A.). The percentage of wetlands within the watershed is second highest in the JGC; (East Jefferson Lake watershed is first). The wetlands in the watershed have historically helped to reduce nutrient loading to German Lake.

Table 1.6 A. Jefferson-German Lake Chain watershed land use (not including water area).

Land use	Lake Name	Percent of Land Area
Cultivated	West Jefferson	40
	Middle Jefferson	61
	Swedes Bay	47
	East Jefferson	21
	German Lake	41
Developed	West Jefferson	25
	Middle Jefferson	15
	Swedes Bay	7
	East Jefferson	15
	German Lake	9
Pasture/Hay	West Jefferson	21
	Middle Jefferson	13
	Swedes Bay	27

	East Jefferson	41
	German Lake	41
Forest	West Jefferson	5
	Middle Jefferson	6
	Swedes Bay	10
	East Jefferson	12
	German Lake	13
Wetland	West Jefferson	7
	Middle Jefferson	3
	Swedes Bay	5
	East Jefferson	9
	German Lake	7
Grassland/Shrub	West Jefferson	2
	Middle Jefferson	1
	Swedes Bay	3
	East Jefferson	2
	German Lake	4

1.7 Geography

The surrounding geographic landscape of the JGC was formed during the period of glaciation that began nearly 2 million years ago and ended about 10,000 years ago (Le Sueur County, 1994). During this time, the Des Moines lobe of the Late Wisconsin Glaciations deposited yellowish gray, calcareous, medium textured material across all of Le Sueur County (Le Sueur County, 1994). In the southern portion of the county where the JGC is located, there are several rolling to steeply sloped moraines. Much of the soil in Le Sueur County is poorly drained; therefore a large proportion of farmland is artificially drained with tile lines (Le Sueur County, 1994). Large deposits of glacial till are present within the eastern portion of Le Sueur County where the JGC is located. Glacial till is normally impermeable to water; therefore, groundwater seepage is unlikely. However, lakeshore owners have reported feeling pockets of cold water within both West Jefferson Lake and German Lake, indicating that there may be some groundwater springs entering the lake. Historical studies have suggested that seepage through the lake bed is plausible.

1.8 Soils

The soil profile for the JGC watershed is complex with multiple soil types present throughout the watershed. Four soil associations occupy a far greater proportion of the watershed in comparison to other soil types. Lester Loam soil is the dominant soil type covering 3,610 acres (Figure 1.8) and supports most of the cropland within the watershed. The slope found within this soil association ranges from 6 to 24 percent. Lester Loam soils are well drained to poorly drained (Le Sueur County, 1994). The second most common soil association is the Lester Hardwik-Storden soil association; covering 2,746 acres (Figure 1.8). This soil type is found most commonly along the southern part of the watershed on rolling to steeply sloped areas ranging 6 to 40%. These soils are well drained and excessively drained (Le Sueur County, 1994). Cordova clay loams are third and account for 1,907 acres, and are mostly located along the western portion of the watershed. These soils are less steeply sloped and are found on ground moraines and uplands. Nearly all of the acreage in this association is used as cropland with corn and soybean being the major crops grown here. The soils are poorly drained and artificial drainage systems are common in this area (Le Sueur County, 1994). The fourth most common soil association is Hamel Clay Loam and covers 1,686 acres within the central portion of the watershed. This soil association is poorly drained and typically fairly flat with only moderate slopes (Le Sueur County, 1994). Caron muck and Caron Blue Earth and Palms soils, ponded; (light green) can be found in low lying depressional areas of the watershed. These soils typically periodically store water throughout the year. Dassel loam soils (pink) can be found around the shoreline of West Jefferson, East Jefferson, Swedes Bay and German lake. Dassel loam soils consist of a fine sandy material. Dundas soils (green) are found mostly in the northern portion of the watershed; typically Dundas soils are black and poorly drained (Anoka County SWCD Soil Directory).

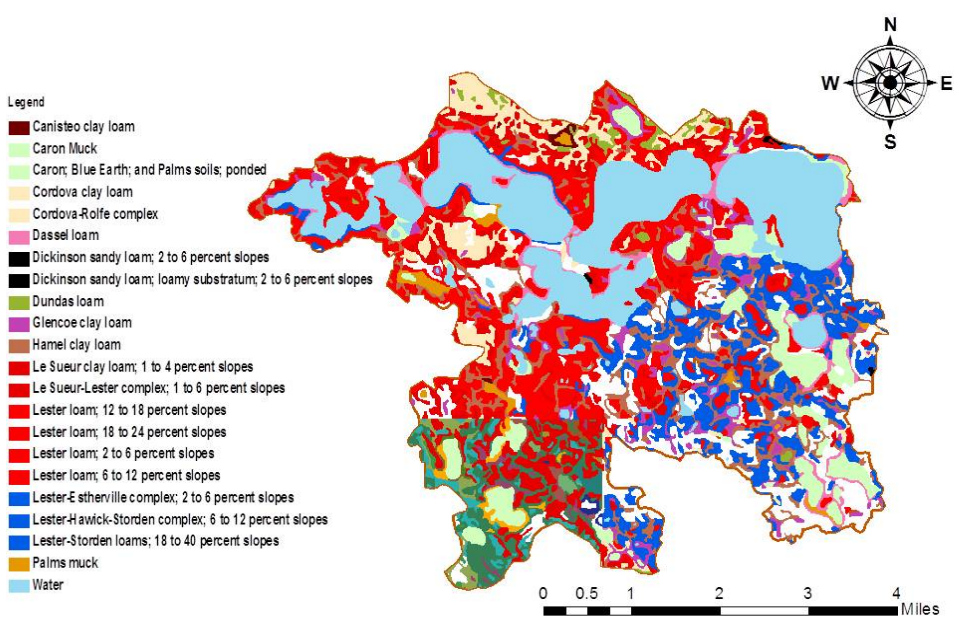

Figure 1.8. The composition of soil found in the JGC watershed is dominated by four soil associations: Lester Loam, Lester Hardwik-Storden, Cordova clay loams, and Hamel Clay Loam.

1.9 Climate

Temperature:

Climatological data was taken daily at St. Peter located in Le Sueur County, Minnesota over the course of 30 years from 1971 to 2000 by the United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS, 2010). Results from this data depict an average daily maximum temperature of 56.0ºF and an average daily minimum temperature of 34.5ºF. On average, January is the coldest month of year, and July is the warmest (Table 2.6 A; USDA NRCS, 2010). The total number of growing degree days for southern Minnesota crops was averaged at 4,648 days with a threshold of 40ºF.

Precipitation:

Between 1971 and 2000, there was an average of 29.67 inches of precipitation in Le Sueur County, Minnesota from April- September (USDA NRCS, 2010). There is also an average of 29.6 inches of snow falling per year with at least 1 inch of snow being present on the ground an average of 41 days per year (USDA NRCS, 2010). There will usually be at least one inch of snow that falls per month between November and April. On average, there will be 52 days throughout the year where at least 0.1 inches of precipitation will fall (USDA NRCS, 2010). June has historically been the wettest in terms of the average amount of precipitation, with February historically having the lowest levels of precipitation (USDA NRCS, 2010). The majority of precipitation falls between May and August (Table 1.9; USDA NRCS, 2010). A TR 525 rain gauge equipped with a tipping bucket was used to determine the amount of precipitation that had fallen within the watershed in 2009 and 2010. Precipitation data collected by the rain gauge includes results from the dry 2009 monitoring season and the wet 2010 season. Rainfall totals during the 2009 monitoring season (4/3-11/1/2009) were 18.14 inches; rainfall totals for the 2010 monitoring season (3/16-11/5/2010) were 27.55 inches. Rainfall totals during the 1993 sampling season (April-September) were 35.90 inches; indicative of the very wet conditions that existed during this study (Le Sueur County, 1994). The average rainfall from the 2009 and 2010 monitoring seasons was 22.85 inches; 13 inches less than the amount of rainfall that occurred over between April and September in 1993. The large difference in the amount of precipitation that fell within the watershed in 1993 vs. 2009/10 suggests that results from the 1993 study may depict a much different nutrient load from the watershed in comparison to results observed in this study.

Table 1.9. Average daily maximum and minimum temperatures and average precipitation for Le Sueur County, Minnesota 1971-2000 United Stated Department of Agriculture Natural Resources Conservation Service.

Month	Avg. Max Temp	Avg. Min. Temp	Avg. Monthly Precipitation (Inches)	2009 Precipitation Data Summary/ Rain Gauge Reading (Inches)	2010 Precipitation Data Summary/Rain Gauge Reading (Inches)
January	23.1	3.0	0.9	Below Average/ NA	Below Average/NA
February	29.5	9.9	0.5	Near Average/NA	Above Average/NA
March	42.1	22.4	1.9	Very wet/NA	Below Average/NA
April	58.1	34.6	2.3	Below Average/1.57	Below Average/1.54
May	71.7	47.1	3.6	Drought/1.23	Below Average/2.41
June	80.3	56.7	4.9	Drought/3.01	Wet/5.91
July	83.8	61.3	3.9	Drought/1.84	Wet/5.38
August	81.2	59.0	4.1	Above Average/5.25	Below Average/3.22
September	73.2	49.0	2.8	Drought/ 0.46	Extremely Wet/7.88
October	60.8	37.0	2.2	Above Average/4.78	Below Average/1.15
November	41.1	24.1	1.7	Below Average/NA	Above Average
December	27.5	9.7	0.9	Below Average/NA	Average
Average (Apr-Oct.)					**22.8**
Total (Annual Average)					**40.6**
Extrapolated Annual Precipitation 2009/10					**39.11**

1.10 Biological Monitoring

Fishery survey and analysis:

A comprehensive fishery survey was completed by the MNDNR on all lake basins of the JGC in 2008 except for Swedes Bay; Swedes Bay was last sampled by the MNDNR in 2002. General observations from this survey indicated that Swedes Bay and Middle Jefferson were prone to winterkills and supported fisheries consisting mainly of tolerant species. The three deeper lakes (West Jefferson Lake, East Jefferson Lake, and German Lake) support a greater diversity of gamefish species; however, all lake basins support moderately high to high populations of rough species including carp and bullheads. A more detailed summary of the fish community is found in Appendix B.

Plant survey and analysis:

Staff from the Water Resource Center in coordination with the Minnesota Pollution Control Agency used a point-intercept sampling technique to provide a representative survey of the aquatic plant community in the Jefferson German Chain (JGC). All of the lake basins of the JGC were sampled twice in 2009; the first survey was completed between May 13th and June 1st when CLP was most abundant. The second survey was completed between August 11th and August 22nd when Eurasian watermilfoil and native species are typically most abundant. Overall, German Lake had the healthiest aquatic plant community while both West and Middle Jefferson Lake share the poorest aquatic plant community. Results from this survey demonstrated the degree of CLP abundance and highlighted areas where native species can still be found within each lake basin of the JGC. A detailed synopsis of findings from the point intercept survey is found in Appendix C.

1.11 Recreational Use

The JGC is the largest lake system in south central Minnesota and supports a wide variety of recreational activities including swimming boating, and angling. The German and Jefferson Lakes Sportsmen's Club has been one of the most successful sportsmen's clubs in southern Minnesota in terms of both duration and contribution to the lake system. The club has been in operation for more than sixty years. During that time, the club has operated a northern pike rearing pond, maintained the floating fishing pier on West Jefferson Lake, acquired over 100 acres of land (including a 40-acre wetland), maintained the public boat landings and provided countless other services all open to the public.

Interest in maintaining a high quality lake system is high on the JGC. The shoreline is highly developed with both recreational and permanent residential houses present on the lake. Regional fishing tournaments are regularly held throughout the summer and winter on the JGC and bass tournaments have been extremely well received. Recreational activities observed while conducting this study in 2009 and 2010 included boating, angling, and swimming. The entire lake system can be extremely busy during the weekends, with multiple user groups enjoying the lake at one time. The majority of recreational activities occur on West Jefferson, East Jefferson, or German Lake throughout the course of the year. Middle Jefferson Lake and Swedes Bay do not provide the same quality of recreation in comparison with other lakes on the chain due to their shallow depth and the abundance of CLP growth in each basin.

Section 2.0 Applicable Water Quality Standards and Numeric Targets

2.1 Applicable Minnesota Water Quality Standards

Impaired waters are listed and reported to the citizens of Minnesota and to the EPA in the 305(b) report and the 303(d) list, named after relevant sections of the Clean Water Act. Assessment of waters for the 305(b) report identifies candidates for listing on the 303(d) list of impaired waters. The purpose of the 303(d) list is to identify impaired water bodies for which a plan will be developed to remedy the pollution problem(s) (the TMDL).

The basis for assessing Minnesota lakes for impairment due to eutrophication includes the narrative water quality standard and assessment factors in Minnesota Rules 7050.0150. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. Lakes were ranked and categorized by common characteristics, such as depth/lake morphometry, lake ecology, geographic setting, and reference lake conditions. Because of regional diversity in lake and watershed characteristics, it was felt that a single total phosphorus value could not be adopted as a statewide criterion for lake protection in Minnesota (Heiskary, et al. 1987). By using the eco-region derived data, natural lake loading is taken into account, and lakes are assessed based on natural landscape settings, local land use, and loading typical of the region.

All five lake basins of the Jefferson German Chain are located in the North Central Hardwood Forest (NCHF) ecoregion, therefore, the standards set forth for lakes in NCHF were applied. The JGC consists of two shallow lake basins (Swedes Bay (40-0092-03) and Middle Jefferson Lake (40-0092-04)) and three deep lake basins (West Jefferson (40-0092-02), East Jefferson (40-0092-01), and German Lake (40-0092-00)). The standards set forth for both shallow lakes and deep lakes were used accordingly (Table 2.1 A.). To be listed as impaired by the MPCA, the monitoring data must show that the standards for both total phosphorus (the causal factor) and either chlorophyll a or Secchi disc depth (the response factors) are not met (MPCA, 2007a). Target start for the TMDL was 2016 and target completion date was 2020, with an original listing year of 2008.

Table 2.1 A. MPCA shallow and deep lake standards for total phosphorus, chlorophyll-a and secchi disc (NCHF ecoregion).

	NCHF Shallow	NCHF Deep
TP (µg/L)	60	40
Chl-a (µg/L)	20	14
Secchi (meters)	1.0	1.4

Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters

TMDL Water Quality Target Concentrations

An explicit 10% Margin of Safety (MOS) was implemented via the numeric total phosphorus concentration goals. Therefore, total phosphorus standards were set at 10% below actual standards for the NCHF ecoregion (Table 2.1 B.).

Table 2.1 B. Total phosphorus goals for the Jefferson German Lake Chain and the actual NCHF ecoregion standard.

	TP (µg/L) actual	TP (µg/L) minus 10%
NCHF Shallow	60	54
NCHF Deep	40	36

The primary water classification that this TMDL addresses are water bodies classified 2B. Class 2 is concerned with aquatic life and recreation, and subclass B refers to cool/warm water fisheries with the water body not protected as a drinking water source.

Section 3.0 Water Quality data

3.1 Data collection

Monitoring was completed through the TMDL study to collect current water quality data, as well as additional data to be used for the BATHTUB modeling program. While data was collected beyond the growing season (June through September), only those data collected within the growing season were used in BATHTUB and subsequently, TMDL development. This time period was chosen because it corresponds to the eutrophication criteria, it spans the months in which the lakes are most used by the public, and the months during which water quality is the most likely to suffer due to excessive nutrients leading to nuisance levels of algal growth (the critical condition).

Many previous projects collected additional water quality data, (1990 MPCA Lake Assessment Program, 1993 Diagnostic and Feasibility Study; Le Sueur County). While many of these studies have investigated similar problems (such as sediment and nutrient loading), these reports were unfortunately completed more than 10 years ago which is the data requirement window of the TMDL process. However, many of these studies were valuable to refer to during the current TMDL study, and can help provide a framework to investigate how the lake has changed over time.

Water quality was monitored at two inlet sites and the lake outlet site during 2009 and 2010 from March to October. While data was collected for the entire open water season, only June-September results were used in the FLUX and BATHTUB calculations. For more detailed results on inlet/outlet water quality, refer to Appendix C.

3.2 Flux Results

FLUX is a computer program designed by the U.S. Army Corps of Engineers Waterways Experimental Station. FLUX is used to estimate the load of nutrients or other water quality constituents passing a location over a given period of time. In this TMDL study, FLUX was used to calculate flow rate, estimated nutrient and sediment loading, and flow weighted mean concentrations (FWMC) from each monitored site (Table 3.2 A). Also, the runoff in inches during the monitoring period for each of the years was gathered. The depth of runoff in meters was calculated by taking the total flow volume divided by the drainage area tributary to the monitoring site. The FWMC is calculated by dividing the total constituent load by the total flow volume.

Measured inlet loads compared to outlet loads indicate the amount of TP accumulating within the lake each season. This is especially apparent in 2010 where the sum TP load of inlets JG6 through JG9 was 1625 kg/yr and the TP load leaving at the JG10 outlet location was 258 kg/yr (Table 3.2 A).

Table 3.2 A. Flux results for monitored inlet/outlet in the JGC TMDL study.

TMDL Site ID JG6	**Year**	**2009**	**2010**	Mean (Input to BATHTUB)
	Monitoring Period	3/24-11/5	3/17-11/1	
	Runoff (meters)	0.044	0.2218	0.1329
	Flow Rate (hm^3/yr)	0.541	2.709	1.625
	TSS FWMC (µg/L) TSS Load (kg/yr)	44,504 21,000	31,463 85,233	32,687 51,116
	NO_3-NO_2 FWMC (µg/L) NO_3-NO_2 Load (kg/yr)	9,944 5,380	17,249 46,727	16,033 26,053
	TP FWMC (µg/L) TP Load (kg/yr)	179 97	271 733	255 415
	PO4 FWMC PO4 Load PO4/TP	NA NA NA	148 402 55	148 402 NA
TMDL Site ID JG7	Year	2009	2010	Mean (Input to BATHTUB)
	Monitoring Period	3/24-11/5	3/18-11/1	
	Runoff (meters)		0.199	0.104*
	Flow Rate (hm^3/yr)	NA	2.487	1.298*
	TSS FWMC (µg/L) TSS Load (kg/yr)	NA NA	9,813 24,404	9,813 24,404
	NO_3-NO_2 FWMC (µg/L) NO_3-NO_2 Load(kg/yr)	NA NA	6,597 16,406	6,597 16,406
	TP FWMC (µg/L) TP Load (kg/yr)	NA NA	337 838	337 838
	PO4 FWMC PO4 Load PO4/TP	NA NA NA	205 509 61	205 509 NA

TMDL Site ID JG8	**Year**	**2009**	**2010**	Mean (Input to BATHTUB)
	Monitoring Period	3/24-11/5	3/18-11/1	
	Runoff (meters)	0.016	0.199	0.1075
	Flow Rate (hm^3/yr)	0.0640	0.784	0.424
	TSS FWMC (µg/L) TSS Load (kg/y)	10,631 680	29,867 23,416	28,415 12,048
	NO_3-NO_2 FWMC (µg/L) NO_3-NO_2 Load (kg/y)	1,366 87	1,476 1,157	1,467 622
	TP FWMC (µg/L) TP Load (kg/y)	299 191	222 174	228 97
	PO4 FWMC (µg/L) PO4 Load (kg/y) PO4/TP	NA NA NA	120 94 54	120 94 54
TMDL Site ID JG9	Year	2009	2010	**Mean (Input to BATHTUB)**
	Monitoring Period	3/24-11/5	3/18-11/1	
	Runoff (meters)	0.0697	0.356	0.213
	Flow (hm^3/yr)	0.0761	0.388	0.232
	TSS FWMC(µg/L) TSS Load(kg/yr)	13,883 1,057	20,606 7,995	19,509 4,526
	NO_3-NO_2 FWMC (µg/L) NO_3-NO_2 Load (kg/yr)	17,780 1,353	17,651 6,848	17,675 4101
	TP FWMC (µg/L) TP Load (kg/yr)	1,501 114	1,636 635	1,616 375
	PO4 FWMC (µg/L) PO4 Load (kg/yr) PO4/TP	NA NA NA	1,380 535 84	1,380 535 NA
TMDL Site ID JG10 (Outlet)	Year	2009	2010	**Mean (Input to BATHTUB)**
	Monitoring Period	3/24-11/5	3/18-11/1	
	Runoff (meters)	NA	NA	
	Flow(hm^3/yr)	0.196	4.509	2.353
	TSS FWMC TSS Load	1,735 340	13,466 60,719	12,974 30,529
	NO_3-NO_2 FWMC NO_3-NO_2 Load	344 67	177 801	184 434
	TP FWMC TP Load	30 6	57 258	56 132
	PO4 FWMC PO4 Load PO4/TP	NA NA NA	5.85 26.4 10	5.85 26.4 NA

3.3 In-lake Sampling Results

Seasonality

Nutrient loading can vary greatly due to seasonal influences. Based on data collected within the lake system, phosphorus levels in the JGC typically start off near or below the NCHF class 2B ecoregion standard in the spring on all five lake basins. During this time, aquatic macrophytes primarily consisting of dense curly-leaf pondweed (CLP) monocultures dominate the littoral zone of each lake basin and water clarity often exceeds the NCHF ecoregion standard. As CLP begins to senesce in mid-June, TP concentrations in the water column begin to rise. In the shallowest lake basins, TP concentrations typically peak immediately after CLP senescence. In the deeper lake basins, the TP concentration present in the water column appears to rise slowly until late August or September when peak TP concentrations are observed. Similar results can be seen with chl-a, with peak chl-a concentrations occurring in late July and into August.

Within the context of the TMDL, all target reductions are calculated for the total nutrient budget of the lake. This budget was developed using annual loading data, and targets are determined based on the highest loading periods (typically the summer months). Using this method, seasonal variation was accounted for within the annual loading calculation.

In-Lake Sampling Summary

In-lake samples were taken at the deepest point found within each of the five basins of the JGC per EPA protocol. The deepest point was then saved on a GPS; each sampling round that followed was conducted at the saved GPS location.

Data that was collected but was not included in this report because it does not impact the TMDL calculations: water quality samples taken prior to or after the growing season (June-September); vertical profiles (1 meter intervals) for temperature, pH, conductivity, and dissolved oxygen using a multi-parameter probe; hypolimnion samples taken with a Van Dorn sampler when a thermocline was detected.

A. West Jefferson Lake:

There were 9 sampling events during the summer season on West Jefferson Lake in both 2009, and 2010, respectively.

Total Phosphorus

The pattern of TP concentrations found in 2009 (Figure 3.3 A.1.) was very similar to that found in 2010 (Figure3.3 A.2.), with the lowest TP concentrations being present in June. TP concentrations increased following the senescence of CLP in mid-June, however, TP concentrations did not peak until September each year. The mean TP concentration over the entire TMDL study was 64 µg/L.

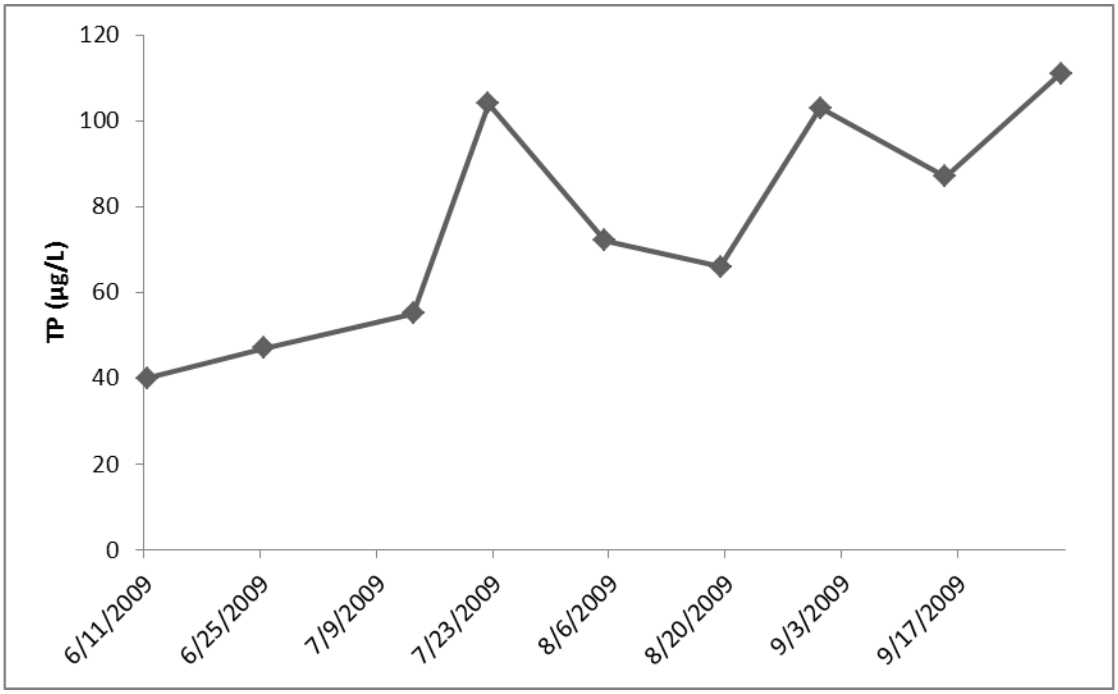

Figure 3.3 A.1. West Jefferson Lake total phosphorus concentrations during the 2009 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

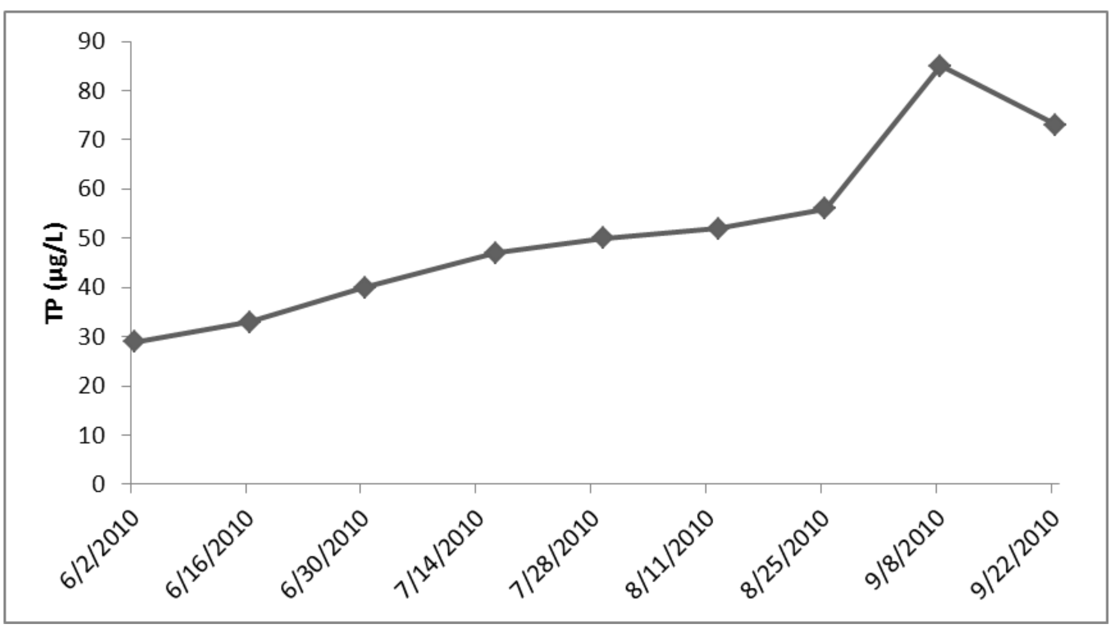

Figure 3.3 A.2. West Jefferson Lake total phosphorus concentrations during the 2010 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

Chlorophyll-a

The mean chl-a concentration over the entire TMDL study period was 36 µg/L. Patterns of chl-a concentrations differed between 2009 (Figure 3.3 A.3.) and 2010 (Figure 3.3 A.4.).

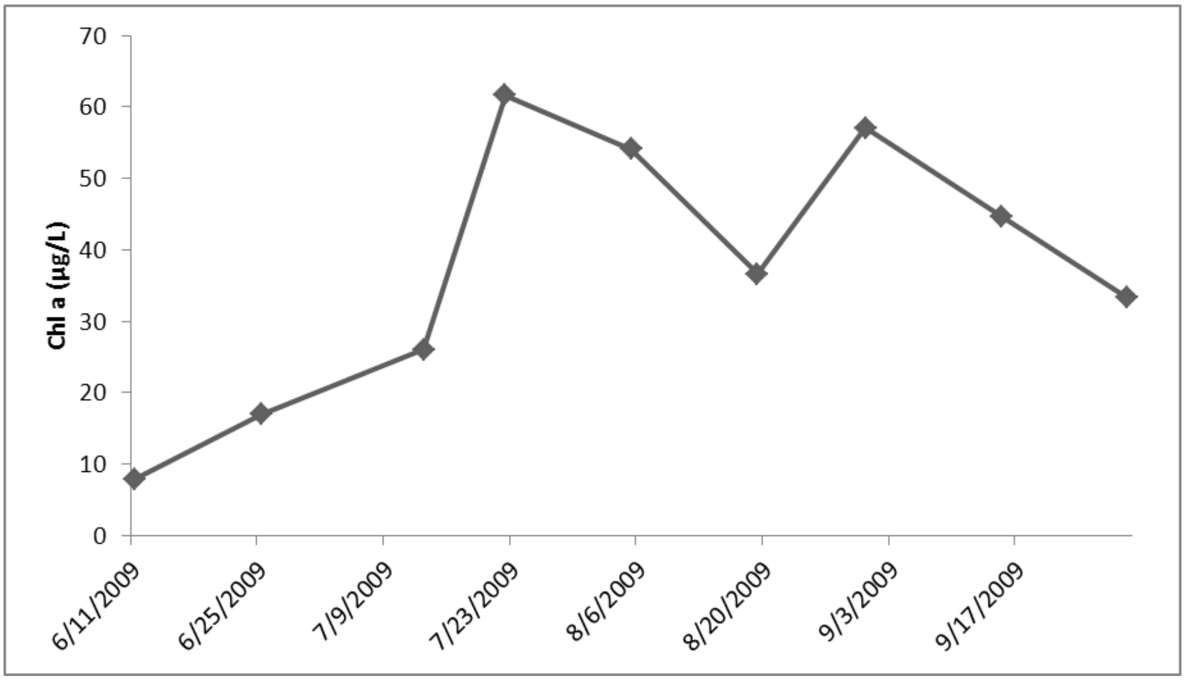

Figure 3.3 A.3. West Jefferson Lake chl-a concentrations from June to September in 2009. The deep lake NCHF ecoregion standard is 14µg/L.

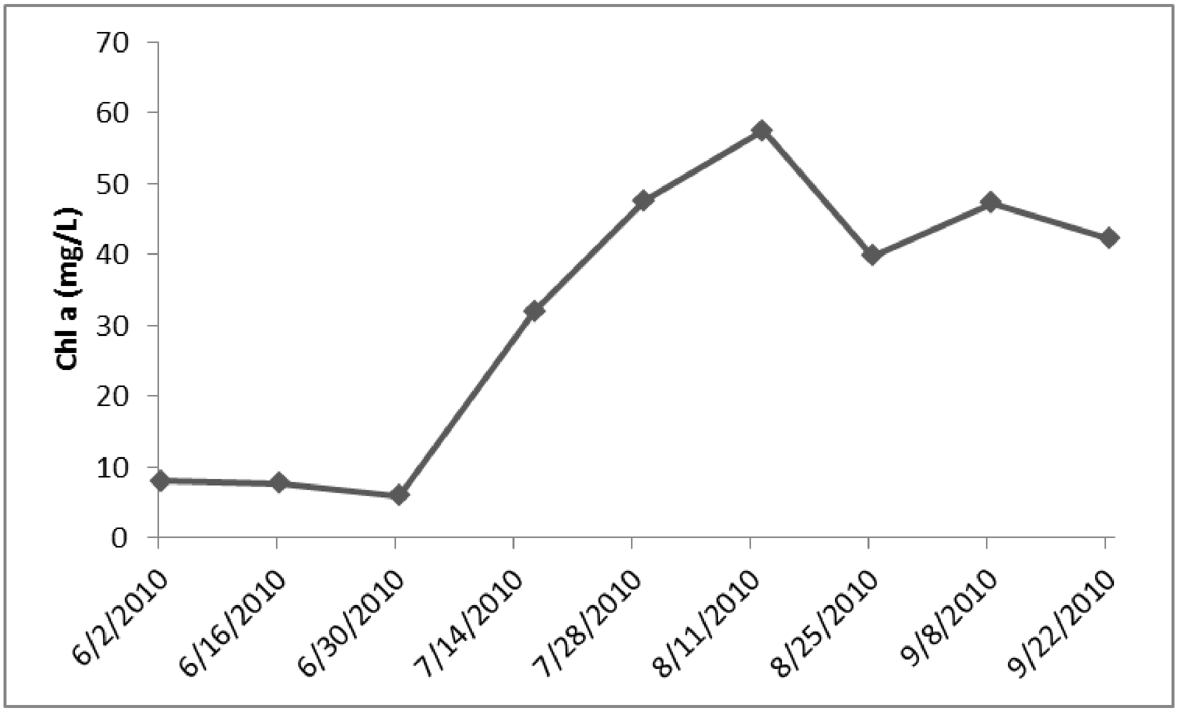

Figure 3.3 A.4. West Jefferson Lake chl-a concentrations from June to September in 2010. The deep lake NCHF ecoregion standard is 14µg/L.

Secchi disk transparency

Secchi disk transparency patterns were similar between 2009 (Figure 3.3 A.5.) and 2010 (Figure 3.3 A.6.). Overall, the average secchi disk transparency for the entire TMDL study was 1.3 m, which nearly meets the NCHF standard of 1.4 m.

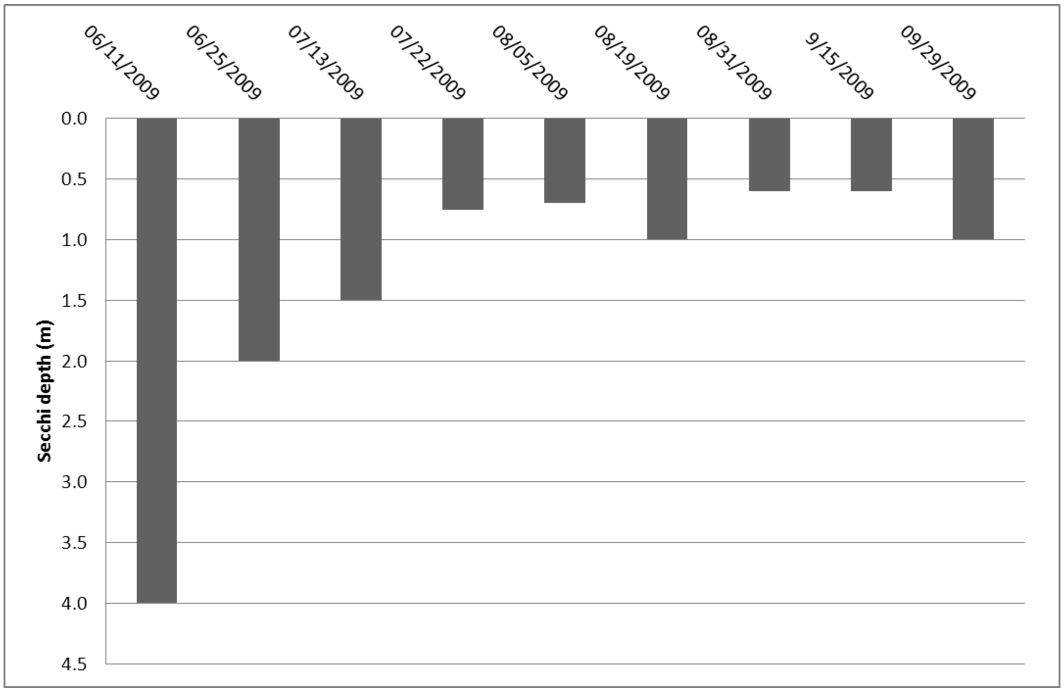

Figure 3.3 A.5. West Jefferson Lake water clarity (secchi disk readings) during 2009. The deep lake NCHF ecoregion standard is 1.4 m.

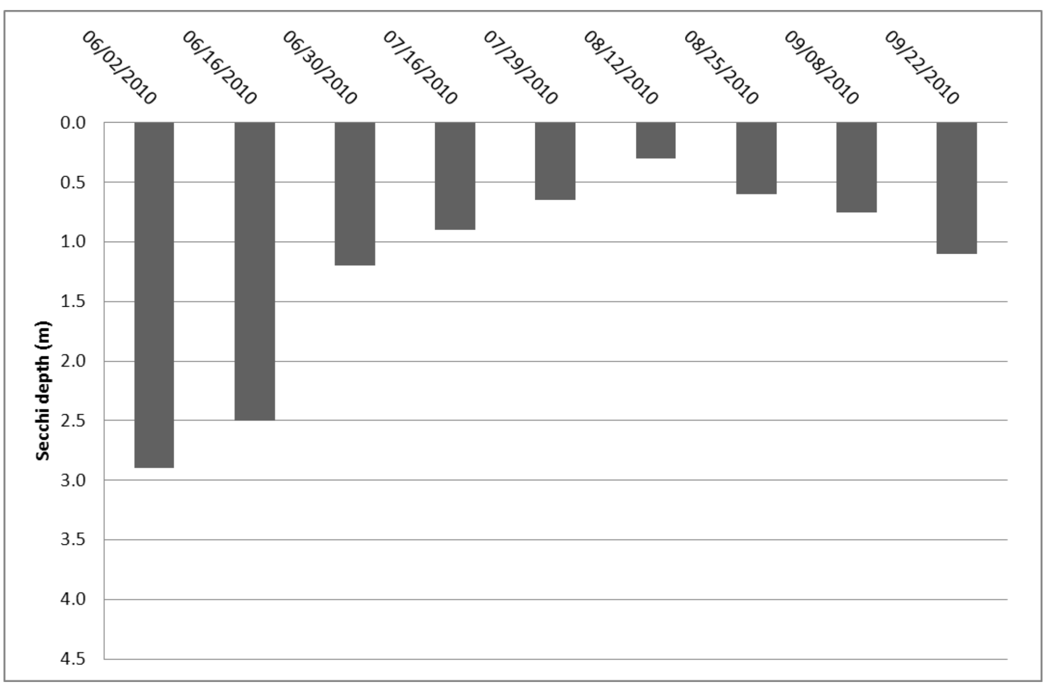

Figure 3.3 A.6. West Jefferson Lake water clarity (secchi disk readings) during 2010. The deep lake NCHF ecoregion standard is 1.4 m.

Additional West Jefferson Lake Findings

In-lake water temperatures were generally higher in 2010 in comparison with 2009. The peak temperature observed in West Jefferson Lake occurred on 8/12/2010 at 29.83^{0}C (85.7^{0} F). Dissolved oxygen concentrations near the surface were 11.72 mg/L on 8/12/2010. Dissolved oxygen concentrations were above 7 mg/l from 0-2 meters on 8/12; however, DO concentrations fell below 0.5 mg/L at a depth of 3 m. Therefore, only the top 2 m of the water column had DO concentrations sufficient to sustain aquatic organisms in West Jefferson Lake during early August.

B. Middle Jefferson Lake:

There were nine sampling events each during the summer season on Middle Jefferson Lake in 2009 and 2010, respectively.

Total Phosphorus

The pattern of TP concentrations found in 2009 (Figure 3.3 B.1.) was different than what was found in 2010 (Figure 3.3 B.2.). Concentrations were the highest in early July and then dropping in late July in 2009. Alternatively, in 2010, were elevated by mid-July and stayed elevated until the middle of September. The mean TP value over the length of the TMDL was 141 µg/L.

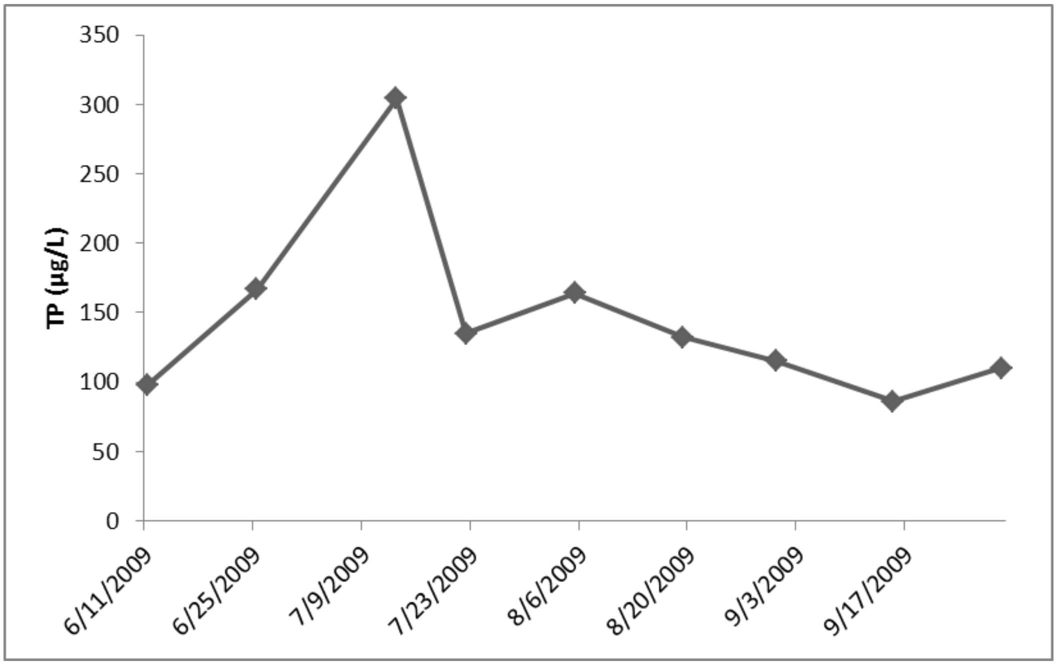

Figure 3.3 B.1. Middle Jefferson Lake total phosphorus concentrations during the 2009 growing season. The shallow lake NCHF ecoregion standard is 60 µg/L.

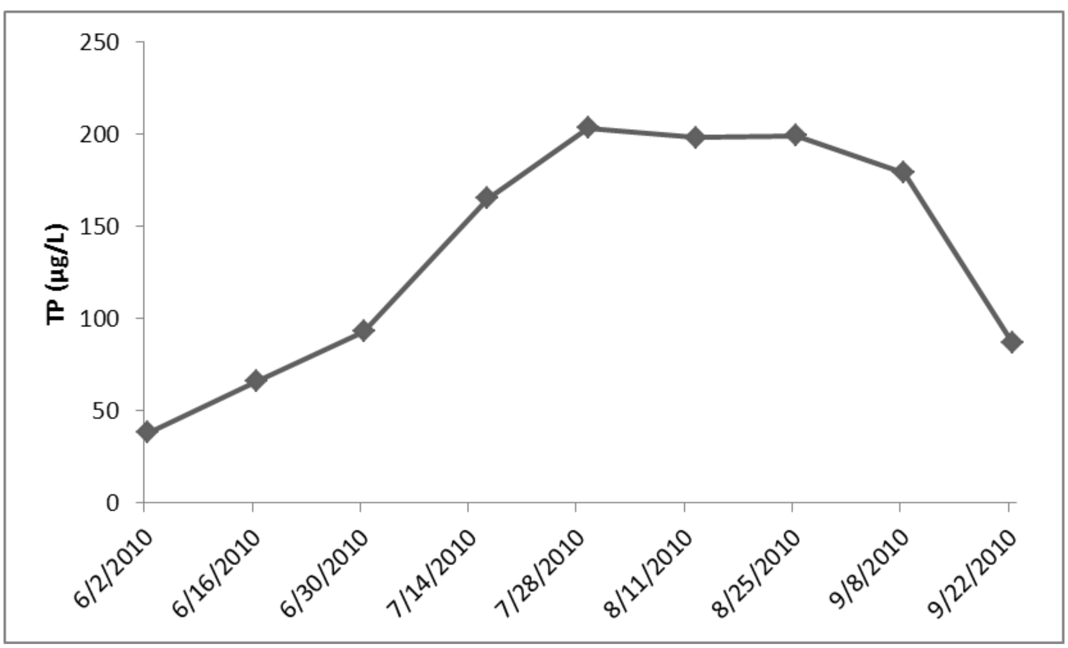

Figure 3.3 B.2. Middle Jefferson Lake total phosphorus concentrations during the 2010 growing season. The shallow lake NCHF ecoregion standard is 60 µg/L.

Chlorophyll-a

Chl-a concentrations peaked at 99 µg/L during the 2009 monitoring season (Figure 3.3 B.3.)and at 219 µg/L on August 25th 2010 (Figure 3.3 B.4.). The mean chl-a concentration for all samples collected during the TMDL study on Middle Jefferson Lake is 71µg/L.

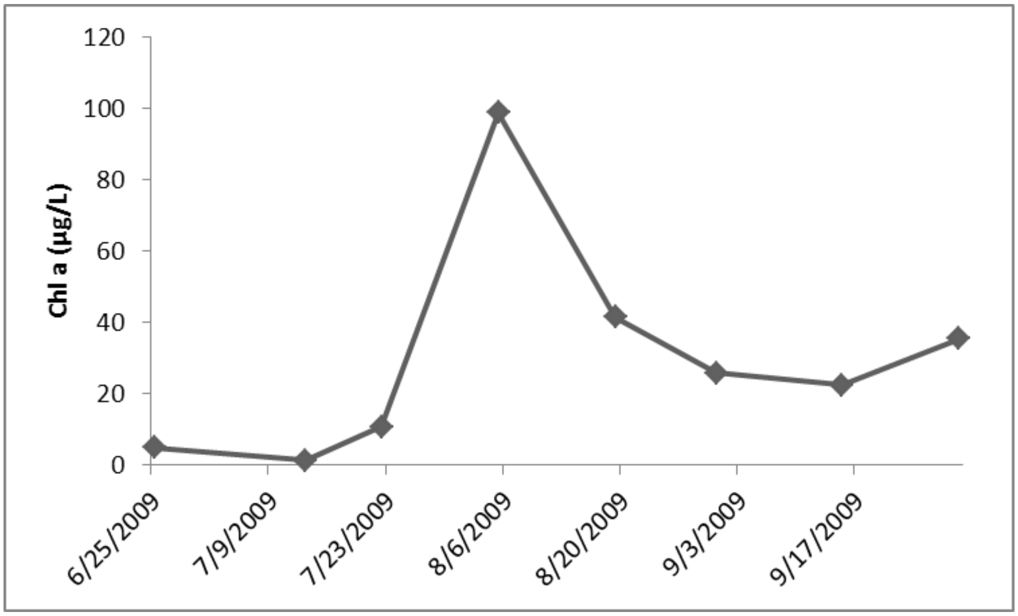

Figure 3.3 B.3. Middle Jefferson Lake chl-a concentrations from June to September in 2009. The shallow lake NCHF ecoregion standard is 20µg/L.

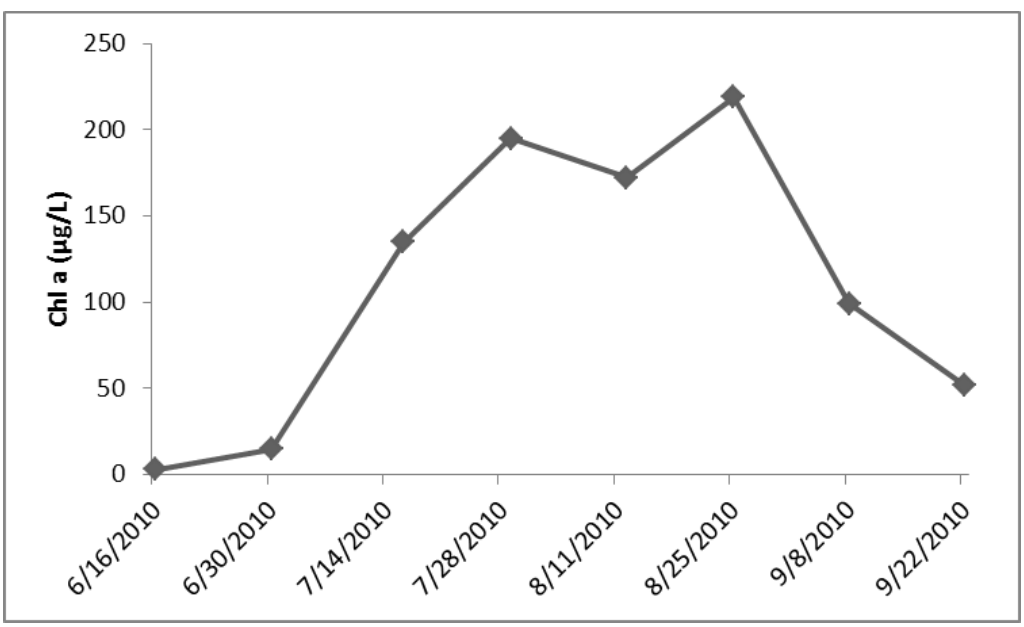

Figure 3.3 B.4. Middle Jefferson Lake chl-a concentrations from June to September in 2010. The shallow lake NCHF ecoregion standard is 20µg/L.

Secci disk transparency

Secchi disk transparency mean depth over the TMDL study was 1.0 m. In 2009, clarity was observed to have diminished at the August 5th sampling event (Figure 3.3 B.5.). In 2009, CLP exhibited a secondary growth phase with biomass being produced twice within a single growing season. The water clarity of Middle Jefferson Lake was closely linked to this cycle, water clarity and CLP abundance were both high early in the monitoring season and subsequently in the late fall when CLP began to regenerate biomass earlier than usual. In 2010, the Secchi disk transparency was observed to have diminished on July 16th and remained below the standard throughout the rest of the monitoring season (Figure 3.3 B.6.). Contrary to the 2009 season, CLP did not have a secondary growth phase on Middle Jefferson Lake, a possible explanation for why water quality did not improve later in the season as it had in 2009.

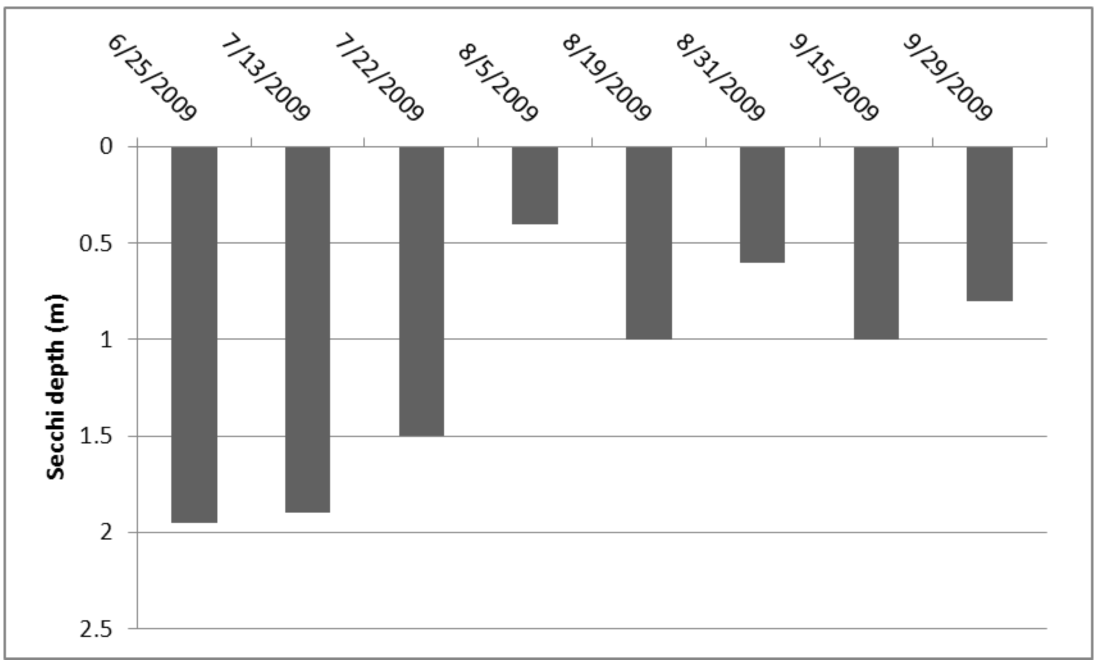

Figure 3.3 B.5. Middle Jefferson Lake water clarity (secchi disk readings) during 2009. The shallow lake NCHF ecoregion standard is 1.0 m (3.3 feet).

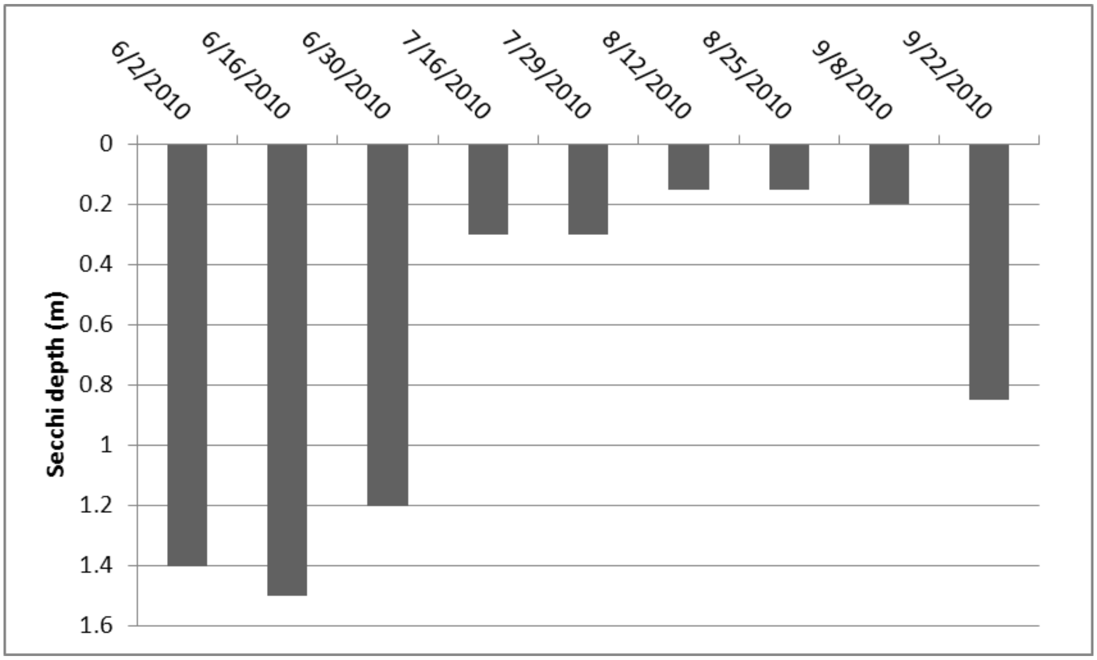

Figure 3.3 B.6. Middle Jefferson Lake water clarity (secchi disk readings) during 2010. The shallow lake NCHF ecoregion standard is 1.0 m (3.3 feet).

Additional Findings

In-lake water temperatures were generally higher in 2010 in comparison with 2009. The peak temperature observed in Middle Jefferson Lake occurred on 8/12/2010 at 29.6^{0}C (85.3^0 F). Dissolved oxygen concentrations near the surface were 15.17 mg/L; however DO concentrations were 0.28 mg/L just 1 meter below the surface on 8/12/2010. This suggests that Middle Jefferson Lake periodically stratifies even though the maximum depth of the entire basin is only 8 feet. Very little oxygen is present below 1 m during these periods of stratification, likely placing a high amount of stress on the fishery present within the lake. Furthermore, phosphorus is likely being released from sediments during these brief periods of stratification. To document how low the dissolved oxygen conditions were dropping to at night, a dissolved oxygen profile of Middle Jefferson Lake was conducted immediately prior to sunrise when dissolved oxygen concentrations are typically at their lowest. An YSI 6820 V2 multiparameter data sonde confirmed that Middle Jefferson Lake had temporarily gone anoxic, with dissolved oxygen readings of 0.15 mg/L just 1.5 meters below the surface.

C. **Swedes Bay:**

Thirteen in-lake sampling events were conducted on Swedes Bay in 2009, 13 near surface water quality samples were generated during this time. In 2010, there were 14 in-lake sampling events conducted on Swedes Bay.

Total Phosphorus

In 2009 TP concentrations peaked at 644 µg/L on July 13th (Figure 3.3 C.1.). In 2010, the peak TP concentration was 382 µg/L observed on July 29th (Figure 3.3 C.2.). The mean TP concentration for all samples taken during the TMDL study was 304 µg/L.

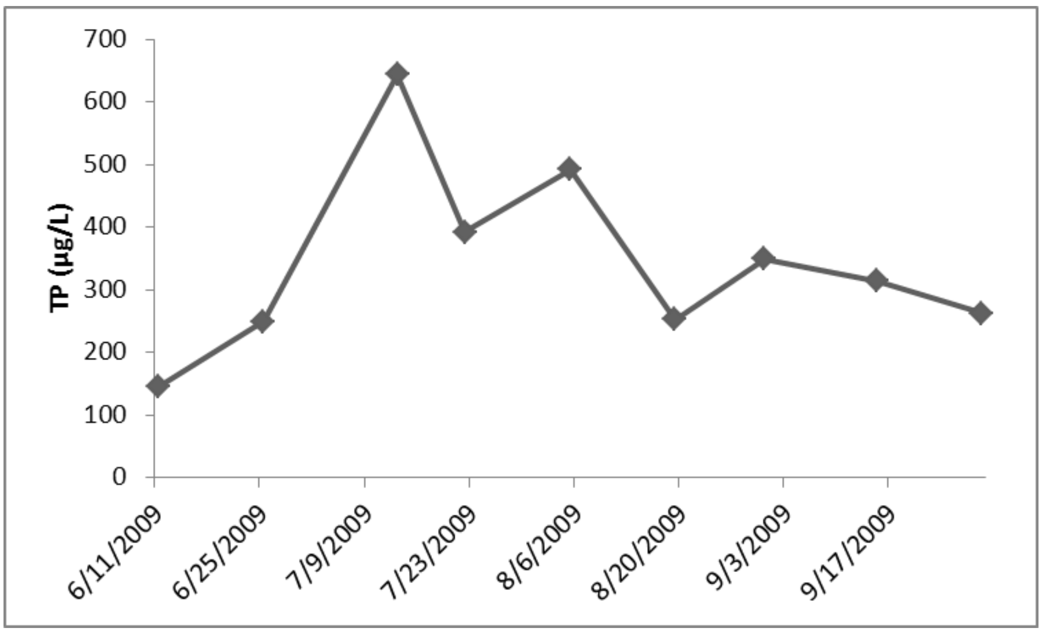

Figure 3.3 C.1. Swedes Bay total phosphorus concentrations during the 2010 growing season. The shallow lake NCHF ecoregion standard is 60 µg/L.

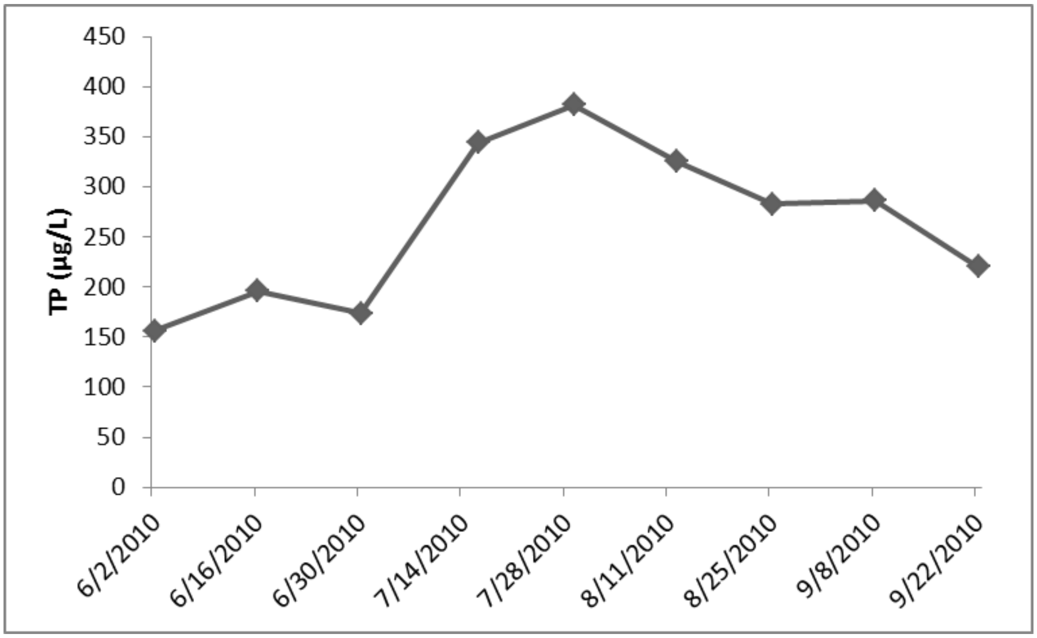

Figure 3.3 C.2. Swedes Bay total phosphorus concentrations during the 2010 growing season. The shallow lake NCHF ecoregion standard is 60 µg/L.

Chlorophyll-a

Chl-a concentrations peaked at 129 µg/L on September 29th in 2009 (Figure 3.3 C.3) and at 320 µg/L on August 12th, 2010 (Figure 3.3 C.4). The average chl-a concentration for all samples taken during the course of the TMDL study was 79µg/L.

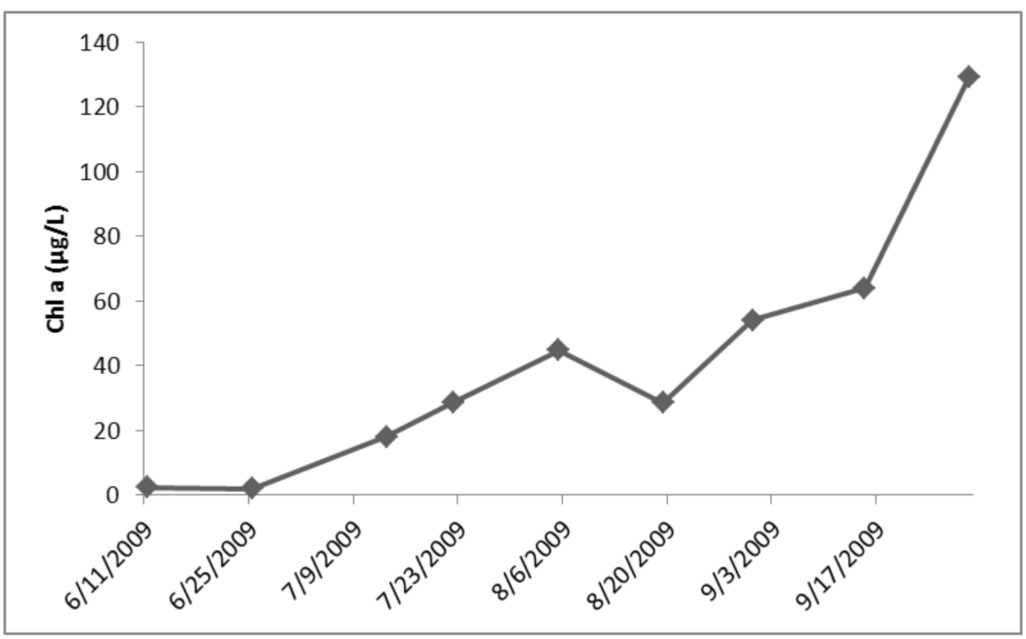

Figure 3.3 C.3. Swedes Bay chl-a concentrations from June to September in 2009. The shallow lake NCHF ecoregion standard is 20µg/L.

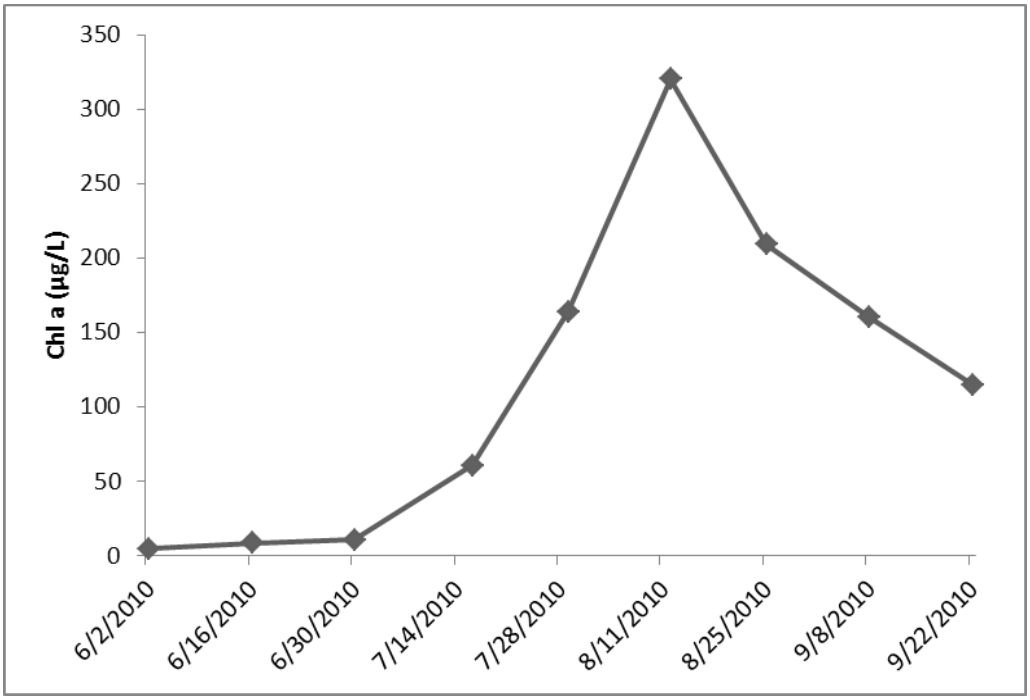

Figure 3.3 C.4. Swedes Bay chl-a concentrations from June to September in 2010. The shallow lake NCHF ecoregion standard is 20µg/L.

Secchi disk transparency

Similar patterns existed for clarity between 2009, (Figure 3.3 C.5) and 2010, (Figure 3.3 C.6). The average Secchi disk reading based on all measurements taken during the 2009 and 2010 time period was 0.79 m.

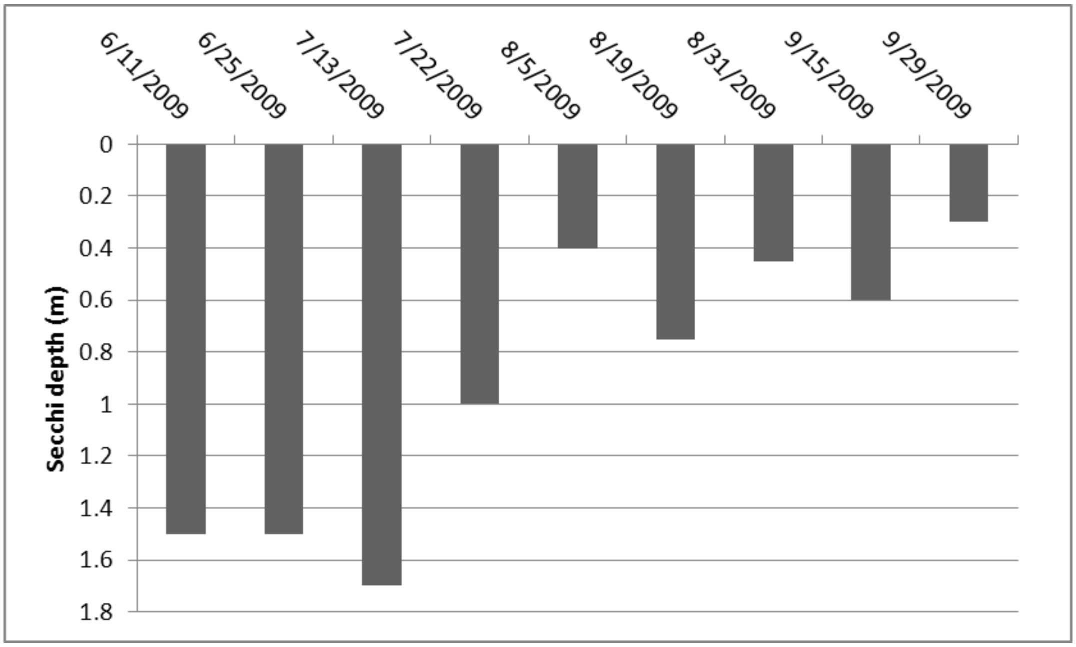

Figure 3.3 C.5. Swedes Bay water clarity (secchi disk readings) in 2009. The shallow lake NCHF ecoregion standard is 1.0 m.

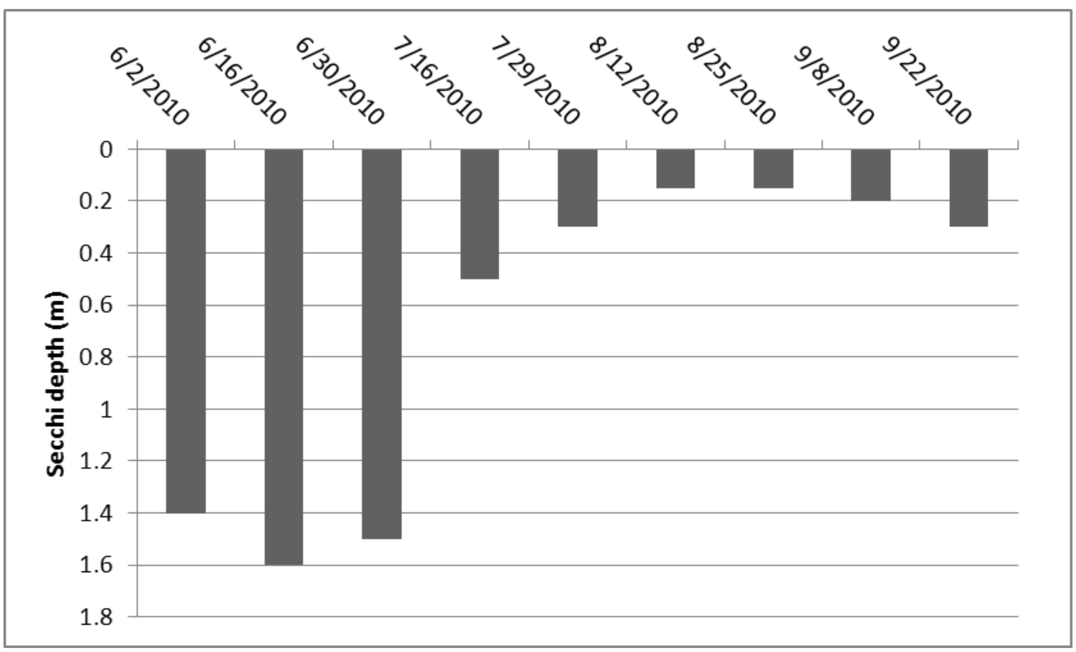

Figure 3.3 C.6. Swedes Bay water clarity (secchi disk readings) in 2010. The shallow lake NCHF ecoregion standard is 1.0 m.

Additional Findings

On June 29th, 2010 the water temperature of Swedes bay reached a peak of 31^0C (87^0F). The dissolved oxygen concentration 1 meter below the surface was only 0.47 mg/l during the August 12th sampling event. To document how low the dissolved oxygen conditions were dropping to at night, a dissolved oxygen profile of Swedes Bay was conducted immediately prior to sunrise when dissolved oxygen concentrations are typically at their lowest. An YSI 6820 V2 multiparameter data sonde confirmed that Swedes Bay had temporarily gone anoxic, with dissolved oxygen readings of 0.15 mg/L just 1.5 meters below the surface.

A fish kill of approximately 100 fish, primarily consisting of juvenile yellow perch (*Perca flavescens*) and largemouth bass (*Micropterus salmoides*) was observed during the 8/12/2010 in-lake sampling event following the confirmation of anoxic conditions on 8/1/2010. Gas bubbles were also observed during the 8/12/2010 sampling event, likely indicating a release of sulfur, phosphorus, and methane from the sediment. Blue-green algae species including aphanizomenon and anabaena were both documented in Swedes Bay in 2010 during both the 7/29 and 8/12/2010 sampling events.

D. East Jefferson Lake:

Nine sampling events were conducted on East Jefferson Lake in 2009, and eight sampling events took place in 2010. East Jefferson is a deep lake.

Total Phosphorus

Similar patterns existed for TP between 2009 (Figure 3.3 D.1) and 2010 (Figure 3.3 D.2). The mean TP concentration of all water quality samples taken during the TMDL study was 73µg/L.

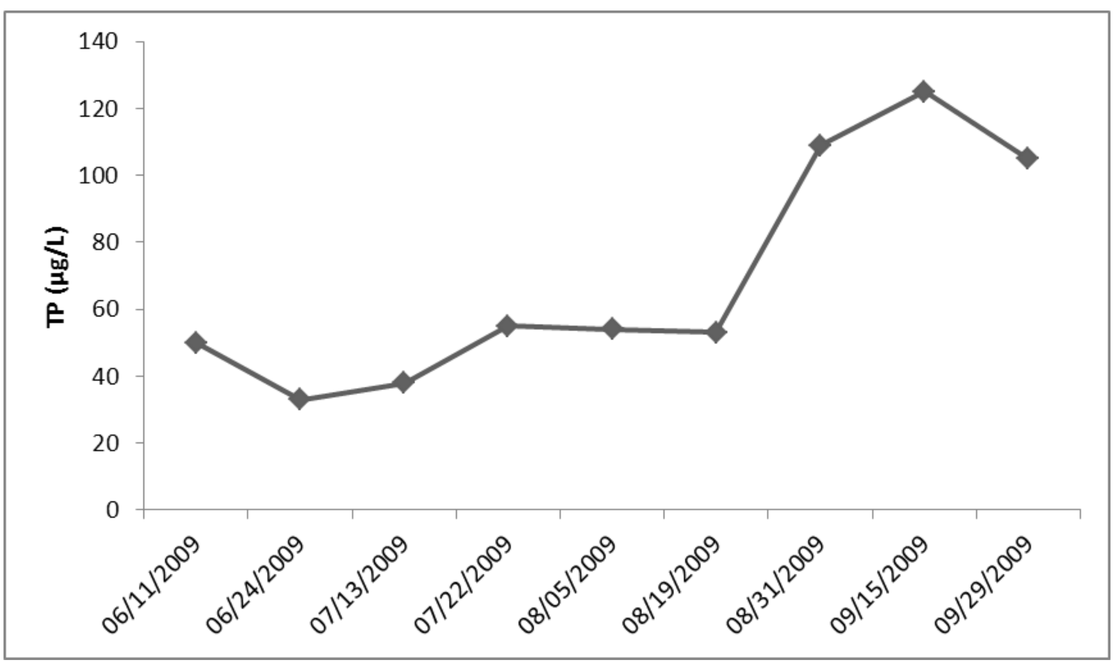

Figure 3.3 D.1. East Jefferson Lake total phosphorus concentrations during the 2009 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

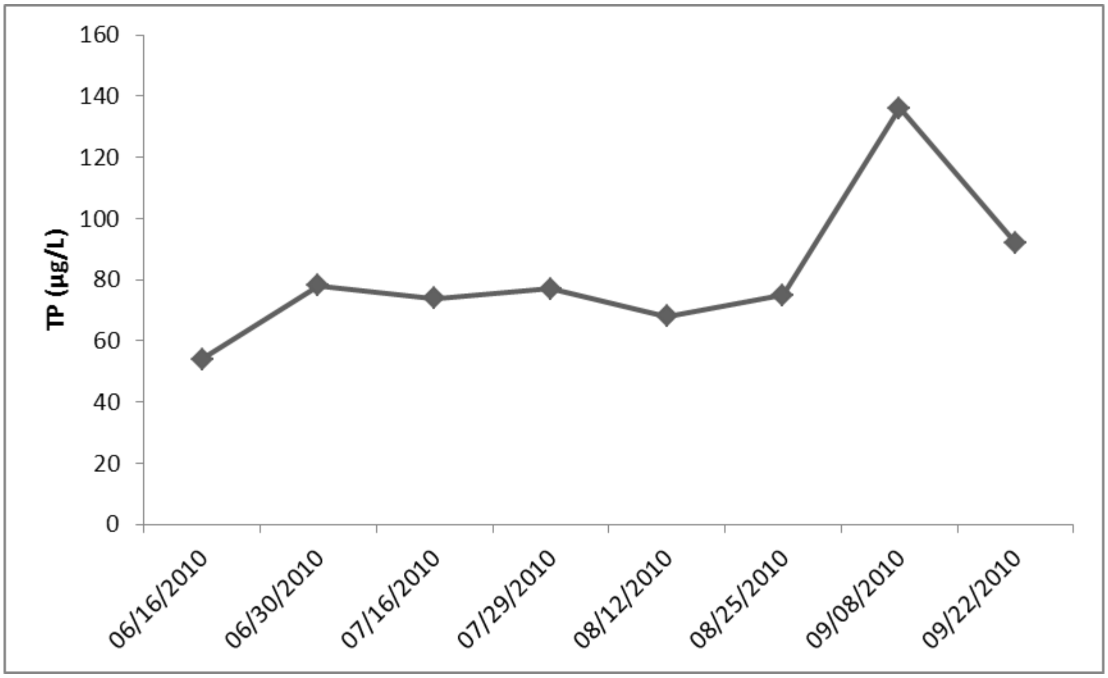

Figure 3.3 D.2. East Jefferson Lake total phosphorus concentrations during the 2010 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

Chlorophyll-a

Values for chl-a peaked at about the same concentration in 2009 (Figure 3.3 D.3) and in 2010(Figure 3.3 D.4). The mean chl-a concentration for all samples collected during the TMDL study was 36µg/L.

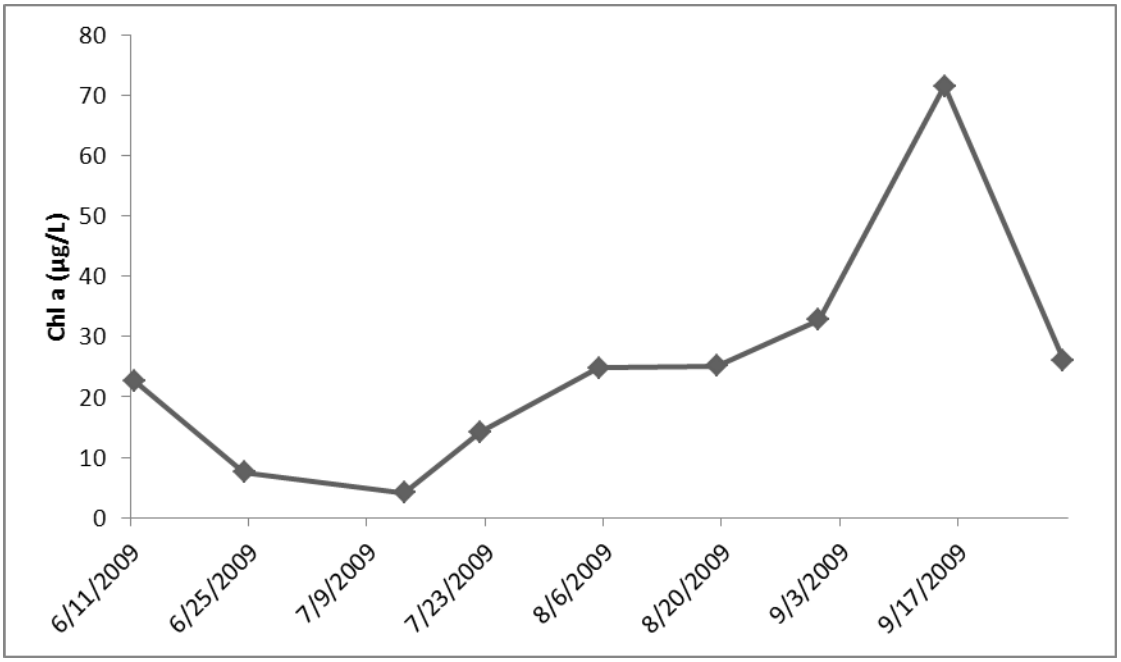

Figure 3.3 D.3. East Jefferson Lake chl-a concentrations, June to September in 2009. The deep lake NCHF ecoregion standard is 14µg/L.

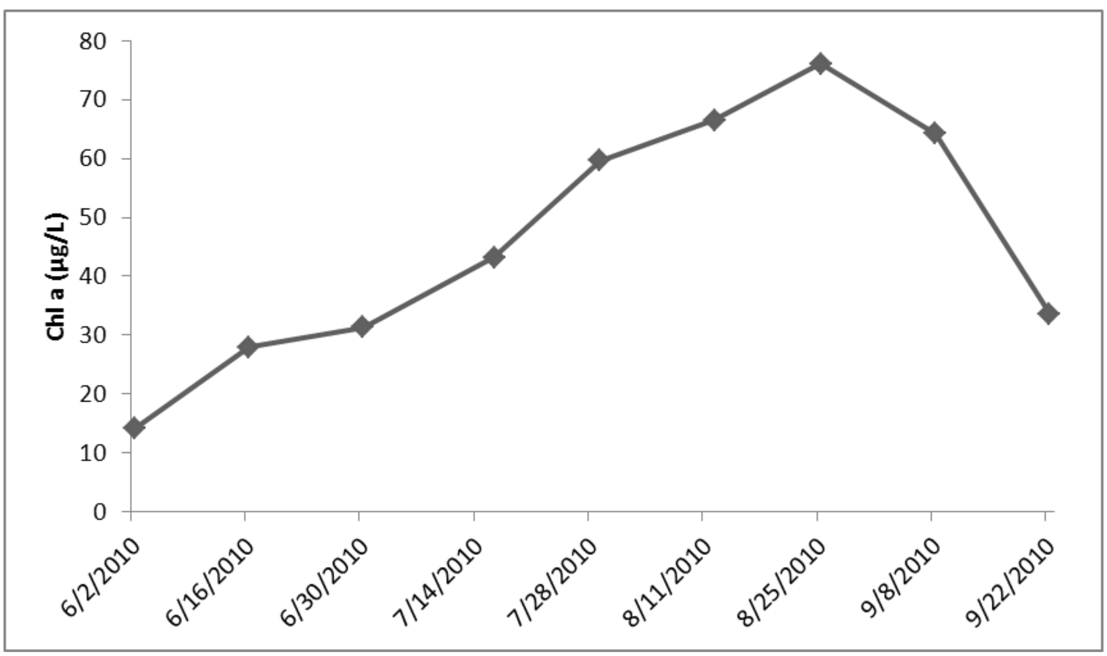

Figure 3.3 D.4. East Jefferson Lake chl-a concentrations, June to September in 2010. The deep lake NCHF ecoregion standard is 14µg/L.

Secchi disk transparency

With the exclusion of 2009's June 11th sample transparency, the secchi disk readings followed a similar pattern between 2009 (Figure 3.3 D.5) and 2010 (Figure 3.3 D.6). The mean Secchi disk reading observed during the TMDL study was 1.8m.

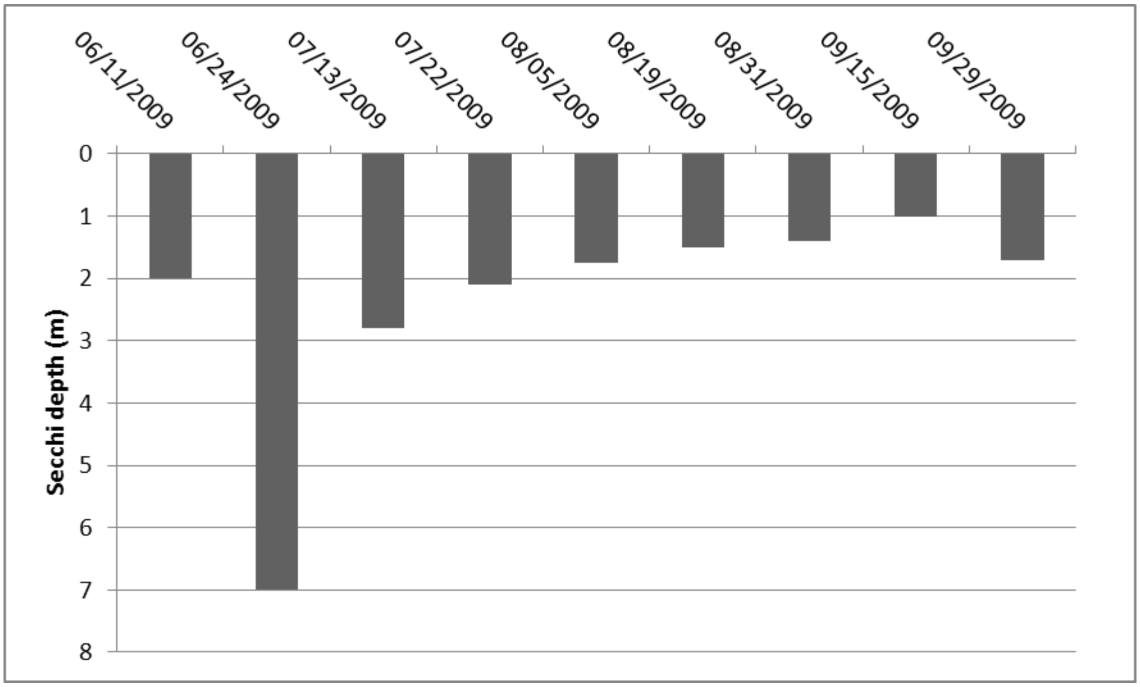

Figure 3.3 D.5. East Jefferson Lake water clarity (secchi disk readings) during 2009. The deep lake NCHF ecoregion standard is 1.4 m .

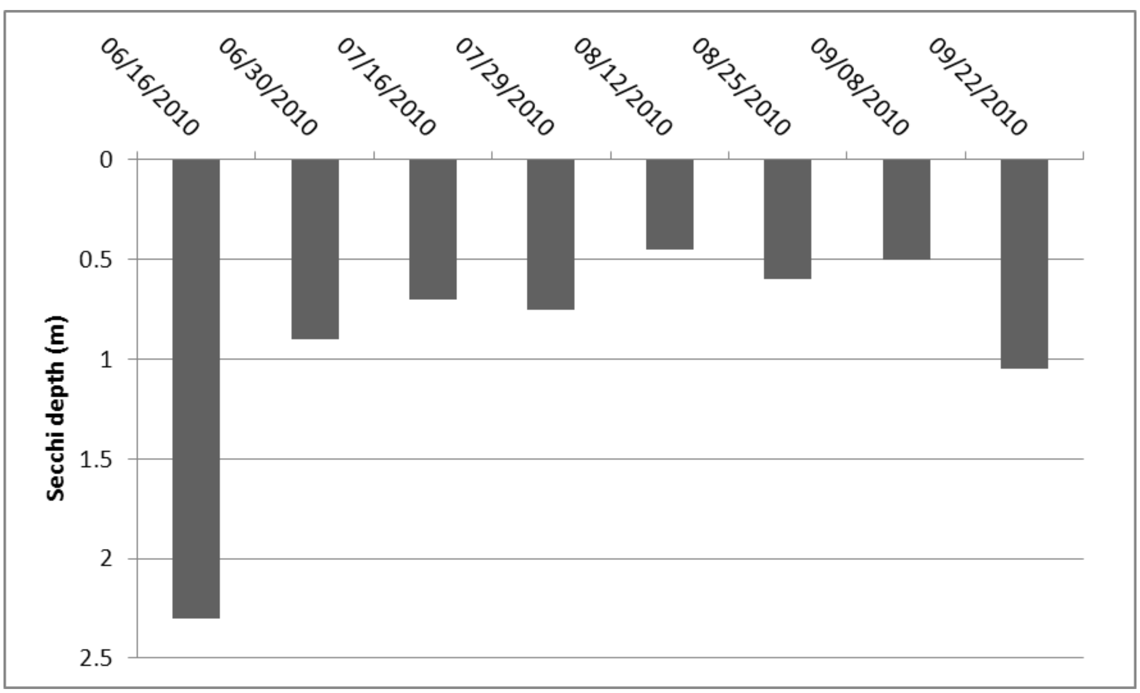

Figure 3.3 D.6. East Jefferson Lake water clarity (secchi disk readings) during 2010. The deep lake NCHF ecoregion standard is 1.4 m.

Additional Findings

Gloeotrichia, a blue - green algae species, appeared in early June 2009 as CLP had first started to senesce. Gloeotrichia has a two stage life-cycle; most of that life cycle is spent absorbing phosphorus from sediments at the bottom of the lake where it over winters from October through May (Forsell and Peterson, 1995). Typically, in mid-June or early July, Gloeotrichia become buoyant enough to float up into the surface waters (Forsell and Peterson, 1995). As Gleotrichia rises from the sediment surface, it brings with it a source of nutrients including phosphorus from the hypolimnion. Consequently, Gloeotrichia itself may be serving as a source of internal fertilization to the epilimnion (Forsell and Petterson, 1995). The peak temperature observed on East Jefferson Lake was 29.01^{0}C (84.3^{0}F) and occurred on 8/12/2010, DO concentrations at the surface on 8/12 were 11.53 mg/L. Despite a high DO concentration at the surface, DO concentrations just 4 m below the surface were 1.16 mg/L. DO concentrations of 2 mg/L is typically associated as the minimum DO concentration needed to support most species of fish, especially during the summer when metabolic rates are highest. Given this statistic, only the top 3m of the water column are capable of supporting fish by early August. Severe nuisance algal blooms followed the senescence of CLP in mid-June on East Jefferson Lake in 2009 and 2010. The algal blooms were especially noticeable during calm periods and produced a noticeably unpleasant odor.

E. **German Lake:**

Nine sampling events occurred during each of the 2009 and 2010 monitoring seasons, respectively. German Lake is a deep lake.

Total Phosphorus

In 2009, the TP concentration peaked in late August with a value of 79 µg/L (Figure 3.3 E.1). In 2010, on July 16th, the highest value in German Lake for the study period was recorded at 183µg/L (Figure 3.3 E.2). . The mean TP concentration for all samples collected during the TMDL study was 65µg/L.

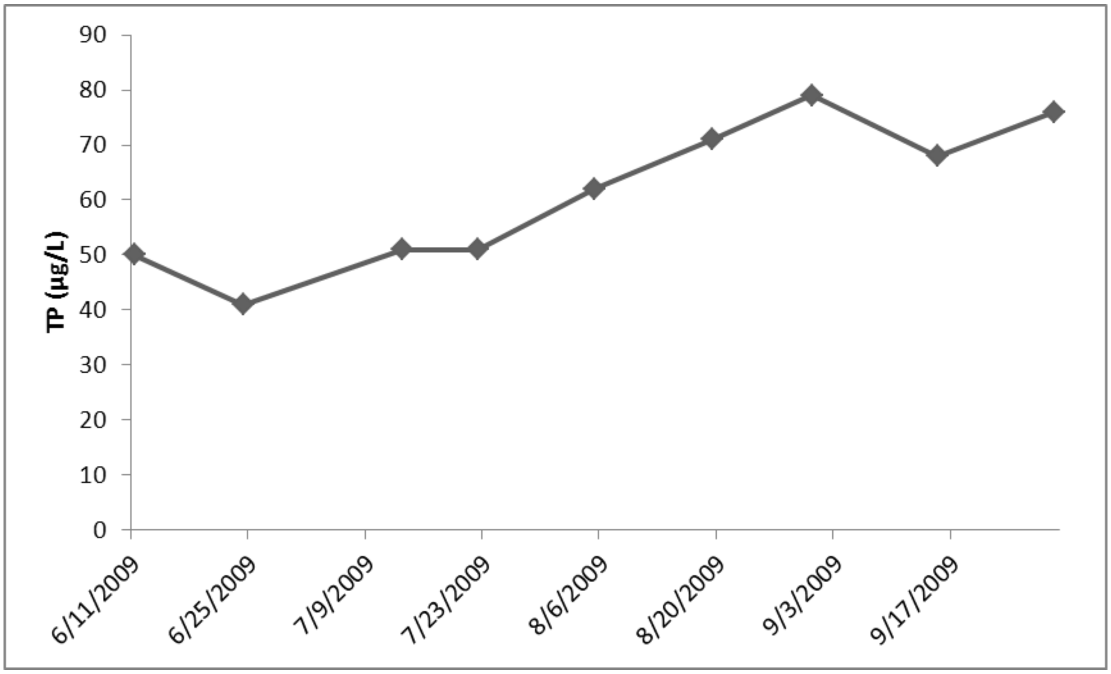

Figure 3.3 E.1. German Lake total phosphorus concentrations during the 2009 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

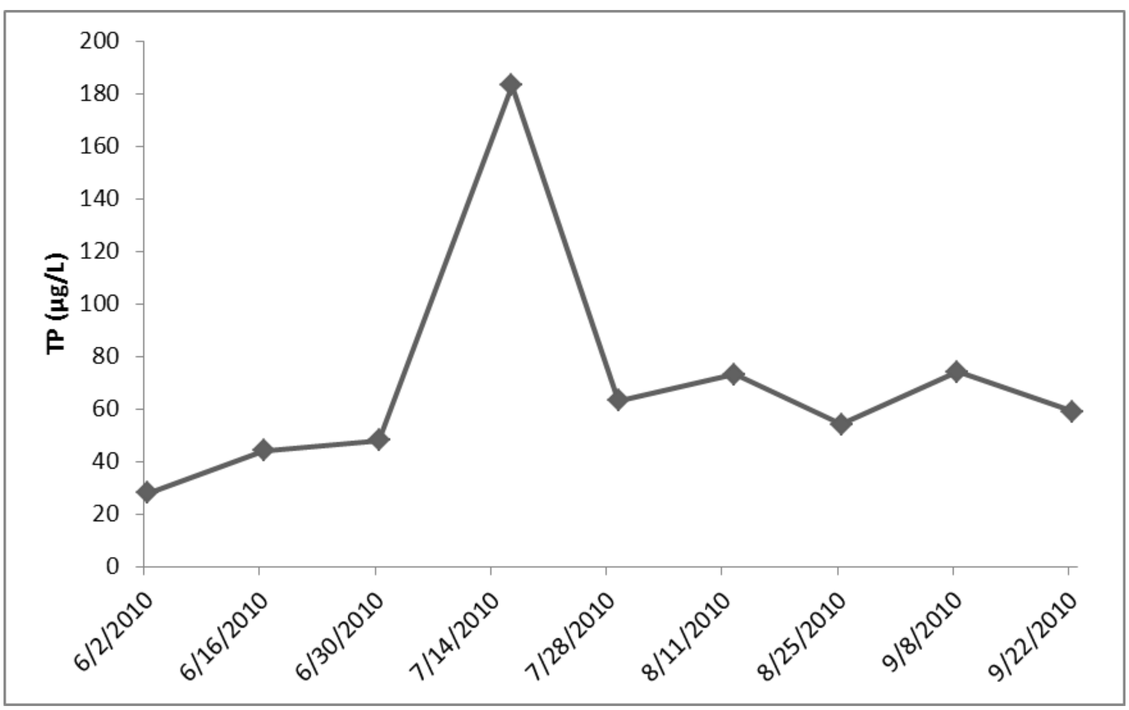

Figure 3.3 E.2. German Lake total phosphorus concentrations during the 2010 growing season. The deep lake NCHF ecoregion standard is 40 µg/L.

Chlorophyll-a

In 2009, chl-a concentrations peaked in mid-August at 52 µg/L (Figure 3.3 E.3). In 2010, chl-a concentrations peaked in late July at 83 µg/L (Figure 3.3 E.4). The mean chl-a concentration for all samples taken during the TMDL study was 43 µg/L.

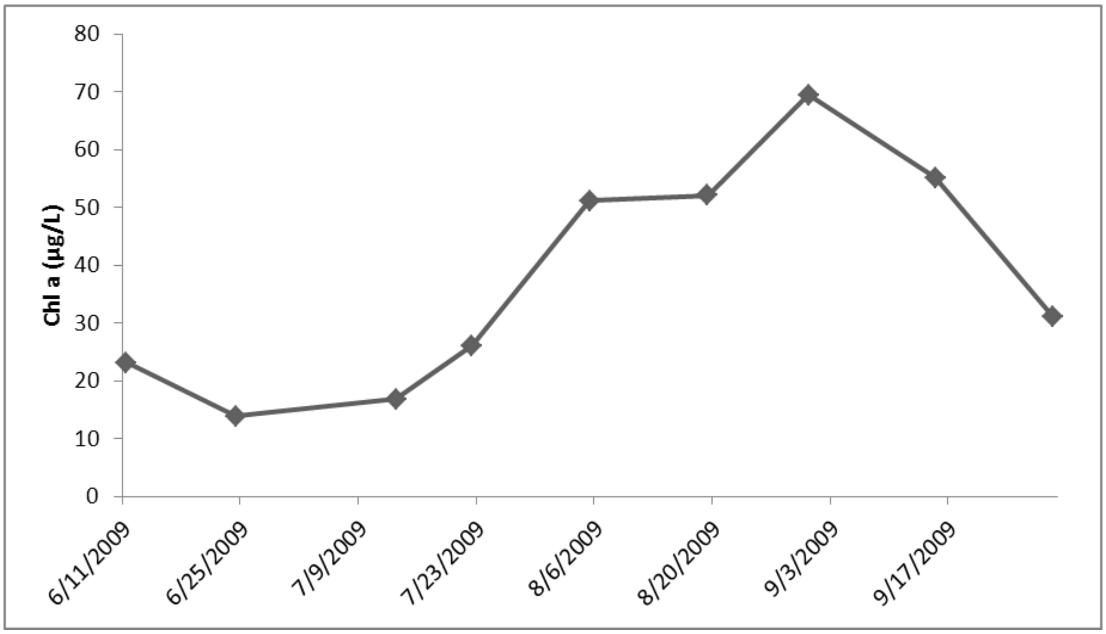

Figure 3.3 E.3. Chlorophyll-a concentration on German Lake during the 2009 monitoring season.

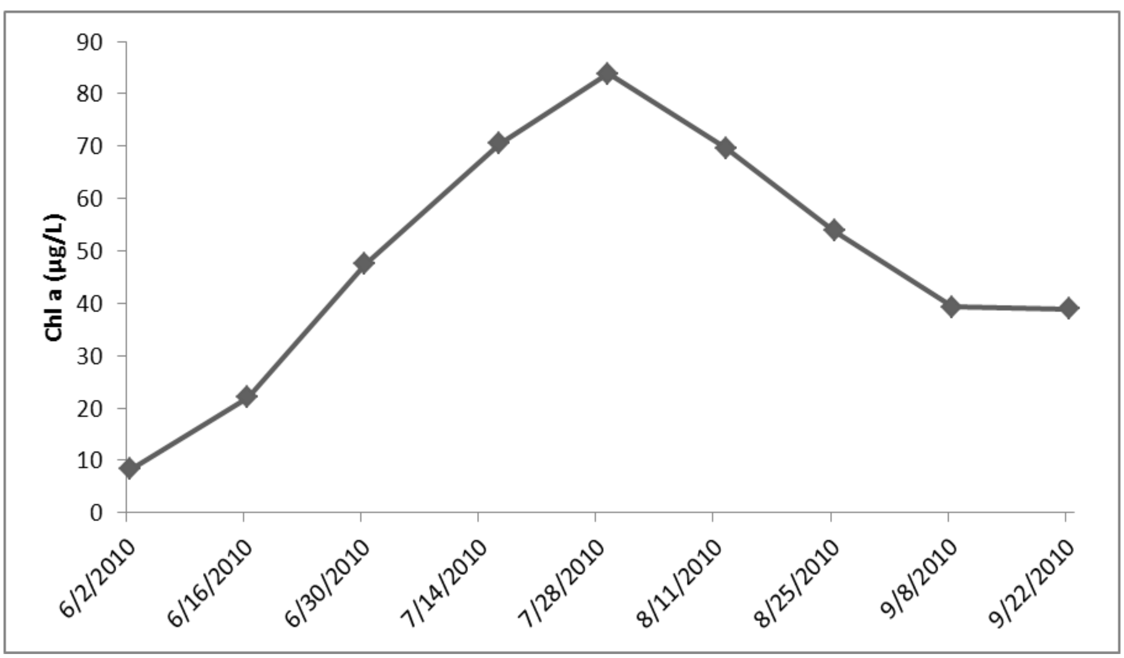

Figure 3.3 E.5. Chlorophyll-a concentration on German Lake during the 2010 monitoring season.

Secchi disk transparency

Secchi disk readings taken during the 2009 was better early in the year (Figure 3.3 E.6.). This pattern was replicated in 2010(Figure 3.3 E.7.). The mean secchi disk reading during the TMDL study on German Lake was 1.2 m.

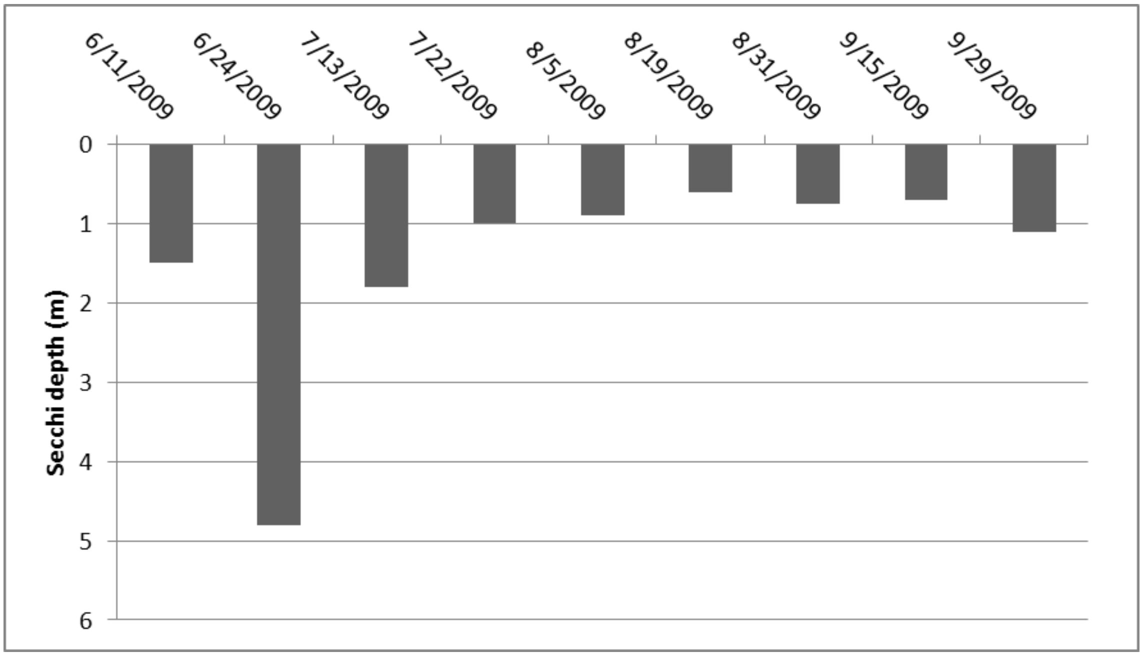

Figure 3.3 E.6. German Lake water clarity (secchi disk readings) in 2009. The deep lake NCHF ecoregion standard is 1.4 m .

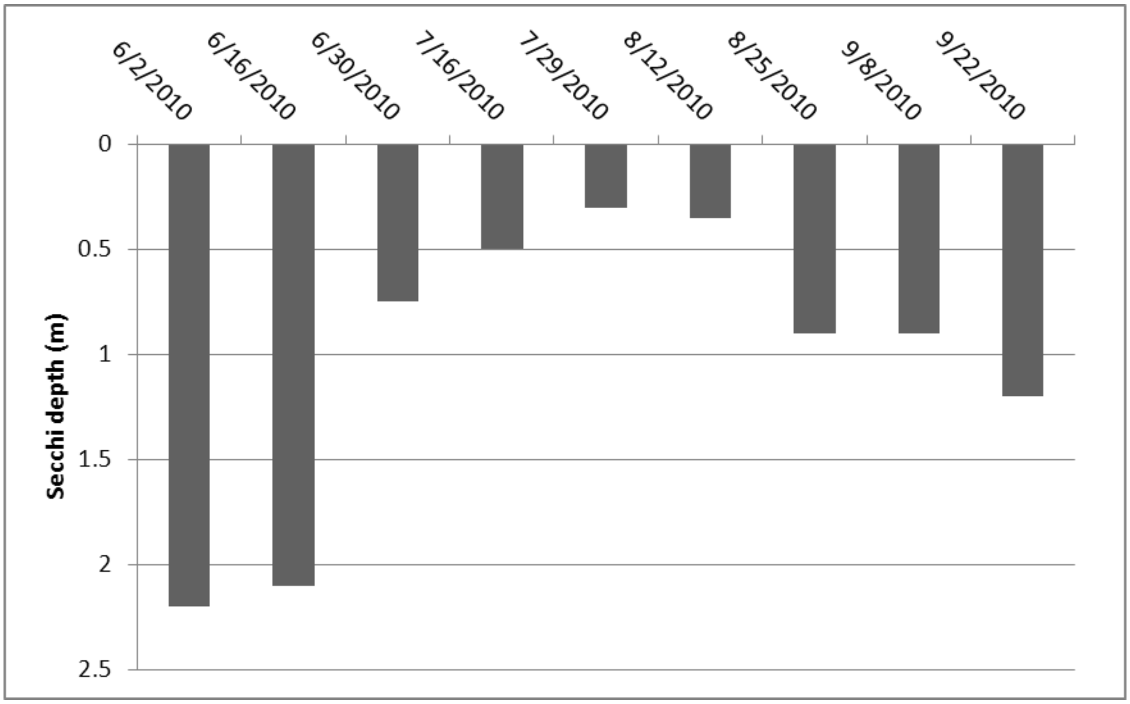

Figure 3.3 E.7. German Lake water clarity (secchi disk readings) in 2010. The deep lake NCHF ecoregion standard is 1.4 m.

Section 4.0 Watershed Data Analysis/Methods

For the purposes of this TMDL, two models were used (MINLEAP and BATHTUB) to analyze the various factors impacting the JGC. In order to accurately use the models, the interaction and influence of the areas contributing waters to each lake basin on the JGC also needed to be investigated, and pollutant loading data needed to be calculated.

In order to do this, the following watersheds were used: West Jefferson Lake watershed, Middle Jefferson Lake watershed, inflow site JG9 watershed, Swedes Bay watershed, inflow site JG 6 watershed, inflow site JG8 watershed, East Jefferson Lake watershed, German Lake watershed, and inflow site JG7 watershed (Figure 4.0 A).

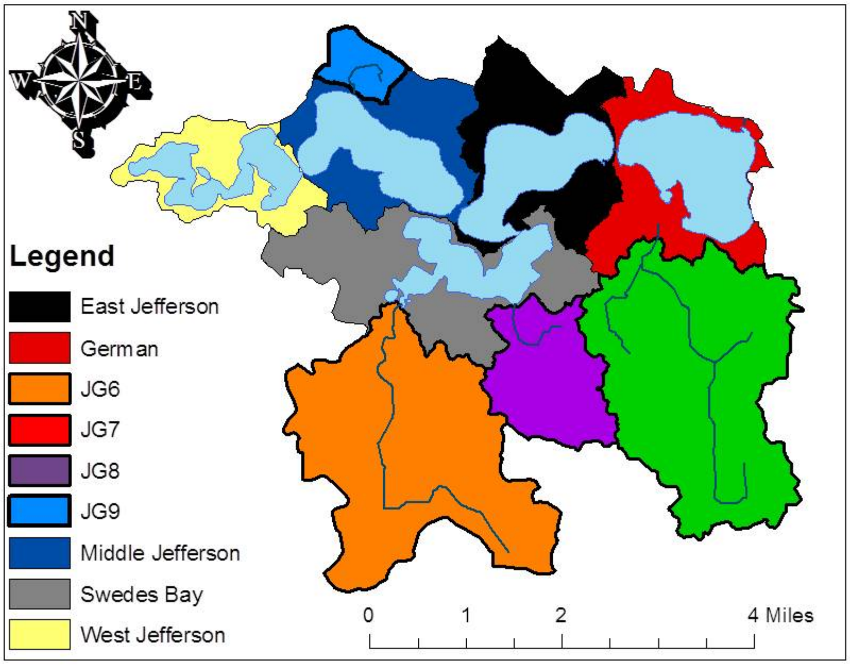

Figure 4.0 A. Sub-watersheds within of the Jefferson German Lake Chain watershed.

As seen in this schematic version of the area, the different lake basins and inflow sites feed into one another, increasing the contributing areas to the watersheds below them, until the total watershed areas are accounted for (Figure 4.0 B).

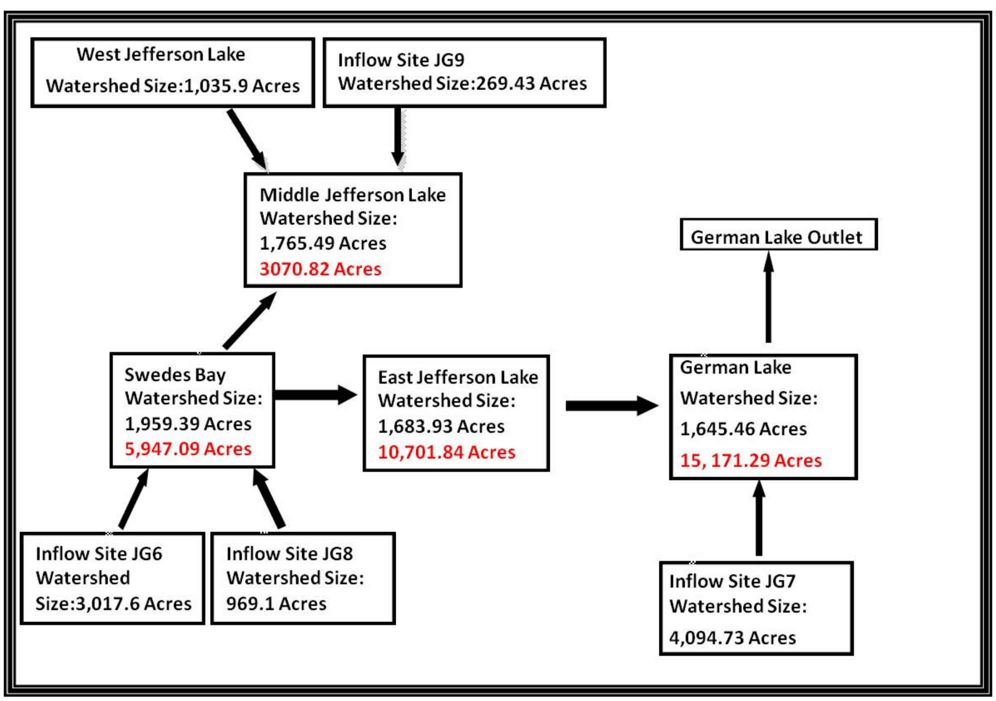

Figure 4.0 B. Schematic diagram of the direction of flow on the JGC. Black text indicates individual watershed area while red text indicates cumulative watershed area.

As discussed in the "Lake TMDL Protocol and Submittal Requirements" developed by the MPCA, two models are used to evaluate the data. These models examine the data, and were used to determine if additional data analysis was required. Starting with a "Level I Assessment", the JGC was evaluated using the MINLEAP model (see Appendix D). Based on the results, additional assessments were also necessary using the BATHTUB model.

Section 5.0 BATHTUB Model

5.1 Model Description

BATHTUB is a lake water quality model developed by William Walker under contract with the US Army Corp of Engineers. BATHTUB has been widely used to model lake nutrient balances within a steady-state, spatially segmented hydraulic network by calculating advective and diffusive transport, and nutrient sedimentation dynamics within the system.

BATHTUB predicts eutrophication-related water quality conditions (expressed in terms of total phosphorus concentration and other parameters) using empirical relationships previously developed and tested, some for reservoir applications (Walker 1985) and others for natural lakes (e.g., Canfield-Bachmann (1981) lake model, incorporated into BATHTUB as an option). This study used the Canfield-Bachmann lake model for all modeled cases.

The JGC lakes were modeled individually, with the outflow volume and phosphorus (P) load from each upstream lake modeled as a tributary to the lake downstream in the system. Monitored tributaries (apart from upstream lakes) were modeled in the same way as "point" sources, with specified flow volume and total phosphorus (TP) concentration (and, hence, specified P load). Runoff and P loads from unmonitored areas were modeled by applying specified runoff depths and TP concentrations based on land use to their areas, The JGC lake models were calibrated by adding internal P loads just sufficient to match the modeled TP concentration to the lake's observed TP, represented by the two-year summer average.

BATHTUB contains a variety of mass balance phosphorus models. This study used the Canfield-Bachmann model because it has been applied successfully to many lakes throughout Minnesota. Because the Canfield-Bachmann model is empirically based, reflecting P loading and water quality data from a large number and variety of lakes, its predictions incorporate implicitly a certain magnitude of internal P loading that may be regarded as "average" for the lakes in its data set. Accordingly, the internal loading added *explicitly* in the calibration of the JGC lakes represents internal loading that is above and beyond the "average" for these lakes.

The BATHTUB model results are presented below. Model input data for both existing conditions and the TMDL are listed in Appendix E.

5.2 BATHTUB Results for JGC:

Existing Conditions. The JGC lake models were calibrated to the observed 2009-2010 summer average TP concentrations by adding internal P loads to achieve a match. The areal internal loading rates ranged from 0.5 to 4.0 milligrams per square meter daily (mg/m^2-day) (Table 5.2 A). Swede's Bay showed the largest internal areal loading rate as well as the largest overall internal load. Tables 5.2 B. through 5.2 F.

present the complete water and P mass balances, as modeled for existing conditions, for all five lakes. The modeled inflow TP concentrations for the monitored sites are the FWMCs presented in Table 3.2.A.

Table 5.2 A. BATHTUB results for current conditions in the Jefferson-German lake chain.

Lake	TP Observed (ug/L)	TP Modeled (ug/L)	Calibrated Internal P Load	
			Areal Rate (mg/m^2-day)	Annual Load (kg/yr)
West Jefferson	63.9	63.9	0.463	299
Middle Jefferson	141.1	141.1	0.837	822
Swedes Bay	303.6	303.6	4.009	2,914
East Jefferson	72.7	72.7	1.050	1,003
German Lake	65.3	65.3	0.547	692

Table 5.2 B. West Jefferson mass balance for current conditions.

Component	Phosphorus Budget Data			Area	Water Budget Data	
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)	Data (km^2)	Flow (hm^3/yr)	Runoff (m/yr)
W Jefferson Local Watershed	44	381	18	2.4	0.12	0.048
Atmosphere	53	30	30	1.8	1.75	0.990
Internal Load	299	--	--	--	--	--
Inflow Total	***397***	--	--	4.2	1.87	0.446
Outflow	7	***64***	2	4.2	0.12	0.028
Retention / Evaporation	389	--	--	1.8	1.75	--

Table 5.2 C. Middle Jefferson mass balance for current conditions.

Component	Phosphorus Budget Data			Area	Water Budget Data	
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)	Data (km^2)	Flow (hm^3/yr)	Runoff (m/yr)
West Jefferson Outflow	7	60	2	4.2	0.12	0.027
Inflow Site JG9	375	1,616	344	1.1	0.23	0.213
M Jefferson Local Watershed	56	346	17	3.4	0.16	0.048
Atmosphere	81	30	30	2.7	2.66	0.990
Internal Load	822	--	--	--	--	--
Inflow Total	***1,340***	--	--	11.3	3.17	0.280
Outflow	72	***141***	6	11.3	0.51	0.045
Retention / Evaporation	1,268	--	--	2.7	2.66	--

Table 5.2 D. Swede's Bay mass balance for current conditions.

Component	Phosphorus Budget Data			Area	Water Budget Data	
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)	Data (km^2)	Flow (hm^3/yr)	Runoff (m/yr)
Inflow Site JG6	414	255	34	12.2	1.63	0.133
Inflow Site JG8	97	228	25	3.9	0.42	0.108
Swede's Bay Local Watershed	81	284	14	5.9	0.29	0.048
Atmosphere	60	30	30	2.0	1.97	0.990
Internal Load	2,914	--	--	--	--	--
Inflow Total	***3,566***	--	--	24.1	4.30	0.179
Outflow	709	***304***	29	24.1	2.33	0.097
Retention / Evaporation	2,857	--	--	--	1.97	--

Table 5.2 E. East Jefferson mass balance for current conditions.

Component	Phosphorus Budget Data			Area	Water Budget Data	
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)	Data (km^2)	Flow (hm^3/yr)	Runoff (m/yr)
Swedes Bay Outflow	536	230	22	24.1	2.33	0.097
Middle Jefferson Outflow	13	111	1	11.3	0.12	0.010
E Jefferson Local Watershed	70	346	17	4.2	0.20	0.048
Atmosphere	78	30	30	2.6	2.59	0.990
Internal Load	1,003	--	--	--	--	--
Inflow Total	***1,700***	--	--	42.2	5.24	0.124
Outflow	192	***73***	5	42.2	2.65	0.063
Retention / Evaporation	1,508	--	--	--	2.59	--

Table 5.2 F. German Lake mass balance for current conditions.

Component	Phosphorus Budget Data			Area	Water Budget Data	
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)	Data (km^2)	Flow (hm^3/yr)	Runoff (m/yr)
East Jefferson Outflow	177	67	4	42.2	2.64	0.063
Inflow Site JG7	462	356	37	12.5	1.30	0.104
German Lake Local Watershed	42	270	13	3.2	0.15	0.048
Atmosphere	104	30	30	3.5	3.43	0.990
Internal Load	692	--	--	--	--	--
Inflow Total	***1,477***	--	--	61.4	7.52	0.122
Outflow	267	***65***	4	61.4	4.09	0.067
Retention / Evaporation	1,209	--	--	--	3.43	--

TMDL Conditions:

For each lake, the TP concentration goal for the TMDL condition was set at 10% below the applicable water quality standard (see Section 2.0). The P loading that just satisfies each lake's TMDL goal is the lake's *P Loading Capacity*; or, when expressed on a daily loading basis, the lake's TMDL. Technically, since the Margin of Safety (MOS) is implemented here by setting the lake TP goal at 10% below the standard, the loading determined above is actually the "TMDL minus the MOS" – even though the MOS terms in mass loading was not explicitly determined in this study. However, use of the Canfield-Bachmann model guarantees that the MOS in mass loading terms is larger than 10% because P retention in the Canfield-Bachmann model is an increasing function of P load. (In other words, "the lower you go, the harder it is to get lower" in terms of the lake's P loading.)

The P Loading Capacity for each lake was found by trial-and-error load reductions, based on the criterion that the modeled in-lake TP concentration must equal the lake's numerical water quality goal (Table 5.2.G.). The lake water balances for TMDL conditions were kept identical to those in the existing-case models.

Table 5.2 G. Jefferson-German Chain TMDL BATHTUB predictions.

Lake	Lake TP Predicted (ug/L)	Lake TP TMDL Goal (ug/L)	Lake TP Standard (ug/L)
West Jefferson	36	36	40
Middle Jefferson	54	54	60
Swede's Bay	54	54	60
East Jefferson	36	36	40
German Lake	36	36	40

Note: For TMDL cases, lake TP goal is 10% below applicable water quality standard.

The overall load reductions required to meet the TP goals (summarized in Table 5.2 H) ranged from 61% to 92%. These reductions are extremely high. Tables 5.2 I. through 5.2 M. present the complete water and P mass balances, as modeled for TMDL conditions, for all five lakes.

Table 5.2 H. Jefferson-German Chain Existing and TMDL Phosphorus Loads.

Lake	P Load Existing (kg/yr)	P Load TMDL (kg/yr)	P Load Reduction (kg/yr)	P Load Reduction (percent)
West Jefferson	397	140	256	65%
Middle Jefferson	1,340	254	1,086	81%
Swede's Bay	3,566	286	3,280	92%
East Jefferson	1,700	534	1,166	69%
German Lake	1,477	583	893	61%

Table 5.2 I. West Jefferson TMDL mass balance.

Component	Phosphorus Budget Data		
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)
W Jefferson Local Watershed	27	234	11
Atmosphere	53	30	30
Internal Load	60	--	--
Inflow Total	***140***	--	--
Outflow	4	***36***	1
Retention / Evaporation	136	--	--

Table 5.2 J. Middle Jefferson TMDL mass balance.

Component	Phosphorus Budget Data		
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)
West Jefferson Outflow	5	40	1
Inflow Site JG9	51	220	47
M Jefferson Local Watershed	36	220	11
Atmosphere	81	30	30
Internal Load	82	--	--
Inflow Total	***254***	--	--
Outflow	27	***54***	2
Retention / Evaporation	227	--	--

Table 5.2 K. Swede's Bay TMDL phosphorus budget per BATHTUB.

Component	Phosphorus Budget Data		
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)
Inflow Site JG6	157	97	13
Inflow Site JG8	41	97	10
Swede's Bay Local Watershed	28	97	5
Atmosphere	60	30	30
Internal Load	0	--	--
Inflow Total	***286***	--	--
Outflow	126	***54***	5
Retention / Evaporation	160	--	--

Table 5.2 L. East Jefferson TMDL phosphorus budget per BATHTUB.

Component	Phosphorus Budget Data		
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)
Swedes Bay Outflow	140	60	6
Middle Jefferson Outflow	7	60	1
E Jefferson Local Watershed	60	300	14
Atmosphere	78	30	30
Internal Load	249	--	--
Inflow Total	***534***	--	--
Outflow	95	***36***	2
Retention / Evaporation	439	--	--

Table 5.2 M. German Lake TMDL phosphorus budget per BATHTUB.

Component	Phosphorus Budget Data		
	P Load (kg/yr)	TP Conc. (ug/L)	P Export (kg/km^2-yr)
East Jefferson Outflow	106	40	3
Inflow Site JG7	272	210	22
German Lake Local Watershed	32	210	10
Atmosphere	104	30	30
Internal Load	69	--	--
Inflow Total	***583***	--	--
Outflow	147	***36***	2
Retention / Evaporation	436	--	--

Section 6.0 Existing P Loading Sources by Lake Basin

Within the Jefferson German Lake Chain watershed, internal load, atmosphere direct inlets are the main sources of phosphorus.

Another documented source is the small community wastewater need of the Jefferson-German Lakes area (Figure 6A). In March of 2013, a report was completed (Jefferson German Septic Inventory Project Final Report, Wenck Associates, Inc.) that determined "to what extent a septic system compliance problem exists within the German Jefferson Subordinate Service District." (Figure 6B) The goal of the project was to "complete as many SSTS compliance inspections in the [subordinate service district] as possible." Inspections were made voluntary by Le Sueur County. Of the 675 properties with a structure generating wastewater who were sent an invitation to participate, 344 (51%) opted for the inspection. Of the 344 inspections, 42% were non-compliant with Minnesota Rules Chapter 7080 and Le Sueur County ordinance. Future steps/recommendations from the report were: to complete wastewater feasibility assessments in areas where there was a high rate of non-compliance; to education of homeowners within the Service District; and to encourage upgrades to the non-compliant systems.

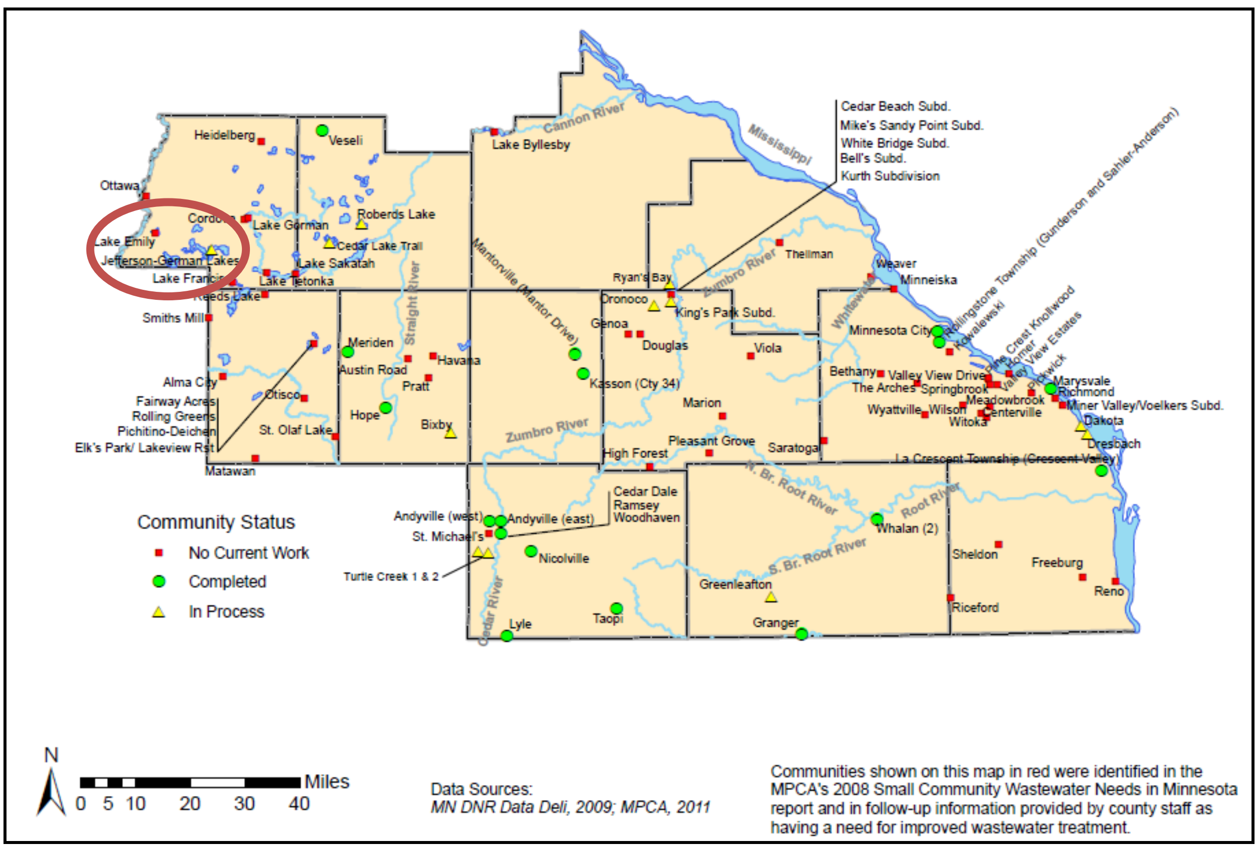

Figure 6A. Progress of Southeast Minnesota Wastewater Initiative as of November, 2012. Communities are also identified in MPCA's 2008 Small Community Wastewater Needs in Minnesota report. Red circle shows location of the Jefferson-German Lakes community.

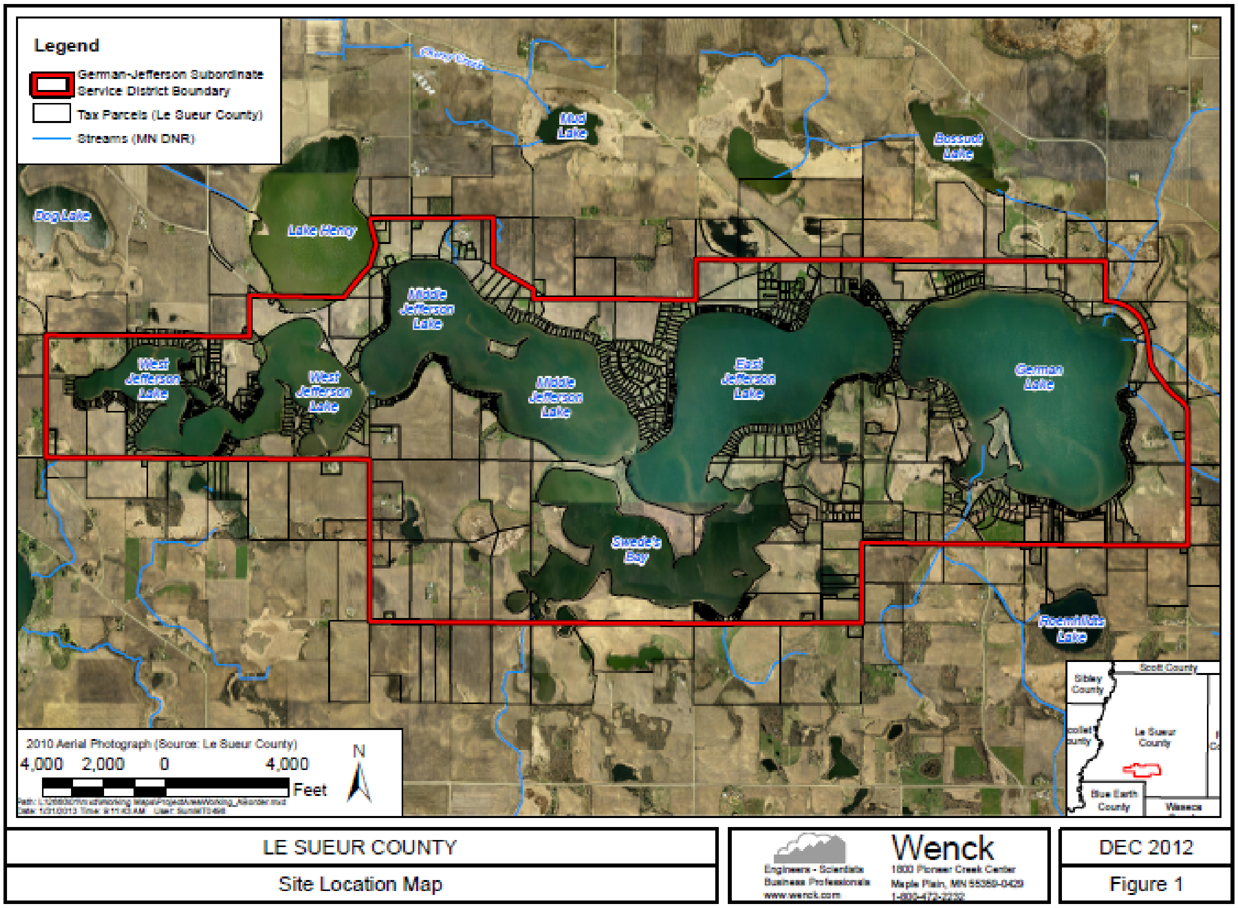

Figure 6B. Boundaries of the German-Jefferson Subordinate Service District.

West Jefferson Lake:

There is no perennial streamflow in the West Jefferson Lake watershed; however, a number of tile lines do contribute water and nutrients to this segment of the lake chain. Based on data collected from the TMDL study, the largest source of phosphorus to West Jefferson Lake was internal loading (Figure 6.0 A.).

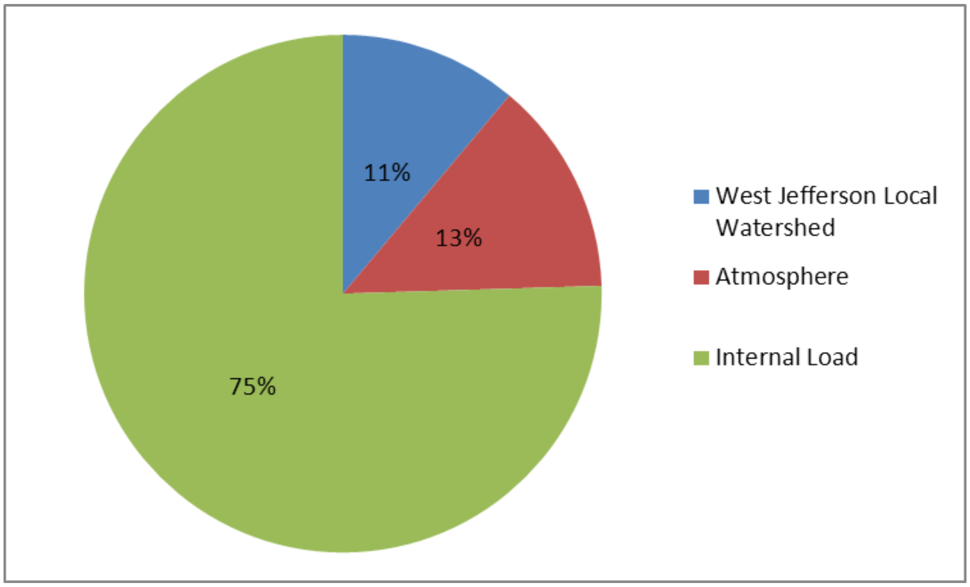

Figure 6.0 A. Contributions of TP by source to West Jefferson Lake.

Middle Jefferson Lake:

Based on data collected from the TMDL, the two largest sources of phosphorus to Middle Jefferson Lake were internal load and contributions from monitoring location JG9 (Figure 6.0 B.).

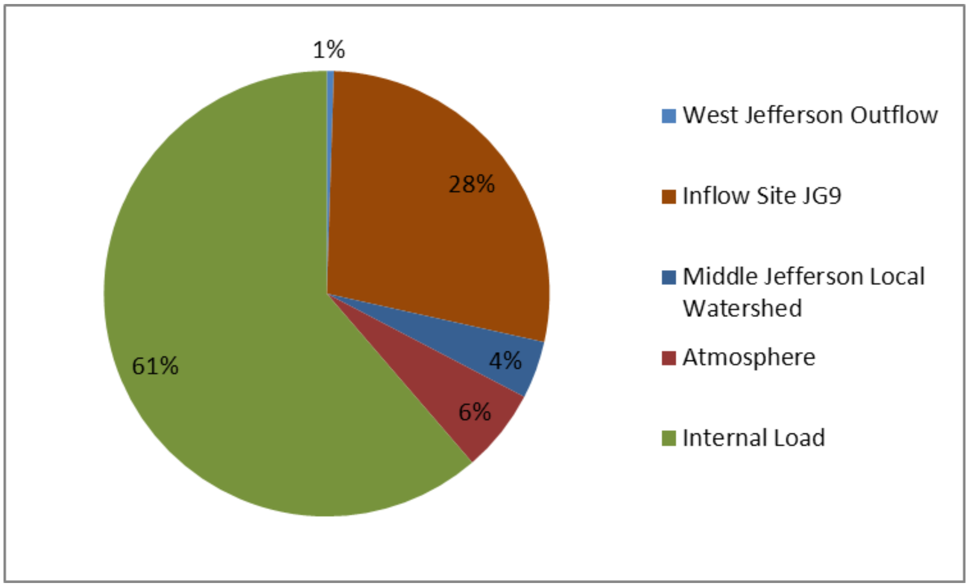

Figure 6.0 B. Contributions of total phosphorus by source to Middle Jefferson Lake.

Swedes Bay:
Based on data collected during this study, the two largest sources of phosphorus to Swedes Bay were contributions from internal sources and inflow from monitoring location JG6 (Figure 6.0 C.).

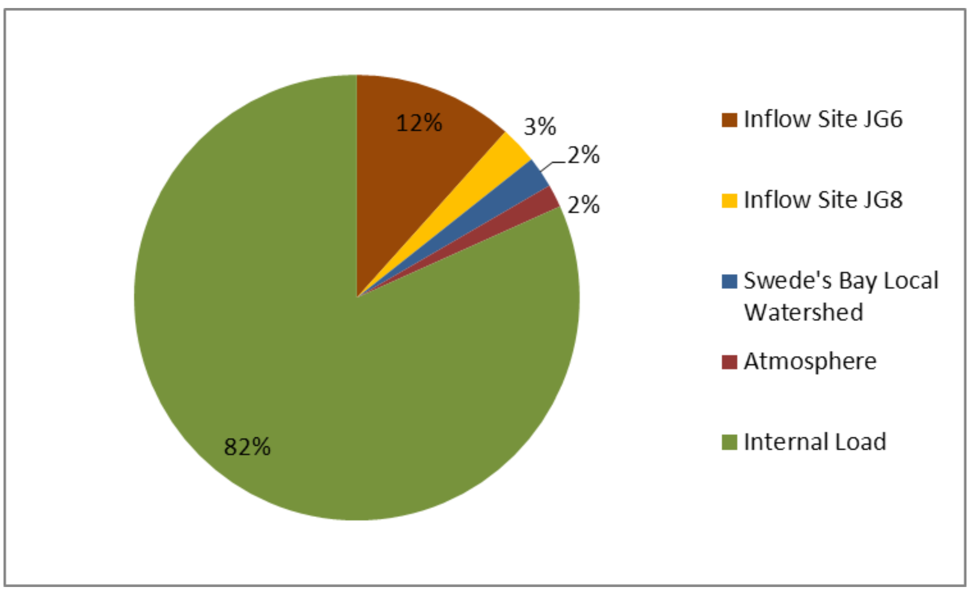

Figure 6.0 C. Contributions of total phosphorus by source to Swedes Bay.

East Jefferson Lake:

The two largest sources of phosphorus to East Jefferson Lake are contributions from internal sources and inflow from monitoring location JG6 (Figure 6.0 D.).

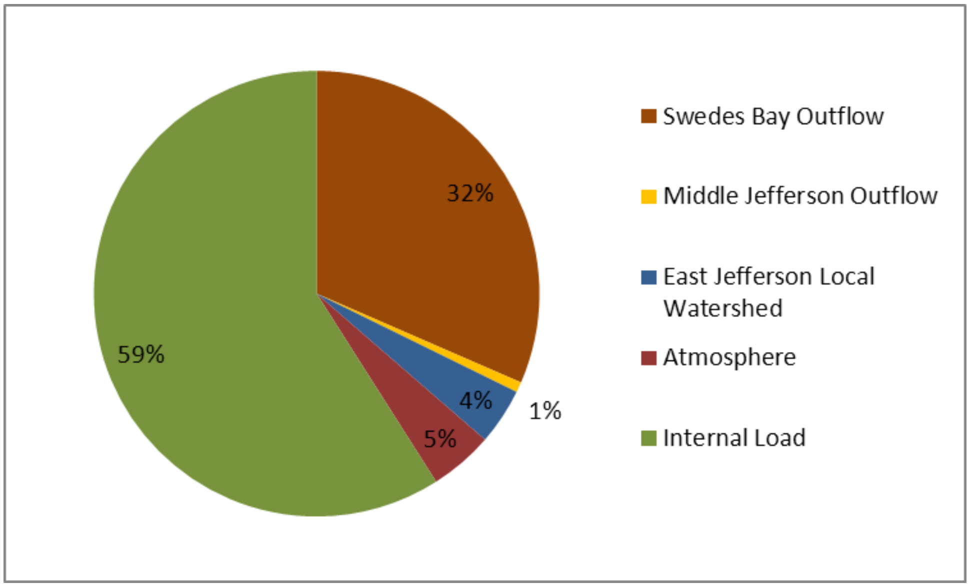

Figure 6.0 D. Contributions of total phosphorus by source to East Jefferson Lake.

German Lake:

All data collected from the TMDL study including surface water inflows, in-lake water quality conditions, and land uses within the watershed were used to determine the largest sources of phosphorus to German Lake (Figure 6.0 E.). The two largest sources of phosphorus to German Lake were internal loads and monitoring location JG7.

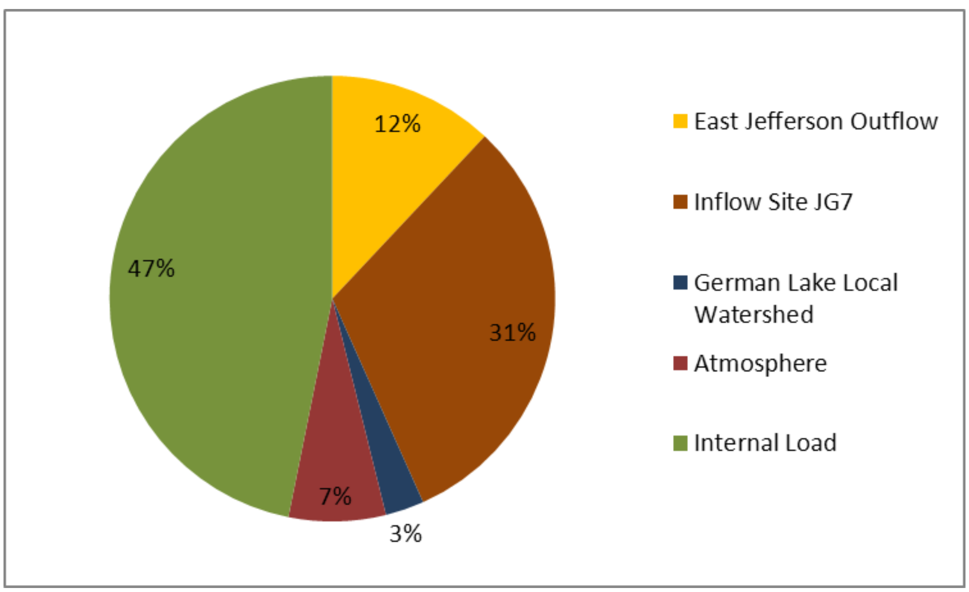

Figure 6.0 E. Contributions of total phosphorus by source to German Lake.

Section 7.0 TMDL Allocation

The TMDL process establishes the allowable loading of pollutants for a waterbody based on the point and nonpoint pollution sources, natural background conditions, and in-stream water quality conditions. In general terms, the process can be described by the following equation:

TMDL = LC = ∑WLA + ∑LA + MOS

Where:

LC = loading capacity, or the maximum amount of loading a water body can receive without violating water quality standards;

WLA = Waste load allocation, or the portion of the TMDL allocated to existing or future point sources;

LA = Load allocation, or the amount of the TMDL allocated to existing or future nonpoint sources;

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and the receiving water quality;

Within the WLA, LA, and MOS, there are additional categories and values taken into account.

7.1 Waste Load Allocation

The waste load allocation is the sum of all the permitted discharges within the watershed of an impaired reach. All permitted sources are designed to not exceed the turbidity surrogates due to permit limits, but must be considered when calculating total loading within a system.

The WLA includes three subcategories: municipalities subject to MS4 NPDES permit requirements; Wastewater Treatment and Industrial); non-MS4 waste water treatment facilities, and Construction and Industrial Stormwater (NPDES).

Municipalities subject to MS4 NPDES permit requirements:

The development of urban areas have led to drainage alteration with impervious surfaces and varying volumes of storm water being delivered to area streams and rivers. Municipalities of a certain size or density, or located in a sensitive area are subject to Municipal Separate Storm

Sewer Systems (MS4) rules (Minnesota Rules, Chapter 7090), which limits the amount of discharge from storm water within the area.

The JGC and its surrounding watershed are not considered a part of a MS4 community under any of these conditions, and therefore have no WLA loading under the MS4 category.

Municipal and industrial wastewater treatment facilities:

No wastewater treatment facilities, either municipal or industrial, are located in the JGC watershed, so there is no loading under this category.

Feedlots:

A review of all MPCA permit records for the JGC watershed over a 10 year period revealed several permitted feedlots (Figure 7.1). The NPDES permits for feedlots allow no nutrient discharges to occur.

Construction stormwater runoff:

A permit is required for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre; or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. A Construction Stormwater runoff WLA is needed in case of future construction. Based on tracking of construction activity by the MPCA’s Construction Stormwater Program in a number of Minnesota counties, a generally appropriate estimate of the WLA for construction stormwater is 0.1% of the TMDL watershed load. This estimate was adopted in the JGC TMDL.

Industrial stormwater runoff:

Little, if any, industrial activity is occurring in the JGC watershed at present. But again, to provide for possible future industrial stormwater, a WLA is included in the TMDL. For simplicity, and in line with a number of EPA-approved Minnesota TMDLs, the same estimate used for construction stormwater, 0.1% of the TMDL watershed load, was adopted for the Industrial Stormwater runoff WLA as well.

Figure 7.1. Nine active permitted feedlots within the JGC watershed are indicated by stars.

7.2 Load allocation

The load allocation (LA) is the portion of the total loading capacity assigned to nonpoint and natural background sources of nutrient loading. These sources include the atmospheric loading and nearly all of the loading from watershed runoff. The only portion of the watershed runoff not included in the LA is the small loading set aside for regulated stormwater runoff from construction and industrial sites. Discussion of both geographic sources and general categories follows:

7.2 A. Natural Background:

Natural Background is not given a separate allocation; rather it will be part of the discussion of goals. For this report, it is included in the LA without differentiation.

7.2 B. TMDL Monitored Inflows:

All four monitored inflow sites studied under this project have been monitored though several projects, including the Jefferson-German Lake Complex Clean Water Partnership (CWP) conducted in 1993 and 1994 and the TMDL study conducted in 2009 and 2010. The CWP study conducted in 1993 and 1994 monitored several additional sites as well. The loading data for the TMDL study was developed through the use of FLUX software. This program calculated loading based on recorded flow and sample data. Data was reviewed from 1993, 1994, 2009 and 2010. The flow and sample data from 1993 and 1994 were not used for the models, but were used as a means of comparison to see how the chain reacts to varying levels of precipitation. 1993 was an extremely wet year, with 35.9 inches of rain falling between April and September. Only 18.14 inches of rainfall occurred during the extremely dry 2009 monitoring season, therefore, the overall average flow coming through the four monitoring locations was significantly reduced in comparison with the 1993-94 study. Ultimately, results from the 1993-94 study provided a useful means of historical comparison to see how the JGC has changed in response to land use changes and changes in precipitation.

7.2 Bi. JG6 (West Swedes Bay Inlet – County Ditch 15) Loading

For the purposes of the TMDL study, JG6 was listed as a monitored inflow within the models.

Even with the data on the ditch, JG6 was a nonpoint source, since much of the loading within the ditch system comes from many diffuse sources within the JG6 watershed. For this reason, no specific loading total is given to the ditch. It should be noted that the loading values for JG6 made up approximately 64% of the nutrient load coming into Swedes Bay in the initial BATHTUB model before internal loading was accounted for. After accounting for internal loading, TP loading from JG6 only comprised 17.9% of the total load derived from all sources. This is largely due to the large contribution of nutrients derived from internal sources and does not suggest that implementation actions are not required in the JG6 watershed. Given the extremely poor water quality of the Swedes Bay Lake basin, implementation of BMP's within the JG6 watershed is critical.

7.2 Bii. JG7 (German Lake Inlet-County Ditch 9) Loading

For the purposes of the TMDL, JG7 was listed as a monitored inflow within the models.

Even with the data on the ditch, JG7 was a nonpoint source, since much of the loading within the ditch system comes from many diffuse sources within the JG7 watershed. For this reason, no specific loading total is given to the ditch. It should be noted that the loading values for JG7 accounted for 38.3% of the total load coming into German Lake even after internal loading was accounted for. For this reason, the ditch at monitoring location JG7 and its surrounding watershed should be a high priority for future implementation efforts.

7.2 Biii. JG8 (East Swedes Bay Inlet) Loading

For the purposes of the TMDL, JG8 was listed as a monitored inflow within the models.

Even with the data on the ditch JG8 was a nonpoint source, since much of the loading within the ditch system comes from many diffuse sources within the JG8 watershed. For this reason, no specific loading total is given to the ditch. Loading values for JG8 accounted for 14.8% of the total load coming into Swedes Bay in the initial BATHTUB model before internal loading was accounted for. After accounting for internal loading, TP loading from JG8 only comprised 4.2% of the total load derived from all sources. JG8 is an ephemeral stream that lacks a true stream channel for much of its length; in 2009, the stream was dry or stagnant for a large portion of the monitoring season in response to the extremely low levels of rainfall that took place during the season. However, this site is extremely flashy and can contribute a large amount of nutrients in a short amount time. In 2010, flow from this location was more consistent and had the potential to contribute a large amount of nutrients especially during/following storm events. Historically, the JG8 watershed has contributed a large amount of nutrients and TSS to Swedes Bay; the watershed contains several steeply sloped areas that have experienced severe erosion. Given the topology and flashy nature of the watershed; implementation of BMP's throughout the watershed are critical.

7.2 Biv. JG9 (Middle Jefferson Lake Inlet) Loading

For the purposes of the TMDL, JG9 was listed as a monitored inflow within the models.

Even with the data on the ditch, JG9 was a nonpoint source, since much of the loading within the ditch system comes from many diffuse sources within the JG9 watershed. For this reason, no specific loading total is given to the ditch. Loading values for JG9 made up approximately 72.3% of the nutrient load coming into Middle Jefferson Lake in the initial BATHTUB model before internal loading was accounted for. After accounting for internal loading, TP loading from JG9 still comprised 42.4% of the total load derived from all sources. Historically, this site has contributed relatively little amounts of flow; however, JG9 has historically contributed a very high TP concentration. This pattern continued during the 2009 and 2010 monitoring seasons. The mean TP concentration for JG9 was 1,163.5 µg/L; significantly higher than the mean TP concentration sampled at every other inflow site.

7.2 C. Internal Loading:

In addition to nutrient loading from external sources, internal loading of phosphorus was a large source of the nutrients for the JGC. Both BATHTUB and MINLEAP suggest that internal phosphorus loading from sources already present within each lake basin contributes a large percentage of the overall nutrient load. Phosphorus release from sediments and loading from the senescence of CLP probably contribute to the internal sources in these lakes.

Internal loading values were estimated indirectly by modeling each lake with the best possible accounting of the external loadings, then determining how much additional load was needed for matching the modeled lake TP to the existing lake TP; this additional load was then considered to be internal load. The estimated internal P load for Swedes Bay was 2,914 kg/yr; while for West Jefferson

Lake it was only 299 kg/yr (see Table 5.2 A). Not surprisingly, CLP was significantly more abundant on Swedes Bay than it was on German Lake. The treatment and reduction of internal loading will be a priority in the future of the JGC; however, the ultimate restoration of the JGC must first begin with a reduction in nutrient sources from external sources.

7.2 D. Urban and residential sources:

Untreated stormwater runoff was a contributor of nutrients to the JGC. Stormwater can transport materials such as sediment, fertilizers, vehicle fluids/chemicals, leaves and grass clippings. A large number of culverts and storm systems are present within the JGC (Figure 7.2). Since the developed areas within the JGC watershed are not part of a MS4 community, they do not have MS4 requirements regarding stormwater discharges. The stormwater loading was calculated by multiplying the total area of developed spaces by a predetermined runoff coefficient (ranging from .5 to 1.25 kg/ha) known for developed land uses (Reckhow and Simpson 1980).

For example, the Middle Jefferson Watershed has approximately 87 ha of urban/developed land use practices. Multiplying the mean phosphorus runoff coefficient for urban land uses of 1 kg/ha by 87 ha yields 87 kg of TP derived from urban sources within the watershed. This value was accounted for in the BATHTUB model.

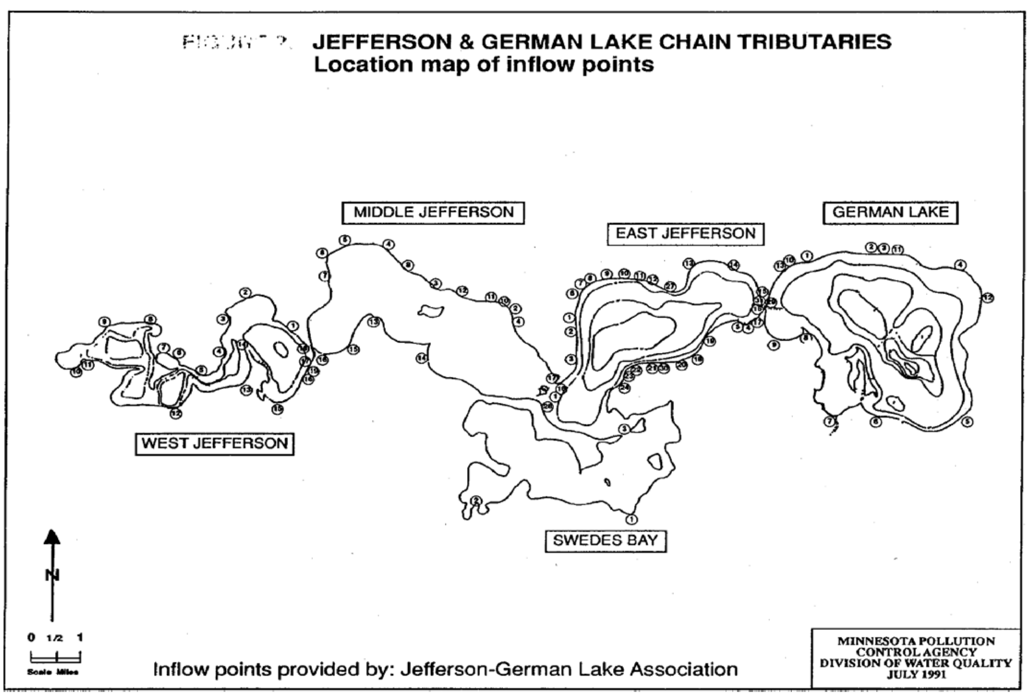

Figure 7.2. Location of culverts, ditches, and other surface water inflow sites on the JGC.

7.2 E. Failing SSTS:

Failing Subsurface Sewer Treatment Systems (SSTS), or failing septic systems and/or "straight pipe systems" (systems without proper holding/discharge areas) around the JGC were another source of nutrients. The nutrient source from leeching of septage (partially treated sewage), may be considerable even under low flow conditions, because it provides nutrients in the form of ortho-phosphorus, a pollutant type that is more readily available for uptake and use by algae. It is likely that nutrient input from septic systems is minimal relative to other sources on the JGC at this time, but should not be ruled out. Continued implementation at the county level will further reduce this potential nutrient input, as this will be a targeted source within the implementation plan. Pollutant contributions from septic systems were not measured in the TMDL monitoring; therefore, were not accounted for directly in the TMDL nutrient budget.

7.2 F. Atmospheric Loading:

Additional loading to the lake system can result from trace levels of phosphorus carried by precipitation. This type of phosphorus can enter the lake via direct input (rain falling on the lake surface) or transported via overland from stormwater flow.

For the purposes of this TMDL, the rate was estimated in BATHTUB model to be 0.3 kg/ha/yr (Walker, 1988). Based on the calculated deposition rates, atmospheric loading was a small portion of the overall nutrient load. The value, even though it was small, was important to consider in the overall budget, especially when this loading source was not possible to control. Based on the estimated rate, the total loading value from atmospheric loading is 0.28 lbs/acre/yr, or .0007 lbs/acre/day.

∑LA = nonpoint sources as listed above. No specific allocations for each area.

7.3 Margin of Safety (MOS)

The third component, MOS, is the allocation that accounts for uncertainty within the calculation methods, sample data, or the allocations which will result in attainment of water quality standards. The Margin of Safety can either be explicit or implicit.

For the purposes of this TMDL, an explicit 10% MOS was selected. The explicit 10% does not allocate any of the available loading capacity. Instead, the 10% MOS was used in modeling the standard value, meaning that the 36 (40 – 10%) was the value used to model the deep lake basins (West Jefferson, East Jefferson, and German Lake) and 54 (60-10%) was the value used to model the shallow lake basins (Middle Jefferson Lake and Swedes Bay). The MPCA uses the term "explicit standard" to reference water quality goals that are lower than the required ecoregion standard. A 10% MOS accounts for the uncertainty that the allocations set forth in this TMDL will result in the JGC meeting the required water quality standards. The uncertainties are a result of the hydrologic complexity of the JGC, the large percentage of surface area within the littoral zone, and the abundance of CLP within this system. However, uncertainties were also minimized by comparing current data with historical water quality data, as well as through the calibration process used in the BATHTUB and MINLEAP models. Using up to date land-use statistics and accurately defining the watershed boundaries for each lake basin on the JGC further helped to minimize uncertainties; therefore an excessive MOS was not necessary. Ultimately, incorporating an explicit standard into the BATHTUB model, and subsequently calibrating the model to match observed conditions helped to reduce uncertainty. Many TMDLs within Minnesota have used an explicit standard of 10%; this standard provides additional assurance that lakes will meet water quality standards by requiring the waterbodies to reach a more rigorous goal. Choosing a MOS greater than 10% would provide additional insurance; however, this would ultimately lead to reduction values that were neither economically feasible, nor practical.

7.4 Reserve Capacity and Future Growth

Within the watershed and contributing areas, there are no NPDES permits (other than construction stormwater) pertaining to nutrient loading. The JGC watershed is not considered to be an area of future development for businesses or industry; additionally, there are no wastewater treatment plants within the watershed. The reserve capacity for this TMDL is zero. The MPCA, in agreement with the US EPA Region 5, have developed a streamlined process for wasteload allocations (WLAs) for new and expanding wastewater discharges to waterbodies with EPA approved TMDLs. This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are sufficiently restrictive to ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs after TMDL approval will be handled by the MPCA, with input and involvement of the US EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and US EPA to comment on the changes and recommendations based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that new or expanded WWTF is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

7.5 Jefferson German Chain TMDL Summary

The Jefferson German Lake Chain TMDL for total phosphorus is summarized in annual and daily increments to better illustrate the division between WLA and LA, with the LA comprising a majority of the allocation (Table 7.5 A; 7.5 B).

Table 7.5 A. Total phosphorus wasteload and load allocation, and TMDL as annual loads.

Lake	Wasteload Allocation (WLA) (kg/yr)	Load Allocation (LA) (kg/yr)	TMDL (kg/yr)
West Jefferson	0.05	140	140
Middle Jefferson	0.20	254	254
Swedes Bay	0.40	286	286
East Jefferson	0.10	534	534
German Lake	0.40	583	583

Table 7.5 B. Total phosphorus wasteload and load allocation, and TMDL as daily loads.

Lake	Wasteload Allocation (WLA) (kg/day)	Load Allocation (LA) (kg/day)	TMDL (kg/day)
West Jefferson	0.00014	0.3834	0.3855
Middle Jefferson	0.00045	0.6951	0.6940
Swedes Bay	0.00120	0.7809	0.7802
East Jefferson	0.00032	1.4630	1.4650
German Lake	0.00095	1.5950	1.5970

7.6 Necessary Reductions

It is helpful to look at TMDLs in terms of reductions necessary to meet the standards. Watershed runoff phosphorus loads need to be reduced from 61% to 92% overall across the chain, with reductions varying from 13% to 80% for individual watershed portions. The same reduction percentages apply to average export and concentrations (Table 7.6).

Note that the “Upstream Lakes” load reductions are for their *outflow* P loads, not their inflow loads. Loads here are shown on an annual basis and in units of pounds, rather than kilograms. Table 7.6 presents one scenario that would probably meet water quality goals. This is a long-term effort and other scenarios that occur over a long time frame could also produce the same results.

Table 7.6. TMDL phosphorus loads and reductions by source for the JGC lakes.

Lake	Allocation	Source	Existing (kg/yr)	TMDL (kg/yr)	Reduction (kg/yr)	Reduction (percent)
West Jefferson	Wasteload	Construction Stormwater	0.05	0.03	0.02	38%
		Industrial Stormwater	0.05	0.03	0.02	38%
	Load	Local & Trib. Watersheds	44	27	17	38%
		Upstream Lakes	0	0	0	--
		Internal Load	299	60	239	80%
		Atmospheric	53	53	0	0%
	Total Load		**396**	**140**	**256**	**65%**
Middle Jefferson	Wasteload	Construction Stormwater	0.43	0.09	0.34	80%
		Industrial Stormwater	0.43	0.09	0.34	80%
	Load	Local & Trib. Watersheds	430	87	343	80%
		Upstream Lakes	6.8	4.5	2.3	33%
		Internal Load	822	82	740	90%
		Atmospheric	81	81	0	0%
	Total Load		**1,340**	**254**	**1,085**	**81%**
Swedes Bay	Wasteload	Construction Stormwater	0.59	0.23	0.36	62%
		Industrial Stormwater	0.59	0.23	0.36	62%
	Load	Local & Trib. Watersheds	591	225	366	62%
		Upstream Lakes	0	0	0	--
		Internal Load	2,914	0	2,914	100%
		Atmospheric	60	60	0	0%
	Total Load		**3,566**	**286**	**3,280**	**92%**
East Jefferson	Wasteload	Construction Stormwater	0.07	0.06	0.009	13%
		Industrial Stormwater	0.07	0.06	0.009	13%
	Load	Local & Trib. Watersheds	69	60	9	13%
		Upstream Lakes	549	146	402	73%
		Internal Load	1,003	249	755	75%
		Atmospheric	78	78	0	0%
	Total Load		**1,700**	**534**	**1,166**	**69%**
German Lake	Wasteload	Construction Stormwater	0.50	0.18	0.32	66%
		Industrial Stormwater	0.50	0.18	0.32	66%
	Load	Local & Trib. Watersheds	503	171	332	66%
		Upstream Lakes	177	106	72	40%
		Internal Load	692	202	489	71%
		Atmospheric	104	104	0	0%
	Total Load		**1,477**	**583**	**894**	**61%**

Section 8.0 Implementation Strategy

Implementation of the Jefferson German Lake Chain TMDL will require significant reductions from non-point sources throughout the watershed. Assigning a predetermined reduction amount per implementation practice is not within the scope of this project. There is not enough research to determine the exact phosphorus reduction incurred by the implementation of given BMPs. Rather, a list of potential tasks that could be completed in both agricultural and developed portions of the watershed is provided. Further stakeholder involvement is needed to determine how this TMDL aligns with other local plans (e.g. county water plans). Nonpoint-source phosphorus BMPs and detailed monitoring of the Cannon River watershed are discussed in the *Cannon River Watershed Management Strategy*.

Also, the Intensive Watershed Monitoring (IWM) was initiated in the Cannon River Watershed in 2011. A HSPF model is in development for the entire Cannon River watershed as well and will help simulate scenarios and water quality on nearby lakes. The next few years of study in the Cannon River Watershed will allow for further cooperation between water resource professionals. It will also allow the use of adaptive management, which is an iterative implementation process that makes progress toward achieving water quality goals while using any new data and information to reduce uncertainty and adjust implementation activities.

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Statutes 2007, section 114D.25]. Restoration options for lakes are numerous with varying rates of success. Consequently, each technology must be evaluated in light of our current understanding of physical and biological processes in that lake. Best estimate using professional judgment and review of other projects in similarly sized watersheds is a range from $1,500,000 to $3,500,000. This estimate will be refined as implementation plans and projects are developed. A list of potential activities by land use is listed below:

Potential Agricultural BMPs to promote:

1) Nutrient management plan development
2) Crop residue management
3) Wetland restoration potential
4) Identification of agricultural producers that are willing to implement water retention on their land
5) Identification and targeting of highly erodible lands and promote appropriate BMPs
6) Drainage considerations:
    a. Determination of potential to redirect drainage outlets through treatment ponds or through water retention basins before directly entering the JGC
    b. Implement drainage projects that improve/maintain water quality
    c. Determination of potential for a two-stage ditch design (specifically at site JG9)
7) Utilization of the Agricultural BMP Handbook for Minnesota (MDA, 2012)

Potential Developed Land BMPs to promote:

1) Identification of lakeshore property owners who are willing to implement stormwater BMPs on their property (rain gardens, rain barrels, etc.)

2) Determine the potential to redirect culverts through treatment ponds or through rain gardens before directly entering the lakes.

3) Sewer system upgrades (Note: currently, a study of current septic system conditions is taking place in the entire watershed)

Potential in-Lake and near shore Implementation Activities to promote:

1) Curly-leaf pondweed (CLP) mechanical harvest

2) Alum feasilbility study

3) Identification of areas in the littoral zone for re-establishment of native vegetation and implementation

4) Aquatic invasive species management as needed

8.1 Implementation Underway

Several recent developments will support the pursuit of this TMDL's goals. As of January 1, 2005, the State of Minnesota banned the use of phosphorus fertilizer on residential lawns.

§ The Southeast Minnesota Wastewater Initiative (SMWI) has been facilitating improvements in sewage treatment for small communities since 2002. Work on the Jefferson-German Lakes unsewered community is currently underway. Le Sueur County was awarded state Clean Water Fund money to conduct a voluntary septic inventory that was completed in May of 2013. Recommendations from the inventory report (e.g. complete wastewater feasibility assessments in the eleven identified areas, to educate homeowners within the Subordinate Service District on septic systems, and to encourage upgrades to non-compliant systems) should be carried forward. SMWI provided input and offered assistance to the inventory project.

§ Two nutrient management specialist positions were funded, in part with Clean Water Fund dollars, in southeast Minnesota: one services the southern part of the region (officed at the Fillmore County SWCD (507-765-3878)), and another services the counties that comprise most of the Byllesby Reservoir watershed: Rice, Steele, Goodhue, Wabasha, Freeborn, and Dodge (officed at the Rice County SWCD (507-332-5408)). Their focus is writing nutrient management plans for farmers, addressing both nitrogen and phosphorus applications to cropland.

§ A landowner on the north shore of Middle Jefferson Lake installed four acres of Conservation Reserve Partnership land in 2013. The NRCS, in partnership with the County, will be installing a $20,000 grade control project in the same area. State funds (LCCMR) will be used to restore the wetlands down on the low grounds. A large amount of support for this project exists from the locals and the county contributed an additional $6,500 to have it installed. This type of project with buy-in from many sources is promising of more implementation activities to come.

§ Shoreland owners are using cost share funds through the county to restore their shorelines and install rain gardens. At this time a total of nine shoreland projects have been completed. Four more projects will be completed in 2014.

§ Previous Activities: A watershed specialist was funded through state Clean Water Partnership funds. A livestock producer installed a fence line to keep cattle from entering Swede's Bay and nine terraces were installed under those funds.

Section 9.0 Reasonable Assurance

Reasonable assurance that the water quality of the Jefferson-German Lake Chain will be improved is formulated on the following points:

- Availability of reliable means of addressing pollutant loads (i.e. best management practices);
- A means of prioritizing and focusing management;
- Development of a strategy for implementation;
- Availability of funding to execute projects;
- A system of tracking progress and monitoring water quality response.
- Interested and engaged members in the Lake Association.

Accordingly, the following summary provides reasonable assurance that implementation will occur and result in phosphorus load reductions in the JGC watershed.

- The BMPs outlined in the *Cannon River Watershed Management Strategy* have all been demonstrated to be effective in reducing transport of pollutants to surface water. The University of Minnesota Extension Service summarizes phosphorus management strategies: http://www.extension.umn.edu/nutrient-management/phosphorus-management/. This suite of practices is supported by the basic programs administered by the SWCDs and the NRCS. Local resource managers are well-trained in promoting, placing and installing these BMPs. Some watershed counties have shown significant levels of adoption of these practices. Thus, these BMPs constitute the standard means of addressing nonpoint source pollutant loads in the JGC watershed.
- Various projects and tools provide means for identifying priority pollutant sources and focusing implementation work in the watershed:
  - Barr Engineering, Inc. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. 2004. http://www.pca.state.mn.us//////hot/legislature/reports/phosphorus-report.html
  - The State of Minnesota funded a shoreland mapping project to inventory land use in riparian areas in southeast Minnesota. The project is complete, and the results are available here: http://www.crwp.net/shoreland-mapping/. This information will be used in the implementation planning process to examine riparian land use in the JGC watershed, and prioritize potential BMP installation.
  - Light Detection and Ranging (LiDAR) data are available for all of southeast Minnesota, and being increasingly used by local government units to examine landscapes, understand water flow and dynamics, and accordingly prioritize BMP targeting.
  - Intensive Watershed Monitoring (IWM) was initiated in the Cannon River Watershed in 2011. Inherent in its design is geographic prioritization and focus. Encompassing site placement across the watershed will allow for a full examination of designated use support, which will be the foundation for subsequent steps, ultimately leading to focused management efforts.
  - In 2007, the lake association for the JGC commissioned A.W. Research Laboratory to perform an Environmental Assessment Overflight (EAO). The purpose of the EAO was to document existing environmental conditions at residences along the shoreline. Visible and hyperspectral images were taken with aircraft mounted and handheld cameras.

The images were analyzed for environmental concerns. The lake association is planning to use the images in future planning and restoration efforts.

- The State of Minnesota (Clean Water Fund) funded development of a watershed management strategy for the Cannon River watershed. This pilot effort constitutes a foundational planning piece that supports and informs local government plans (e.g. local water plans). It was conceptualized and composed by the local watershed partnership (Cannon River Watershed Partnership), which includes a diverse cross-section of stakeholders. The document includes strategies and tools specific to the various landscapes in the watershed. It will be revised and maintained as further prioritization and understanding of pollutant dynamics are made available.
- On November 4, 2008, Minnesota voters approved the Clean Water, Land & Legacy Amendment to the constitution to:
    - protect drinking water sources;
    - protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
    - preserve arts and cultural heritage;
    - support parks and trails;
    - and protect, enhance, and restore lakes, rivers, streams, and groundwater.

  This is a secure funding mechanism with the explicit purpose of supporting water quality improvement projects.

- Le Sueur County Activities:

    1. The Le Sueur County Local Water Plan: implementation of this plan is ongoing and supersedes other plans for Le Sueur County.

  (http://www.co.le-sueur.mn.us/environmentalservices/LeSueurCountyWaterPlan.pdf)

    2. Establishment of a program for cost share on shoreland BMP projects

- Monitoring components in the Cannon River watershed are diverse and constitute a sufficient means for focusing work, tracking progress and supporting adaptive management. One example is the Citizen Lake Monitoring performed on the JGC since the 1970's that has shown a steady trend (neither increasing nor decreasing) in water clarity.

- The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites > 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

- The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

Further, preliminary results of MPCA trend analysis have documented decreasing total suspended solids and total phosphorus concentrations at the Cannon River Milestone site (S000-003). This provides reasonable assurance in that it suggests that long-term, enduring efforts to decrease erosion and nutrient loading to surface waters have the potential for positive impacts.

Section 10.0 Monitoring

The *Cannon River Watershed Management Strategy* (CRWP, 2011) includes a detailed monitoring plan that is applicable to the JGC. There is a long history of data that will allow comparison. *Citizen Lake Monitoring Program* (CLMP) volunteers regularly monitor water clarity in each water body. Each lake in the chain shows no overall trend since 1973 (German Lake) and the 1980's (Jefferson Lakes and Swede's Bay).

The implementation plan will provide further detail on an effectiveness monitoring plan that will discuss site locations, parameters, and frequency. The JGC and inlets both included in this TMDL document and otherwise, will be included. Focus will be on areas where significant phosphorus reduction strategies have been placed on the landscape.

Section 11.0 Public Participation

Public participation and involvement are important in the successful design, review, and implementation of a TMDL study. For this reason, the JGC TMDL project worked closely with a broad array of county, state and citizen groups and organizations. To address the broad interests that would be involved in the project, the technical advisory team was created and was composed of various representatives of stakeholders groups to help ensure that all groups would remain up to date and able to raise concerns and/or opinions as necessary.

The Technical group included state and federal and local government employees, research groups and projects, and joint powers boards. Agencies on the mailing and contact lists include SWCD, MPCA, CRWP, BWSR, MSU, DNR, County Employees, JGC Lake Association members, volunteers, and concerned citizens.

<u>Stakeholder and Advisory Meetings</u>

- Public/stakeholder open house meeting, April 22nd, 2009: This meeting was held at St. Paul's Lutheran Church (located within the JGC watershed.) The overall objectives for the TMDL study were discussed at this time. A large number of stakeholders and concerned citizens voiced their opinion in regards to different aspects of the study. All of these opinions were documented and incorporated into the overall project design.
- Stakeholder Meeting, November 12th 2009: The WRC at MSU-Mankato in conjunction with the MPCA, and CRWP provided a PowerPoint presentation highlighting progress made to date (Appendix E). A majority of the presentation focused on water quality data collected during the 2009 season as well as results from the aquatic plant survey conducted in 2009. This information was presented by Katie Brosch Rassmussen and Joe Pallardy of the WRC at MSU, Mankato. Shaina Keseley of the MPCA provided additional data regarding the overall TMDL process. All questions and input from stakeholders were addressed accordingly at this time.
- Technical Committee Meeting, June 17th 2010: The WRC at MSU-Mankato in coordination with the MPCA, Le Sueur County, and the CRWP held a technical meeting. A large amount of information was discussed at this time, including many historical and future implementation strategies (Appendix A).
- Lake Association/Stakeholder Meeting, May 28th, 2011: Shaina Keseley from the Minnesota Pollution Control Agency (MPCA) and Joe Pallardy of the WRC at MSU-Mankato presented a draft of the JGC TMDL to the JGCLA. Aaron Willis of the CRWP provided technical support and helped to arrange the meeting location. Members of the JGCLA were given the chance to ask questions about the TMDL. The members of the JGCLA were supportive of findings from the TMDL study.

Websites, Mailings, and Citations in Newsletters

- The CRWP website maintained updates on the progress of the TMDL study on their websites www.cwrp.net
- In May 2010, CRWP sent out a newsletter to the JGC property owners with information highlighting progress made on the TMDL study to date.
- The CRWP sent out a mailing to all stakeholders within the JGC watershed informing stakeholders of the November 12th meeting.
- The CRWP sent out a mailing to all stakeholders within the JGC watershed informing stakeholders of the April 22nd meeting.
- A press release was sent out to local newspapers informing area residents of the April 22nd and November 12th meeting.

Public Notice

This TMDL study was open for public comment from December 9, 2013 to January 9, 2014 and then again for an extended public comment period from February 17 to March 3, 2014. Five public comment letters were received and responded to.

Section 12.0 References

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Section 13.0 Appendices

Appendix A: MN DNR Fishery Survey Results

West Jefferson

West Jefferson Lake was last surveyed by the Minnesota Department of Natural Resources in 2008. Black bullheads (*Ameiurus melas*) were extremely abundant with an average of 104 black bullheads per gill net (MNDNR 2011_a). Northern pike (*Esox lucius*) trap net catches were lower in 2008 than during 2002 when northern pike had reached record numbers of 15 fish per gill net (MNDNR 2011_a). In 2008, northern pike were caught at a rate of 1.5 fish per gill net and 0.2 fish per trap net. Some large northern pike were present in the population, including fish up to 35 inches (MNDNR 2011_a). Walleye catch rates remained stable in comparison to 2002 with an average catch of less than one fish per gill net (MNDNR 2011_a). A smith-root electrofishing boat documented an excellent bass fishery with bass from 5-20 inches present (MNDNR 2011_a). Panfish catches have been near the eco-region average while rough fish including common carp (*Cyprinus carpio*) have been very high (MNDNR 2011_a).

Middle Jefferson Lake

Middle Jefferson Lake occasionally experiences partial winter kills resulting in a fishery that is dominated by tolerant species such as black bullheads and juvenile pan fish (MNDNR 2011_b). Northern pike and white crappie (*Pomoxis annularis*) were absent in the 2008 survey (MNDNR 2011_b). Only three walleye were caught in total during the 2008 survey (MNDNR 2011_b). Yellow perch were caught at a rate of 12 fish per gill net ranging in size from 5-10 inches (MNDNR 2011_b). Six largemouth bass (*Micropterus dolomieu*) were captured in trap nets with one individual exceeding 20 inches found in close proximity to the narrows that lead to East Jefferson Lake (MNDNR 2011_b).Common carp and freshwater drum were also abundant in both gill nets and trap nets; both young of the year and adult specimens from both species were present.

Swede's Bay

A fisheries survey conducted by the MNDNR in 2002 found an abundant black bullhead population present in Swede's Bay (MNDNR 2011_c). Bluegill, black crappie, and yellow perch were also fairly common including some black crappie up to 12 inches in length (MNDNR 2011_c). Largemouth bass and walleye were also sampled, however they have historically been found in relatively low numbers in Swede's Bay. Northern pike were not sampled in the 2002 survey, and have historically not recruited well to Swede's Bay (MNDNR 2011_c). A documented history of winterkill has largely produced a fishery consisting of only tolerant species (carp, bullheads; MNDNR 2011_c).

East Jefferson Lake

East Jefferson Lake was sampled by the MNDNR in 2008 using both trap nets and gill nets to assess the existing fish community. Black bullheads and yellow perch were both caught in high abundance however the average number of fish caught per net has dropped since 2002 (MNDNR 2011_d). Walleye and northern pike abundance has remained stable with 2.2 and 0.5 fish caught respectively per gill net (MNDNR 2011_d). White bass from a strong 2004 year class were also found in the survey; these fish are likely a result of the connection with the Cannon River system via county ditch 59 (MNDNR 2011_d). Common carp, freshwater drum, yellow bullhead, and bowfin (dogfish) represent additional species caught during the 2008 survey.

German Lake

German Lake was last surveyed in 2008 by the MN DNR using both gill nets and trap nets. Bluegills were the most numerous fish species caught in both gill nets and trap nets (MNDNR 2011_e). Bluegills averaged 48 fish per gill net and 76 fish per trap net with a mean size of 7 inches (MNDNR 2011_e). Black crappies catch rates were higher in German Lake than in nearly 75 percent of lakes similar in size and depth to German Lake (MNDNR 2011_e). Black crappie displayed a healthy size range from 6 to 11 inches with an average of 8 inches (MNDNR 2011_e). Yellow perch catch rates remained stable at 21.38 fish per gill net; perch from 5-10 inches were the most common(MNDNR 2011_e). Walleye catch rates on German Lake are low; however the fish that are sampled are large ranging in size from 18-27 inches (MNDNR 2011_e). As of 2008, German Lake contained a very healthy northern pike population with an average catch rate of 4.3 fish per gill net (MNDNR 2011_e). The northern pike population exhibits good size structure with individuals from 18 to 35 inches present and a mean size of 25 inches (MNDNR 2011_e). Common carp and freshwater drum were also caught in both gill nets and trap nets, young of the year and adult age groups were present in both species.

Appendix B: Aquatic Plant Point-Intercept Study

Intro

Staff from the Water Resource Center in coordination with the Minnesota Pollution Control Agency used a point-intercept sampling technique to provide a representative survey of the aquatic plant community in the Jefferson German Chain (JGC). All of the lake basins of the JGC were sampled twice in 2009; the first survey was completed between May 13th and June 1st when CLP was most abundant. The second survey was completed between August 11th and August 22nd when Eurasian watermilfoil and native species are typically most abundant. Overall, German Lake had the healthiest aquatic plant community while both West and Middle Jefferson Lake share the poorest aquatic plant community. Results from this survey demonstrated the degree of CLP abundance and highlighted areas where native species can still be found within each lake basin of the JGC. A detailed synopsis of findings from the point intercept survey is found in appendix C.

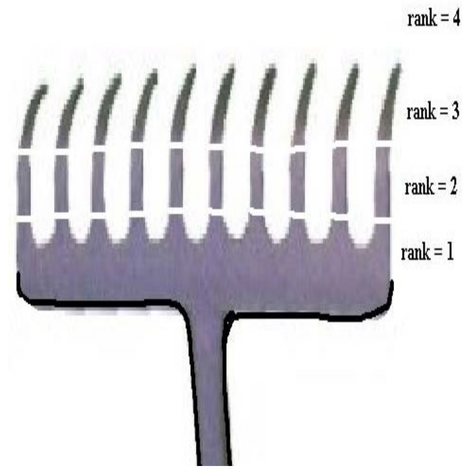
Methods

In order to use the point-intercept method, A 100*100 meter grid was created using a geographic information systems (GIS) process. Hawth's Analysis Tools for Arc GIS was used to outline the image of each lake basin; the 100*100 meter grid was then placed over the outlined image of each lake basin. The point-intercept method allows researchers to sample a variety of points that include locations near shore and off shore while ensuring that the entire lake basin is included (Madsen, 1999). The point-intercept method is used by both the Wisconsin and Minnesota Department of Natural Resources because it provides a less subjective and statistically appropriate method of sampling across all lake types (Madsen, 1999). The grid points were then downloaded to a handheld GPS device. We used the Garmin E Trek Legend because of its capability to store waypoints, therefore being useful in the field to locate each GPS sampling location.

In order to collect vegetation samples, the rake sampler method was employed. This method is described as the best means of getting a representative sample at each locale (UWSP, 2008).
At each site, a sample was taken using a double headed rake attached to a 3 m (10 ft.) PVC pole. The rake head was extended to the bottom of the water column and into the top layer of sediment. The depth and sediment type present was also recorded at each site. The person operating the "rake sampler" twisted the rake two times in the sediment in an attempt to grab any macrophytes at the present location. Grid sampling points located greater than 10 feet prohibited the use of pole method. Instead, a double headed rake (same diameter as the rake head used in the pole method) was attached to the end of a rope (UWSP, 2008). At locations over 3 m, the rake head was allowed to fall to the bottom of the lake and into the top layer of sediment, and then retrieved back to the surface. The size of the rake head is the same for both techniques, therefore, the area sampled was similar.
Each rake sample was then carefully lifted up through the water column and any plants that were attached to the rake were identified and recorded. Additionally, at each site the abundance of each species and the overall rake was rated on a 0-4 scale (Table 2.6a). The following two plant identification keys were used as aids during each sampling round: Wetland Plants and Plant Communities of Minnesota and Wisconsin (Eggers and Reed, 1997) and Through the Looking Glass (Borman et al., 1997). This process was repeated at each of the intercept points until the grid was completed (Crowell, 2006).

Table 2.6 A: Description of rake ranking used during point intercept study conducted in 2009.

Rake Ranking	Description of Rake Ranking
0	No plants present
1	Plants filling less than 1/3rd of the rake head/rake tines
2	Plants fill greater than 1/3rd but less than 2/3rd of the rake head/rake tines
3	Plants filling greater than 2/3 of the rake head but not the entire rake head
4	Plants fill all rake tines and are over the top of the rake.



Calculations of plant diversity

Two calculations of species diversity were used in an attempt to demonstrate the macrophyte diversity found in each lake basin. The first calculation of species diversity used was the floristic quality index (FQI). A FQI is useful for several reasons; the most applicable reason for this study is that the FQI allows for a means of comparison between given lakes/within different areas of the same lake, (Swink and Wilhem 1994; Rocchio 2007). A FQI uses aspects of both conservation and rarity to allow for a representative calculation to be made that will help to determine how much disturbance a given lake might have experienced (Rocchio 2007). Every macrophyte in the state of Minnesota has been assigned a coefficient of conservatism value (c-value) ranging from 0 to 10. The c-value of all macrophytes sampled from a lake is used to determine the FQI for a given lake. Species with a c-value of 0 include species like CLP because this species is non-native and indicative of a highly disturbed environment. In comparison, a species like Oakes pondweed (*Potamogeton oakesainus*) has a c-value of 10 because this species is extremely rare and only found in undisturbed, pristine settings.

Shannon's evenness index was the second species diversity index used in this study. Species evenness refers to the distribution and abundance of species within an ecosystem, i.e. West Jefferson Lake. By calculating species evenness, the intensity of dominance for a given species can be determined. As values for Shannon's evenness index calculation become closer and closer to 1, a given macrophyte community becomes dominated more and more by a single species. A lake environment that exhibited great species evenness would contain multiple plant species dispersed evenly throughout without any single species outcompeting all others and would have a Shannon's evenness index value close to the total number of species found in lake.

Floristic Quality Index (FQI)

$FQI = \overline{C} * \sqrt{S}$

$\overline{C}$= Mean coefficient of conservatism value

S= Number of species in sample

Shannon-Weiner Index (h)

$h= - (\sum p_1 * \ln p)$

p= proportion of individuals found for a given species.

Shannon's evenness index (J)

$J=e^h/\ln S.$

h= Shannon-Weiner Index

S= Number of species in sample

B.1 West Jefferson Lake Plant Survey Results

5/13/2009 Point-Intercept Survey Results

A total of 7 species were found during the May survey (Table B).Of the 169 points sampled, CLP was present at 95 of them (Figure B.1a). Furthermore, 37 out of 169 points were too deep to sample (over 20 feet). Given this statistic, of the 132 points that were capable of supporting macrophytes, approximately 72% contained CLP. The FQI score for the 5/13/2009 study of West Jefferson Lake was 9.2 (Table B.1a). Shannon's evenness index score was 1.03, indicative of the dominance of CLP in this lake basin.

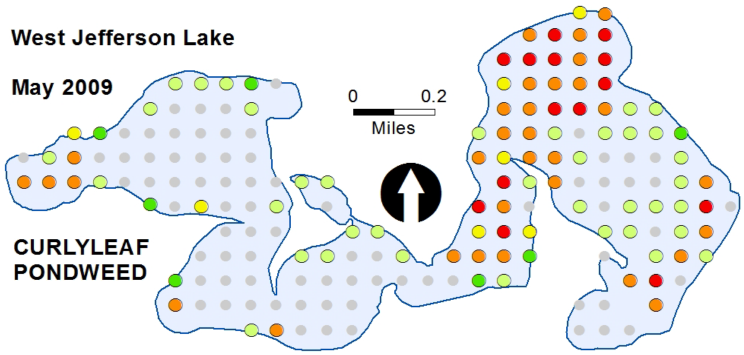


Figure B.1a: Curly leaf pondweed (*Potamogeton crispus*) distribution West Jefferson Lake 5/13/2009.

Table B.1a: Species name and respective coefficient of conservatism (C) value for macrophytes found during point-intercept survey conducted in May, 2009 on West Jefferson Lake. FQI values less than 20 are indicative of degraded habitats.

Common Name	Genus species	Coefficient of Conservatism (C)
Narrow Leaf Cattail	*Typha lattifolia*	1
Burr reed	*Sparganium spp.*	5
Sago Pondweed	*Potamogeton pectinatus*	3
Curly Leaf Pondweed	*Potamogeton crispus*	0
Hard-stem Bulrush	*Scirpus acutus*	5
Clasping Leaf Pondweed	*Potamogeton richardsonii*	5
Muskgrass	*Chara spp.*	7
Average C-value		**3.71**
FQI Score	**3.71 *√7**	**9.82**

<u>8/12/2009 Point-Intercept Survey Results</u>

A total of 10 species were found during the August survey (Table B.1b). CLP was found at only 6 of 165 (3.64%) sites sampled; in sharp contrast with the May study. Prior to the start of the August plant survey, CLP had undergone complete senescence. The result was a steady decline in water clarity from mid-June as evidenced by secci disk readings taken throughout the year. The late summer FQI value of 12.02 is most likely directly correlated to the dominance and subsequent senescence of CLP in this lake basin (Table B.1b). Applying Shannon's evenness calculation yields a value of 2.45 during the August point-intercept survey.

Table B.1b: Species name and respective coefficient of conservatism (C) values for macrophytes found during point-intercept survey on West Jefferson Lake. FQI values less than 20 are indicative of degraded habitats with very little natural vegetation left in the ecosystem.

Common name	Scientific Name	Coefficient of Conservatism (C)
Curly-leaf pondweed	*Potamogeton crispus*	0
Slender Niad, Bushy pondweed	*Najas flexillis*	6
Hardstem Bulrush	*Scirpus validus*	5
Cattails	*Typha spp.*	1
Sago pondweed	*Potamogeton pectinatus*	3
Muskgrass	*Chara spp.*	7
Floating-leaf pondweed	*Potamogeton natans*	5
Common waterweed	*Elodea canadensis*	3
Coontail	*Ceratophyllum demersum*	3
Burr reed	*Sparganium eurycarpum*	5
Average C-Value		**3.8**
FQI Score	***3.8* *√10**	**12.02**

B.2 Middle Jefferson Lake Plant Survey Results

5/14, 5/18/2009 Point-Intercept Survey Results

Two hundred thirty five points were sampled on Middle Jefferson Lake; aquatic macrophytes (primarily CLP) were sampled on the rake at 232 of those points (Figure B.2a). Samples from 3-8 feet deep comprised 190 out of the 235 total samples. CLP was present at all 190 locations between 3 and 8 feet. Other species were found at 9 locations; or less than 5% of the time. In contrast, of the 45 samples taken in water less than 3 ft deep, 17 or 38% of samples had species other than CLP present. A total of 5 species were documented during the survey conducted on 5/14/2009 on Middle Jefferson Lake with a calculated FQI of 2.98 (Table B.2). An FQI score of 2.98 is representative of a plant community that has experienced a significant amount of disturbance. Shannon's evenness index for the May survey when CLP was extremely abundant yielded a value of 1.05.

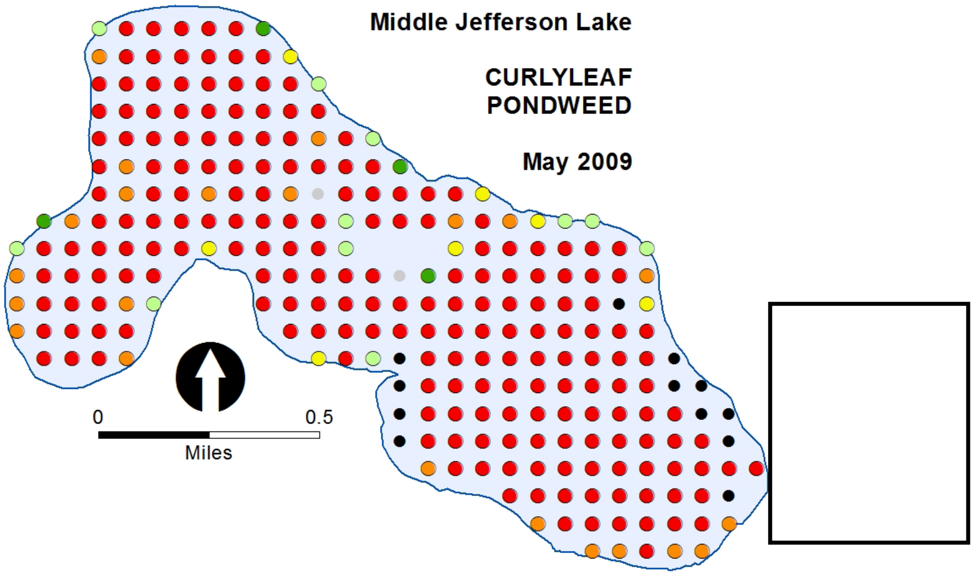


Figure B.2a Curly leaf pondweed distribution on Middle Jefferson Lake: May, 2009.

Table B.2a: Species name and respective coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in May, 2009 on Middle Jefferson Lake. FQI values less than 20 are indicative of degraded habitats with very little natural vegetation left in the ecosystem.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Cattails	*Typha spp.*	0
Common Waterweed	*Elodea canadensis*	3
Average C-Value		**1.2**
FQI Score	**1.2* √5 =**	**2.68**

<u>8/13, 8/14/2009 Point-Intercept Survey Results</u>
Species richness increased during the August plant survey in comparison to the May survey when CLP dominated much of the lake basin. Although CLP was found (secondary growth in 2009) at 188 of 235 (80%) of sites sampled during the August survey, the average biomass at these sites was significantly reduced and usually consisted of a couple of small CLP strands attached to turions. A total of 10 species were found in August for a calculated FQI value of 12.02. An FQI value of 12.02 for the 10 species found

within Middle Jefferson Lake indicates that the plant community present is represented mostly by tolerant species. Shannon's evenness index yields a value of 2.09 for the August survey.

B.3 Swedes Bay Plant Survey Results

Results from 6/1, 6/2/2009 Point-Intercept Survey

Swedes Bay has a maximum depth of 6 ft; therefore the entire lake basin is capable of supporting macrophyte growth. Of the 195 total points sampled, CLP was found at 185 or 95% of sites sampled during the early June survey. Despite the high percentage of sites with CLP present, Swedes Bay exhibited the highest FQI score (Figure B.3a) of any lake basin during the May sampling period (Table B.3a).

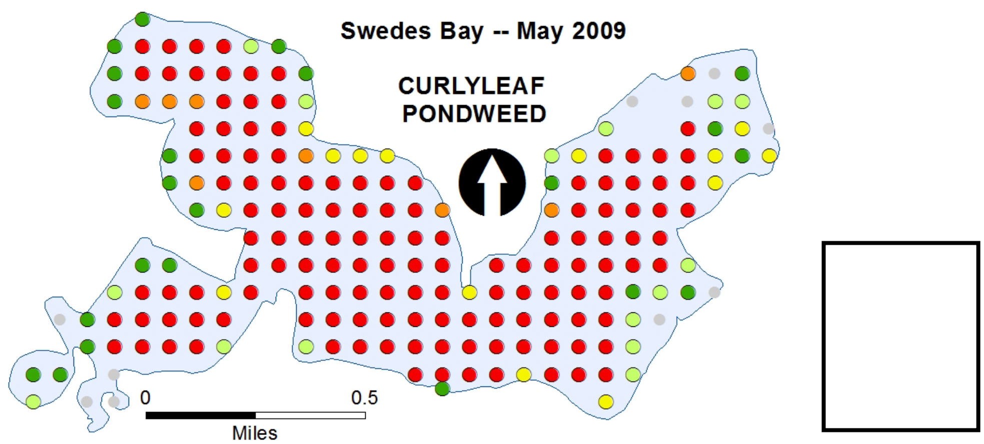


Figure 2.6 B.3a: Curly leaf pondweed distribution Swedes Bay 6/1, 6/2/2009.

Table 2.6 B.3a: Species name and coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in early June on Swede's Bay.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Coontail	*Ceratophyllum demersum*	3
White Water Lily	*Nymphea spp.*	6

Fine leafed Pondweed	*Potamogeton Freisii*	8
Flat Stem Pondweed	*Potamogeton zosteriformis*	6
Common Arrowhead	*Sagitaria latifolia*	3
Wild Celery	*Vallisneria americana*	6
Northern Watermilfoil	*Myriophyllum sibiricum*	6
Common Waterweed	*Elodea canadensis*	3
Narrow leafed cattail	*Typha angustifolia*	0
Muskgrass	*Chara spp.*	7
Lesser duckweed	*Lemna minor*	5
Common burr reed	*Sparganium eurycarpum*	5
Average C-Value		**4.0667**
FQI Score	***4.0667* * √15 =**	**15.75**

Wild celery (*Vallisneria americana*) and northern water-milfoil (*Myriophyllum sibiricum*) were not found in any other lake basins in May; typically, both species are indicators of good water quality. However, an overall FQI score less than 20 is still indicative of an environment that has experienced extensive anthropogenic disturbance. A Shannon's evenness index calculation for the May survey resulted in a value of 3.26.

<u>8/22/2009 Point-Intercept Survey Results</u>

Twenty-one species of macrophytes were found during the August plant survey (Table B.3b); coontail (*Ceratophyllum demersum*), sago pondweed (*Potamogeton pectinatus*) and CLP were more abundant than any other species. CLP was only found at 54% of sites during the August survey and was typically in the beginning stages of growth. The FQI score for the August survey was 20.51 and is representative of a plant community consisting of low to moderate diversity (Table B.4b). A Shannon's evenness index calculation for the August survey resulted in a value of 5.82. Both the FQI score and Shannon's evenness index suggest that the diversity of plants found in Swedes Bay is better than that found in every other lake basin with the exception of German Lake.

Table B.3b: Species name and respective coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in August on Swede's Bay.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Coontail	*Ceratophyllum demersum*	3
Sedge spp.	*Carex spp.*	6
Narrow-leaf Pondweed	*Potamogeton Freisii*	8
Yellow Water Lily	*Nuphar spp.*	6
White Water Lily	*Nymphea spp.*	6
Waterstargrass	*Heteranthera dubia*	8
Flat Stem Pondweed	*Potamogeton zosteriformis*	6
Common Arrowhead	*Sagitaria latifolia*	3
Wild Celery	*Vallisneria americana*	6
Northern Watermilfoil	*Myriophyllum sibiricum*	6
Common Waterweed	*Elodea canadensis*	3
Cattails	*Typha spp.*	1
Lesser duckweed	*Lemna minor*	5
Common burr reed	*Sparganium eurycarpum*	5
Slender Niad, Bushy Pondweed	*Najas Flexilis*	6
Common Reed Grass	*Phragmites communis*	1
Watershield	*Brasenia schreberi*	7
Hardstem Bulrush	*Scirpus acutus*	5
Average C-Value	**4.476**	
FQI Score	**$4.476 * \sqrt{21}$ =**	**20.51**

B.4 East Jefferson Plant Survey Results

5/14, 5/18/2009 Point-Intercept Survey Results

A total of 205 point-intercept sites were located less than 20 ft deep, thereby being capable of supporting macrophytes. Of those sites, 178 or approximately 87% contained CLP (Figure B.4a). Moreover, CLP was found to be growing as deep as 19 feet; a feature that attests to both early season water clarity and the life cycle of CLP (Bolduan et al. 1994). The 12 species found during the May survey had a calculated FQI value of 12.12, representative of a low diversity, highly disturbed plant community (Table B.4a). Eurasian water milfoil, also a non-native species was documented during the May survey, another indication that the JGC has experienced intense anthropogenic related disturbance. Shannon's evenness index for the May point-intercept survey when CLP was extremely abundant returns a value of 1.33. A low FQI score coupled with a low Shannon's evenness index indicate a degraded macrophyte community exists in East Jefferson Lake, representative of CLP's dominance in this system.

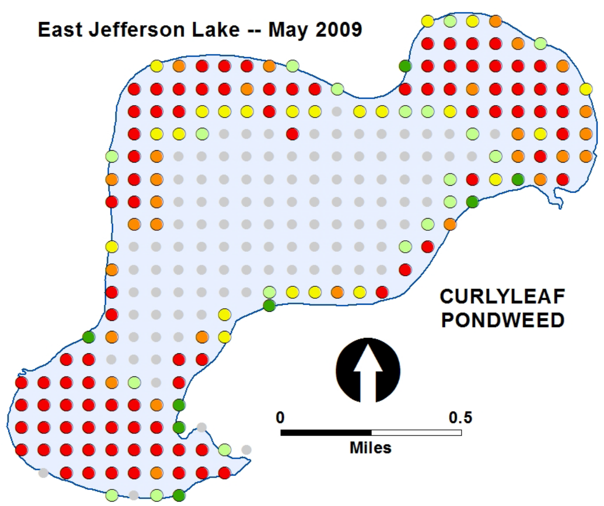


Figure B.4a: Curly leaf pondweed distribution on East Jefferson Lake, May, 2009.

Table B.4a: Species name and coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in May on East Jefferson Lake.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Clasping leaf Pondweed	*Potamogeton richardsonii*	5
Softstem Bulrush	*Scirpus validus*	4
Coontail	*Ceratophyllum demersum*	3
White Water Lily	*Nymphea spp.*	6
Yellow Water Lily	*Nuphar spp.*	6
Common Waterweed	*Elodea canadensis*	3
Cattails	*Typha spp.*	1
Greater duckweed	*Spirodela polyrhiza*	5
Muskgrass	*Chara spp.*	7
Average C-Value		**3.5**
FQI Score	***3.5*** ***√12**	**12.12**

<u>8/12, 8/13, 8/14/2009 Point-Intercept Survey Results</u>
A total of 19 species were found during the second point-intercept survey with a calculated FQI value of 19.5 (Table B.4b). CLP was found to be sprouting from turions and regenerating biomass for the next year in 89 of 162 sites (55%). Sampling locations that had previously contained dense stands of CLP were more likely to contain multiple species of macrophytes. Coontail (*Ceratophyllum demersum)* was fairly abundant in East Jefferson Lake; 78 of 162 (49%) of sites sampled contained coontail. Additionally, Eurasian water-milfoil was found at 41 of 162 (25%) sites. Shannon's evenness index calculation yields a value of 3.42 for the August point-intercept survey. The diversity of macrophytes sampled in August on East Jefferson Lake was superior to that found during the May survey; however, the macrophyte community is most dominated by tolerant or invasive species.

Table B.4b: Species name and coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in August on East Jefferson Lake.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Northern Water Milfoil	*Myriophyllum sibericum*	7
Sago Pondweed	*Potamogeton pectinatus*	3
Clasping leaf Pondweed	*Potamogeton richardsonii*	5
Hardstem Bulrush	*Scirpus acutus*	5
Coontail	*Ceratophyllum demersum*	3
White Water Lily	*Nymphea spp.*	6
Yellow Water Lily	*Nuphar spp.*	6
Cattail spp.	*Typha spp.*	1
Lesser duckweed	*Lemna minor*	5
Muskgrass	*Chara spp.*	7
Common waterweed	*Elodea canadensis*	3
Wild celery	*Valisneria americana*	6
Slender Niad, Bushy Pondweed	*Najas flexilis*	6
Small Pondweed	*Potamogeton pusillus*	7
Ivory Duckweed	*Lemna trisulca*	6
Water Stargrass	*Heteranthera dubia*	8
Common Reed Grass	*Phragmites communis*	1
Average C-Value		**4.474**
FQI Score	***4.474* *√19**	**19.5**

B.5 German Lake Plant Survey Results

5/13/2009 Point-Intercept Survey Results

During the 5/13/2009 point intercept survey a total of 13 species of macrophytes were found, 11 of those were native species (Table B.5a). The calculated FQI for the 13 species found was 14.4 (Table B.5a). Macrophytes were found as deep as 16 feet in one location, however macrophytes were absent at depths greater than 17 ft. CLP was present at 153 of 211 or 72.5% of sites sampled (Figure B.5a); this was an increase of 24.5% from a plant survey conducted by the Minnesota Department of Natural Resources in 2004 (Perleberg, 2006). Shannon's evenness index for the May survey when CLP was extremely abundant yielded a value of 2.72. The FQI index and low Shannon's evenness index score are indicative of a degraded macrophyte community.

Table B.5a: Species name and coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in August on East Jefferson Lake.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Clasping leaf Pondweed	*Potamogeton richardsonii*	5
Softstem Bulrush	*Scirpus validus*	4
Coontail	*Ceratophyllum demersum*	3
White Water Lily	*Nymphea spp.*	6
Yellow Water Lily	*Nuphar spp.*	6
Fine leafed Pondweed	*Potamogeton Freisii*	8
Common Waterweed	*Elodea canadensis*	3
Narrow leafed cattail	*Typha angustifolia*	0
Muskgrass	*Chara spp.*	7
Greater duckweed	*Spirodela polyrhiza*	5
Average C-Value		**3.85**
FQI Score	***3.85* * √13 =**	**14.4**

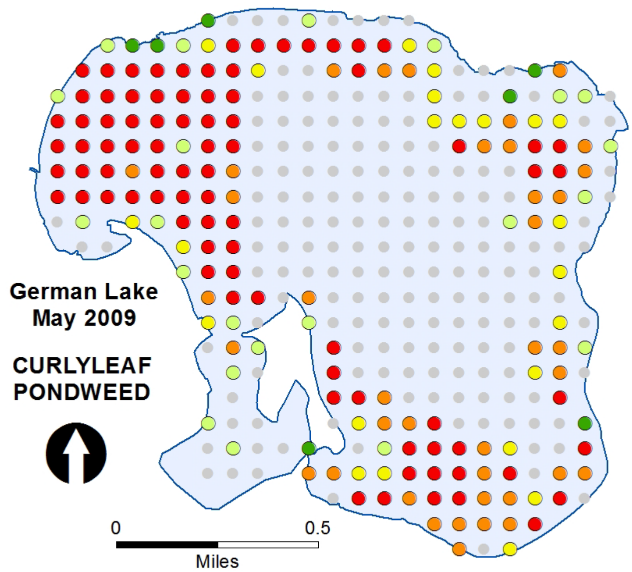


Figure B.5a: Curly leaf pondweed distribution on German Lake, May, 2009.

8/11/2009 Point-Intercept Survey Results

Twenty-two plant species were found during the August survey on German Lake (Table B.5b); equivalent to the number of species found by the MNDNR in 2004 (Perleberg, 2006). The most common species sampled included Eurasian water-milfoil (*Myriophyllum spicatum*), muskgrass (*Chara spp.),* coontail (*Ceratophyllum demersum*), sago pondweed (*Potamogeton pectinatus*), slender niad (*Najas flexilis*), and flat-stem pondweed (*Potamogeton zosteriformes).* In contrast with the point-intercept survey conducted in May, CLP was found at a much lower rate during the August survey (Figure B.5b). The FQI value of 22.8 for German Lake represents the highest quality and most diverse plant community present on the entire Jefferson-German Chain. The stability in the number of species present within this system suggests an ecosystem that is moderately stable; not surprisingly, German Lake has the best water quality of any lake on the JGC. Shannon's evenness index for German Lake was 13.48 for the August survey. A value of 13.48 for Shannon's evenness index for the August survey is representative of the fairly diverse plant community with a large number of species found at multiple locations throughout the lake.

Table 2.6 B.8: Species name and coefficient of conservatism (C) values for macrophytes found during point-intercept survey conducted in August, 2009 on German Lake.

Common name	Scientific Name	Coefficient of Conservatism
Curly Leaf Pondweed	*Potamogeton crispus*	0
Eurasian Water Milfoil	*Myriophyllum spicatum*	0
Sago Pondweed	*Potamogeton pectinatus*	3
Clasping leaf Pondweed	*Potamogeton richardsonii*	5
Hardstem Bulrush	*Scirpus validus*	5
Coontail	*Ceratophyllum demersum*	3
White Water Lily	*Nymphea spp.*	6
Yellow Water Lily	*Nuphar spp.*	6
Common Waterweed	*Elodea canadensis*	3
Narrow leafed cattail	*Typha angustifolia*	1
Lesser duckweed	*Lemna minor*	5
Muskgrass	*Chara spp.*	7
Common waterweed	*Elodea canadensis*	3
Wild celery	*Valisneria americana*	6
Slender Niad, Bushy Pondweed	*Najas flexilis*	6
Small Pondweed	*Potamogeton pusillus*	7
Ivory Duckweed	*Lemna trisulca*	6
Fries' Pondweed	*Potamogeton friesii*	8
Flatstem Pondweed	*Potamogeton zosteriformis*	6
Watershield	*Brasenia schreberi*	7
Large-leaf Pondweed	*Potamogeton amplifolius*	7
Northern Watermifoil	*Myriophyllum sibericum*	7
Average C-Value		**4.86**
FQI Score	***4.86* *√22**	**22.8**

Appendix C: Inlet/Outlet Sampling Results for Jefferson-German Chain of Lakes

Sampling Results Summary:

Water quality data was collected from four inflow sites (JG6, JG7, JG8, JG9) and one outflow site (JG10) during the 2009 and 2010 monitoring season. All water quality samples were taken from the middle of each monitoring location where the thalweg (or channel) is deepest. Each monitoring location contained a reference point that is used to determine the measured stage. The measured stage is used to ensure that the stage read by the monitoring equipment (gauge height) was accurate. A difference of 0.03 between the two devices was maintained. Flow data and water quality samples were used to calculate flow-weighted mean concentrations for nutrients entering the JGC. As samples were collected, a transparency tube reading, general weather, and general notes were recorded. Water quality samples were sent to state certified Minnesota Valley Testing Laboratories (MVTL) for analysis.

Monitoring Location JG6 on Swedes Bay:

Inflow site JG6 is located off of 480th street near Madison Lake, MN. The ditch enters on the south west side of Swedes Bay (Figure 1). JG6 was equipped with an ISCO 2150 area velocity flow module and sensor that used continuous wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave, and then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow. Level or stage measurements are achieved by a differential pressure transducer. The equipment takes a reading every 3 minutes, averages the data, and compiles the stage and velocity data every 15 minutes. Stage and velocity data were stored on the module until the data was downloaded using Flowlink® software installed to a PC. Water quality samples were taken 14 times in 2009 and 31 times in 2010 with an emphasis placed upon sampling during or following storm events (Table 1). The 2009 sampling season began with grab samples being taken on 3/24; however equipment was not officially installed at this site until 4/7. The last water quality sample was taken on 11/5 and all equipment was removed at this time. The 2010 sampling season began on 3/17 with the installation of sampling equipment and ended on 11/1 when all equipment was removed.

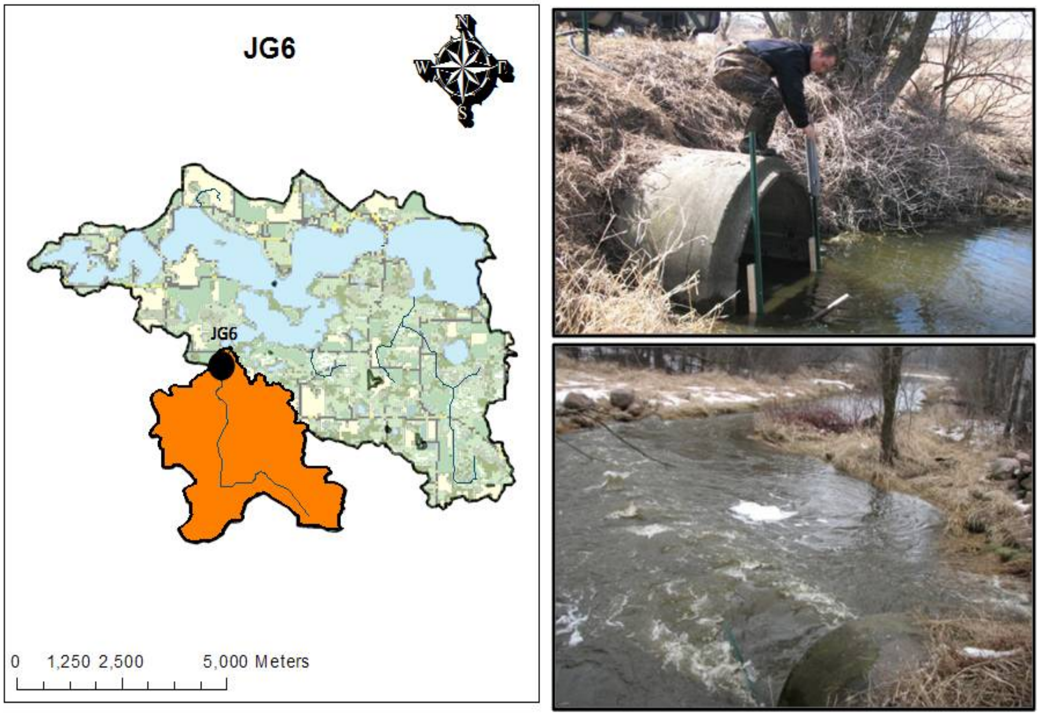


Figure 1. JG6 monitoring location on southwest side of Swedes Bay. Picture on top right shows installation of stage monitoring equipment and bottom right shows high flow at site during snowmelt.

Table 1. JG6 water quality data summation for 2009/10.

2009	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.17	12.47	15.14	NA	NA	39.51
Max	0.36	23.70	57.00	NA	NA	60.00
Min	0.08	0.10	5.00	NA	NA	9.10
Number of samples taken	14	14	14	NA	NA	14
2010	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.25	15.75	28.07	0.11	55.25	42.12
Max	1.11	31.30	191.00	0.27	76.44	60.00
Min	0.05	6.09	2.00	0.05	6.98	7.00
Number of samples taken	31	31	31	31	31	31

Monitoring Location JG7 on German Lake:
Inflow site JG7 is located off of Beaver Dam road near Elysian, MN. The ditch at this location flows underneath Beaver Dam Road and enters into German Lake (Figure 2). In 2009, JG7 was equipped with an INW9805 submersible pressure transducer that was connected to a CR 1000 datalogger. The pressure transducer was used to measure the stage height. A TR 525 rain gauge equipped with a tipping bucket was located at this site in 2009 as well. The equipment recorded a stage and precipitation reading every 3 minutes, averaged the data, and compiled the stage data every 15 minutes. This data was then downloaded and stored on a PC using PC 200W software. JG7 is hydrologically complex and experiences periods of reverse flow that were not necessarily relatable to the stage. Given the complexity of this site, it was determined that an area velocity (AV) sensor would be a more appropriate equipment choice. In 2010, an AV sensor setup very similar to the set up at JG6 was installed at JG7. Flow at JG7 was often so minimal that the AV sensor could not adequately determine a consistent velocity reading for much of the year. The 2009 sampling season began with a grab sample on 3/24; however equipment was not officially installed at this site until 4/3. The last water quality sample was taken on 11/5; all equipment was removed at this time. The 2010 sampling season began on 3/18 with the installation of sampling equipment and ended on 11/1 when all equipment was removed. Water quality samples were taken 12 times in 2009 and 24 times in 2010 (Table 2)

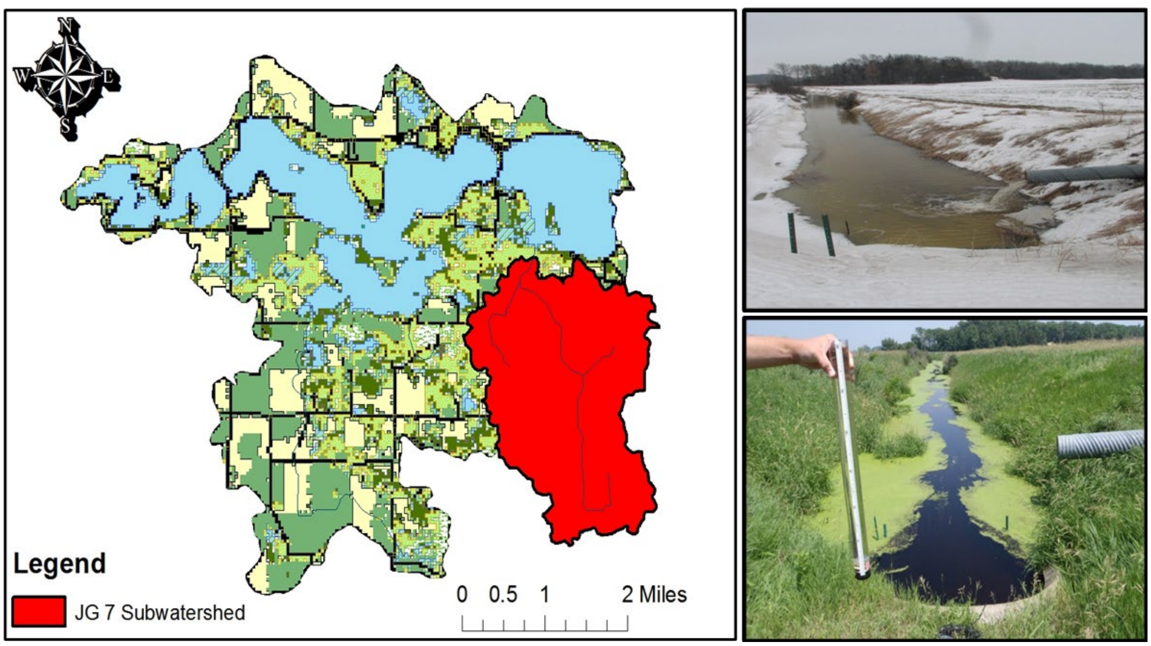


Figure 2. Monitoring location JG7 on the south side of German Lake. Picture on top right shows the site during the beginning of snowmelt and the bottom right shows the site mid-summer with correlating transparency tube.

Table 2. JG7 water quality data summation for 2009/10 monitoring season.

2009	TP (mg/L)	NO_3-NO_2 (mg/L)	TSS (mg/L)	PO4 (mg/L)	% PO4	T-Tube (cm)
Average	0.25	5.85	10.60	NA	NA	53.11
Max	0.44	9.02	32.00	NA	NA	60.00
Min	0.09	1.72	2.00	NA	NA	24.50
Number of samples taken	12	12	12	12	12	12
2010	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.26	4.77	7.50	0.15	47.59	56.83
Max	0.89	18.00	88.00	0.33	87.54	60.00
Min	0.05	0.33	1.00	0.01	9.88	9.30
Number of samples taken	24	24	24	24	24	24

Monitoring Location JG8 on Swedes Bay:

Inflow site JG8 is located off of Swedes Bay Lane near Elysian, MN. The ditch at this location crosses underneath Swedes Bay Lane and flows into Swedes Bay's southeastern most bay (Figure 3). In 2009 and 2010 this site was equipped with an INW9805 pressure transducer paired with a CR1000 data logger. A TR525 tipping bucket rain gage was located at this site in 2010. A new culvert was installed in January, 2010 to replace the old culvert that was partially collapsed. With the installation of the new culvert the stream channel was altered and we decided to move the location of the monitoring equipment closer to the new culvert. The equipment recorded a stage and precipitation reading every 3 minutes, averaged the data, and compiled the stage data every 15 minutes. This data was then downloaded and stored on a PC using PC 200W software. The 2009 sampling season began with a grab sample on 3/24; however equipment was not officially installed at this site until 4/6. The last water quality sample was taken on 11/5 and all equipment was removed at this time. The 2010 sampling season began on 3/18 with the installation of sampling equipment and ended on 11/1 when all equipment was removed. Water quality samples were taken 13 times in 2009 and 31 times in 2010 with the number of samples directly correlated with the difference in frequency of rain/storm events (Table 3).

JG8

JG8

Figure 3. JG8 monitoring location on the southeast side of Swedes Bay. Picture on top right shows the site after a rain event, and bottom right shows site mid-summer with correlating transparency tube.

Table 3. JG8 water quality data summation for 2009/10 monitoring season.

2009	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.32	1.11	14.08	NA	NA	52.32
Max	0.95	4.58	56.00	NA	NA	60.00
Min	0.08	0.10	1.00	NA	NA	25.00
Number of samples taken	13	13	13	13	13	13
2010	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.22	1.40	15.03	0.14	57.54	56.72
Max	0.79	7.05	256.00	0.30	97.55	60.00
Min	0.05	0.10	1.00	0.04	28.35	3.10
Number of samples taken	31	31	31	31	31	31

Monitoring Location JG9:

Inflow site JG9 was located off of County Road 18 (Lake Jefferson Road) near Cleveland, MN. The ditch at this location crosses underneath County Road 18 and enters into Middle Jefferson Lake. In 2009, JG9 was equipped with an INW9805 submersible pressure transducer that was connected to a CR 510 datalogger (Figure 4). The pressure transducer was used to measure the stage. Stage measurements were taken every three minutes, the datalogger than averaged the 3-minute measurements into an overall 15-minute average that was compiled and stored until the data was downloaded onto a PC using PC200W software. Water quality samples were taken 24 times in 2009 and 37 times in 2010. The difference in the number of sampling events was directly correlated with the difference in rain/storm events in 2009 versus 2010. The 2009 sampling season began with a grab sample on 3/24; however equipment was not officially installed at this site until 4/9. The last water quality sample was taken on 11/5; all equipment was removed at this time. The 2010 sampling season began with the installation of sampling equipment on 3/18 and ended on when all equipment was removed on 11/1 (Table 4).

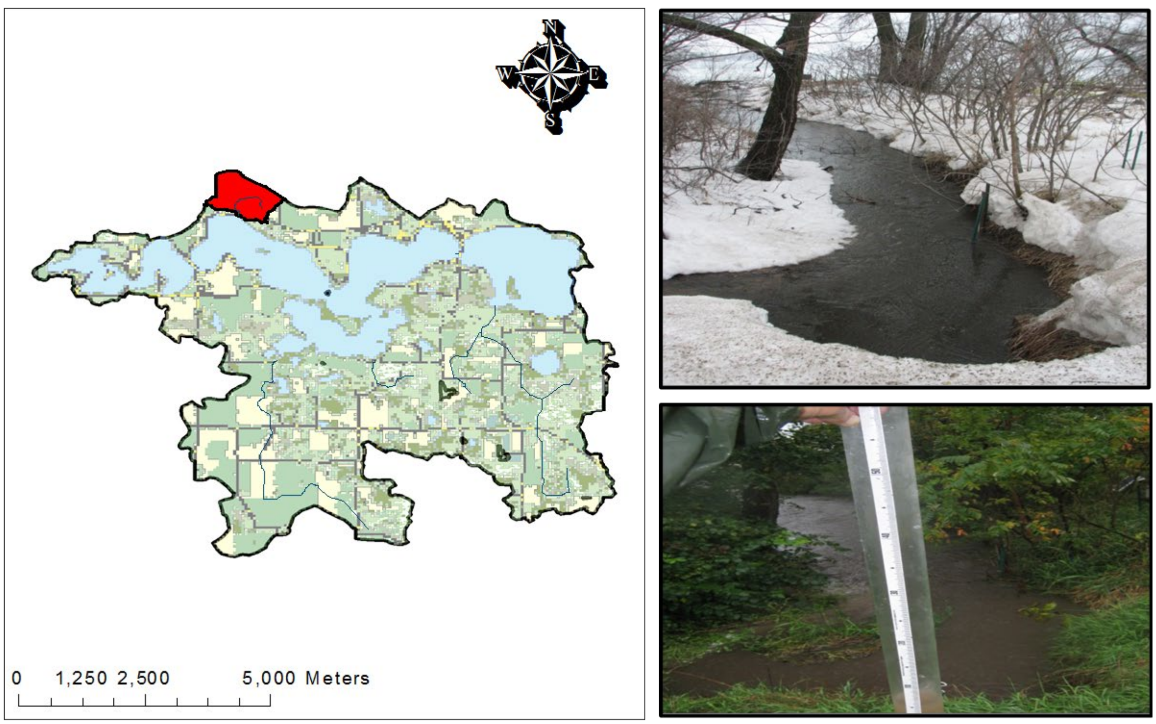


Figure 4. JG9 monitoring location on the north side of Middle Jefferson Lake. Picture at top right shows site as snowmelt was beginning and bottom right shows site during an event with correlating transparency tube.

Table 4. JG9 water quality data summation for 2009/10 monitoring season.

2009	TP (mg/L)	NO_3-NO_2 (mg/L)	TSS (mg/L)	PO4 (mg/L)	% PO4	T-Tube (cm)
Average	1.15	11.67	11.26	NA	NA	57.45
Max	3.44	23.90	39.00	NA	NA	60.00
Min	0.27	0.10	1.00	NA	NA	6.00
Number of samples taken	24	24	24	24	24	24
2010	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	1.18	17.58	15.19	0.79	64.10	56.06
Max	2.86	26.50	230.00	2.26	107.24	60.00
Min	0.27	4.74	1.00	0.02	2.48	5.30
Number of samples taken	37	37	37	37	37	37

Monitoring Location JG10 on German Lake:

Inflow site JG10 is located off of County Road 11 (German Lake Road) near Cleveland, MN (Figure 4.3 F). This location serves as the outlet site for the entire JGC and is located on the north east side of German Lake (Figure 5). JG10 was equipped with an ISCO 2150 area velocity flow module and sensor that use continuous wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave, and then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow. Level or stage measurements were achieved with a differential pressure transducer. The equipment takes a reading every 3 minutes, averages the data, and compiles the stage and velocity data every 15 minutes. Stage and velocity data were stored on the module until the data was downloaded using Flowlink® software with a PC. The AV sensor at this location is set to read the depth of water exiting through the culvert. The mounting plate was installed within the culvert, allowing for an accurate reading of the water depth and flow at this location. Water quality samples were taken 24 times in 2009 and 33 times in 2010. The 2009 sampling season began on 3/24 with the collection of a grab sample; however equipment was not officially installed at this site until 4/3. The last water quality sample was taken on 11/5; all equipment was removed at this time. The 2010 sampling season began on 3/18 with the installation of sampling equipment and ended on 11/1 when all equipment was removed (Table 5).

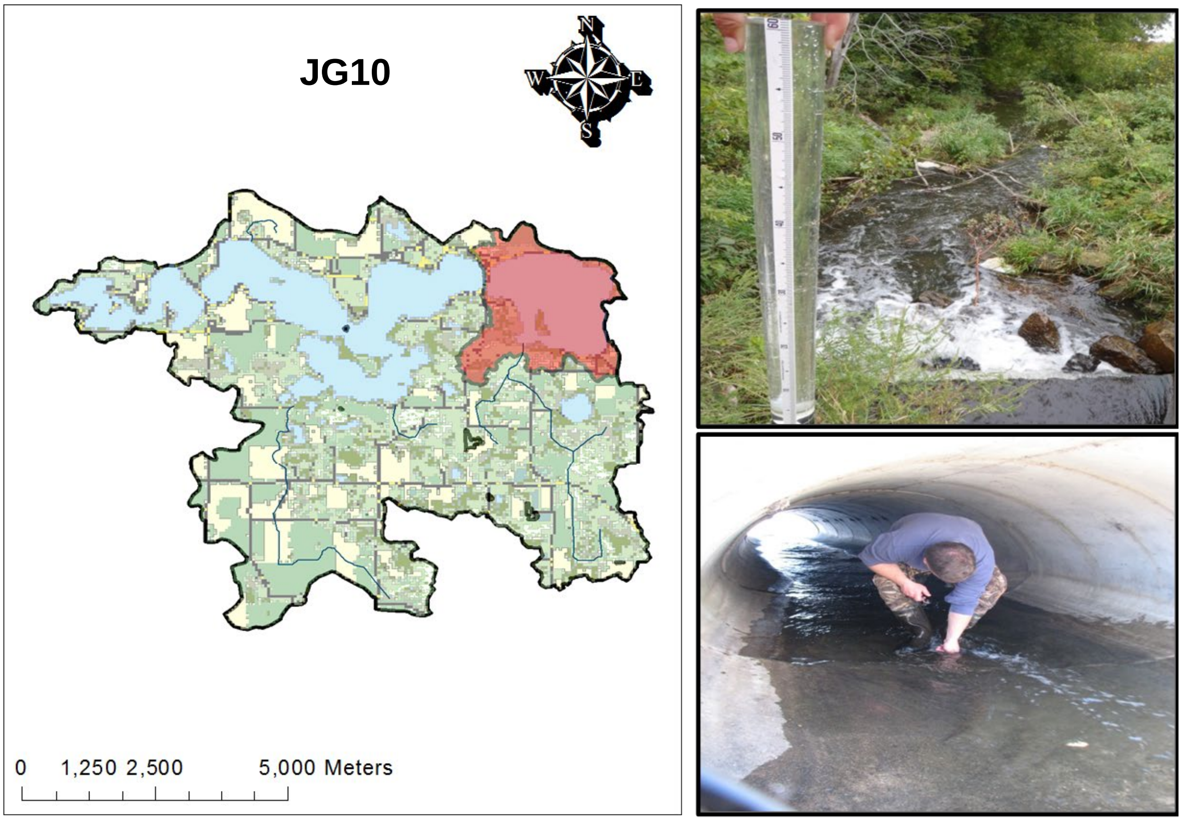


Figure 5. JG10 monitoring location is the outlet site for the JGC and is located on German Lake. Picture at top right shows the site during a routine sampling event with correlating transparency tube and bottom right shows a grab sample being collected within the culvert at the site.

Table 5. JG10 water quality data summation for 2009/10 monitoring season.

2009	**TP (mg/L)**	**NO_3-NO_2 (mg/L)**	**TSS (mg/L)**	**PO4 (mg/L)**	**% PO4**	**T-Tube (cm)**
Average	0.05	0.16	2.25	NA	NA	60.00
Max	0.11	0.29	6.00	NA	NA	60.00
Min	0.03	0.10	1.00	NA	NA	60.00
Number of samples taken	24	24	24	24	24	24
2010	TP (mg/L)	NO_3-NO_2 (mg/L)	TSS (mg/L)	PO4 (mg/L)	% PO4	T-Tube (cm)
Average	0.04	0.20	8.03	0.01	11.26	58.64
Max	0.13	0.65	46.00	0.01	22.22	60.00
Min	0.01	0.10	1.00	0.00	4.46	31.00
Number of samples taken	33	33	33	33	33	33

Appendix D: MINLEAP modeling results for all basins in the Jefferson-German lake chain.

Developed by Bruce Wilson and Dr. William Walker Jr., the "Minnesota Lake Eutrophication Analysis Procedure" or MINLEAP, is a simple modeling method used to estimate loading levels and lake response based on specific lake data when compared to reference lakes within the same ecoregion.

This model is useful because it allows the comparison between the predicted phosphorus, chlorophyll-a and Secchi depths to the actual, observed data. This comparison allows a quick comparison of the range the values in the lake should be based on its location and reference lakes in the area, to actual loading levels based on the sample results.

A. Model Results West Jefferson Lake:

Based on the initial modeling run using only data from 2009, West Jefferson Lake was predicted to have a lower TP value and a lower chl-a value in comparison with other lakes found in the NCHF ecoregion. MINLEAP predicts that TP concentrations, chl-a concentrations, and secchi disk readings should all be better than the NCHF standard (Table A.1). This is likely due to the small size of the West Jefferson Lake watershed and the fact that the watershed to lake ratio is less than 3:1. MINLEAP uses average values for land use within a given ecoregion *i.e.,* NCHF, the mean depth of a given lake, and run off coefficients to predict what is likely entering the system.

Table A.1. West Jefferson MINLEAP model predictions using 2009 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
217	134	0.86	0.62	8.4	0.35
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	70	31	13	0.35	1.85
Chl-a (µg/L)	30.8	10	6.9	0.49	1.52
Secchi (m)	1.7	2	0.9	-0.07	-0.36

Based on the initial modeling run using only data from 2010, West Jefferson Lake was predicted to have a lower TP value and a lower chl-a value in comparison with other lakes in the NCHF ecoregion. MINLEAP predicts that TP concentrations, chl-a concentrations, and secchi disk readings should be better than the NCHF standard; however, observed values were worse than the ecoregion standard for each of the variables represented in this model (Table A.2).

A.2. West Jefferson Lake MINLEAP model predictions using 2010 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
217	134	0.86	0.62	8.4	0.35
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	48	31	13	0.19	1.02
Chl-a (µg/L)	27.7	9.9	6.9	0.45	1.39
Secchi (m)	1.6	2	0.9	-0.09	-0.42

Based on the initial modeling run using all data collected during the TMDL study, West Jefferson Lake is predicted to have a lower TP value and a lower chl-a value in comparison with other lakes found in the NCHF ecoregion (Table A.3). MINLEAP predicts that TP concentrations, chl-a concentrations, and secchi disk readings should be less than the NCHF standard; however, observed values were worse than the ecoregion standard for each of the variables represented in this model.

Table A.3. West Jefferson MINLEAP model predictions using all data collected during the 2009 and 2010 monitoring seasons.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
217	134	0.86	0.62	8.3	0.35
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	59	31	13	0.28	1.47
Chl-a (µg/L)	29.3	9.9	6.9	0.47	1.46
Secchi (m)	1.7	2	0.9	-0.07	-0.34

B. Model Results Middle Jefferson Lake:

Based on the initial modeling run using all data collected in 2009, Middle Jefferson Lake was predicted to have a higher TP concentration, and a higher chl-a level reading in comparison with other lakes in the ecoregion (Table B.1). This was likely due to the shallow morphometry of the Middle Jefferson Lake basin. Middle Jefferson Lake has a watershed to lake ratio of 3:1, similar to West Jefferson Lake. The only difference between the two lakes was that Middle Jefferson Lake is much shallower on average than West Jefferson Lake. MINLEAP uses average values for land use within a given ecoregion (*i.e.,* NCHF), run off coefficients, and the mean depth of the lake to predict what is likely entering the system and the mean TP concentration likely present within the lake. The observed TP concentration for Middle Jefferson Lake was significantly higher than the predicted TP concentration; this indicates that Middle Jefferson Lake has a significantly higher mean TP concentration in comparison to other lakes that have a similar watershed size and similar basin morphometry. The TP concentration observed in Middle Jefferson Lake suggests that Middle Jefferson Lake is subject to excessive nutrient loading uncharacteristic of lakes in this eco region.

Table B.1 Middle Jefferson MINLEAP model predictions using 2009 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
210	218	0.79	1.04	3.6	0.39
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	111	44	17	0.4	**2.22**
Chl-a (µg/L)	24	16.8	11.1	0.15	0.5
Secchi (m)	1.3	1.5	0.6	-0.05	-0.23

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected in 2010, Middle Jefferson Lake is predicted to have a higher TP concentration and chl-a concentration in comparison with other lakes in the ecoregion (Table B.2). The TP and chl-a concentration observed on Middle Jefferson Lake is still significantly different than the predicted conditions; even though MINLEAP accurately predicted that both values would be worse than the NCHF standard. The TP and chl-a concentration observed in 2010 suggest that Middle Jefferson Lake is subject to excessive nutrient loading and has algal concentrations uncharacteristic of lakes in this eco region.

Table B.2 Middle Jefferson MINLEAP model predictions using 2010 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
210	218	0.79	1.04	3.6	0.39
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	111	44	17	0.4	**2.22**
Chl-a (µg/L)	74.7	16.8	11.1	0.65	**2.10**
Secchi (m)	1.0	1.5	0.6	-0.17	-0.86

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected during both the 2009 and 2010 monitoring seasons, Middle Jefferson Lake is predicted to have a higher TP concentration and chl-a level in comparison with other lakes in the ecoregion (Table B.3). The TP concentration observed on Middle Jefferson Lake is still significantly different than the predicted conditions; even though MINLEAP accurately predicted that both values would be worse than the NCHF standard. The TP concentration observed in 2010 suggests that Middle Jefferson Lake is subject to excessive nutrient loading uncharacteristic of lakes in this eco region.

Table B.3. Middle Jefferson MINLEAP model predictions using all data collected during the 2009 and 2010 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
210	218	0.79	1.04	3.6	0.39
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	111	44	17	0.4	**2.22**
Chl-a (µg/L)	50.4	16.8	11.1	0.48	1.55
Secchi (m)	1.2	1.5	0.6	-0.1	-0.52

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

C. Model Results Swedes Bay:

Based on the initial modeling run using all data collected in 2009, Swedes Bay is predicted to have a higher TP concentration and chl-a level in comparison with the ecoregion standard (Table C.1). This is likely due to the large size of the Swedes Bay watershed, the fact that the watershed to lake ratio is greater than 10:1, and the shallow morphology of the Swedes Bay basin. Given the amount of area that drains into Swedes Bay, MINLEAP suggests that TP concentrations and chl-a values are likely going to be higher than the NCHF standard and secchi disk transparency will be less than the ecoregion standard. MINLEAP uses average values for land use within a given ecoregion (*i.e.,* NCHF), the mean depth of a given lake, and run-off coefficients to predict what is likely entering the system and the mean TP concentration present within the lake. The observed TP concentration for Swedes Bay was still significantly higher than the predicted TP concentration; this indicates that Swedes Bay has a significantly higher mean TP concentration in comparison to other water bodies that have a similar watershed size and similar basin morphometry within the NCHF ecoregion.

Table C.1 Swedes Bay MINLEAP model predictions using 2009 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
163	523.00	0.55	3.21	0.50	1.61
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	254.00	74.00	21	0.54	**3.72**
Chl-a (µg/L)	32.00	35.30	19.5	-0.04	-0.16
Secchi (m)	0.70	0.90	0.4	-0.16	-0.9

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected during the 2010 monitoring seasons, Swedes Bay is predicted to have a higher TP concentration and chl-a level in comparison with the ecoregion standard (Table C.2). MINLEAP predicts that TP concentrations and chl-a concentrations should all be greater (worse) and secchi disk transparency readings less (worse) than the NCHF standard given the watershed size and shallow morphometry of the Swedes Bay basin. Observed TP concentrations taken during the 2010 monitoring season were still significantly worse than the predicted values for lakes with similar morphometry and watershed size within the NCHF ecoregion.

Table C.2 Swedes Bay MINLEAP model predictions using 2010 data.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
163	523	0.55	3.21	0.5	1.61
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	210	74	21	0.45	**3.14**
Chl-a (µg/L)	90.4	35.3	19.5	0.41	1.53
Secchi (m)	0.8	0.9	0.4	-0.1	-0.55

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected during both the 2009 and the 2010 monitoring seasons, Swedes Bay is predicted to have a higher TP concentration and chl-a level in comparison with the eco region standard (Table C.3). MINLEAP predicts that TP concentrations and chl-a concentrations should all be greater (worse) and secchi disk transparency readings less (worse) than the NCHF standard given the watershed size and shallow morphometry of the Swedes Bay basin. The observed mean TP concentration calculated using data from both the 2009 and 2010 monitoring seasons was still significantly worse than the predicted mean TP concentration for lakes with similar morphometry and watershed size within the NCHF ecoregion.

Table C.3 Swedes Bay MINLEAP model predictions using all data collected during the 2009 and 2010 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
163	523	0.55	3.21	0.5	1.61
Var	***Observed***	***Predicted***	***Std Err***	***Residual***	***T-test***
TP (µg/L)	230	74	21	0.49	**3.42**
Chl-a (µg/L)	62.3	35.3	19.5	0.25	0.93
Secchi (m)	0.9	0.9	0.4	-0.05	-0.27

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

D. Model Results East Jefferson Lake:

Based on the initial modeling run using all data collected during the 2009 monitoring seasons, MINLEAP predicts that TP concentrations and chl-a concentrations should all be less than (better) and Secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the East Jefferson Lake basin. However, the observed mean TP concentration taken during the 2009 monitoring season was significantly worse than the predicted values for lakes with similar morphometry and watershed size (Table D.1). The observed TP concentration suggests that East Jefferson Lake is subject to excessive nutrient loading uncharacteristic of lakes in this ecoregion.

Table D.1. East Jefferson Lake MINLEAP model predictions using all data collected during the 2009 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
212	210	0.89	0.99	14.7	0.38
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	63	23	10	0.43	**2.2**
Chl-a (µg/L)	18.8	6.6	4.6	.46	1.39
Secchi (m)	3.2	2.6	1.2	0.09	0.45

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected during the 2010 monitoring season, MINLEAP predicts that TP concentrations and Chl-a concentrations should all be less than (better) and secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the East Jefferson Lake basin(Table D.2). However, the observed mean TP concentration and mean Chl-a. concentration observed during the 2010 monitoring season was significantly worse than the predicted values for lakes with similar morphometry and watershed size. The observed TP and Chl-a concentration suggests that East Jefferson Lake is subject to excessive nutrient loading and has algal concentrations uncharacteristic of lakes in this eco region.

Table D.2. East Jefferson Lake MINLEAP model predictions using all data collected during the 2010 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
212	210	0.89	0.99	14.7	0.38
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	70	23	10	0.48	**2.44**
Chl-a (µg/L)	36	6.6	4.6	0.74	**2.25**
Secchi (m)	2.2	2.6	1.2	-0.07	-0.32

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

Based on the initial modeling run using all data collected during the 2009 and 2010 monitoring seasons, MINLEAP predicts that TP concentrations and Chl-a concentrations should all be less (better) than and secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the East Jefferson Lake basin (Table D.3). However, the observed mean TP concentration observed based upon all data collected in 2009 and 2010 monitoring seasons was significantly worse than the predicted values for lakes with similar morphometry and watershed size. The observed TP concentration suggests that East Jefferson Lake is subject to excessive nutrient loading uncharacteristic of lakes in this eco region.

Table D.3. East Jefferson Lake MINLEAP model predictions using all data collected during the 2009 and 2010 monitoring seasons.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
212	210	0.81	0.99	14.5	0.38
Var	*Observed*	*Predicted*	*Std Err*	*Residual*	*T-test*
TP (µg/L)	67	23	10	0.46	2.34
Chl-a (µg/L)	28	6.6	4.7	0.63	1.91
Secchi (m)	2.7	2.5	1.2	0.02	0.09

*** Bolded sections indicate a significant difference between the predicted values for lakes in the NCHF and the observed value.**

E. Model Results German Lake:

Based on the initial modeling run using all data collected during the 2009 monitoring season, MINLEAP predicts that TP concentrations and chl-a concentrations should be less (better) than and secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the German Lake basin (Table E.1). The observed mean TP and chl-a concentration observed during the 2009 monitoring season was worse than the predicted values for lakes with similar morphometry and watershed size; however, the difference was not statistically significant.

Table E.1. German Lake MINLEAP model predictions using all data collected during the 2009 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
180	473	0.81	2.63	5	0.76
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	56	35	13	0.2	1.12
Chl-a (µg/L)	33	11.7	7.8	0.45	1.44
Secchi (m)	1.6	1.8	0.8	-0.06	-0.32

Based on the initial modeling run using all data collected during the 2010 monitoring season, MINLEAP predicts that TP concentrations and chl-a concentrations should be less (better) than and secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the German Lake basin (Table E.2). The observed mean TP and chl-a concentration observed during the 2010 monitoring season was worse than the predicted values for lakes with similar morphometry and watershed size; however, the difference was not statistically significant.

Table E.2. German Lake MINLEAP model predictions using all data collected during the 2010 monitoring season.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
180	473	0.81	2.63	5	0.76
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	57	35	13	0.22	1.18
Chl-a (µg/L)	37.7	11.7	7.8	0.51	1.63
Secchi (m)	1.3	1.8	0.8	-0.13	-0.66

Based on the initial modeling run using all data collected during the 2009 and 2010 monitoring seasons, MINLEAP predicts that TP concentrations and chl-a concentrations should be less (better) than and secchi disk transparency readings greater (better) than the NCHF standard given the watershed size and morphometry of the German Lake basin (Table E.3). The observed mean TP and chl-a concentration observed during the 2010 monitoring season was worse than the predicted values for lakes with similar morphometry and watershed size; however, the difference was not statistically significant.

Table E.3. German Lake MINLEAP model predictions using all data collected during the 2009 and 2010 monitoring seasons.

Avg TP Inflow (µg/L)	TP Load (kg/yr)	Phos Ret Coef	Lake Outflow (hm3/yr)	Res Time (years)	Areal Water Load (m/yr)
180	473	0.81	2.63	5	0.76
Var	**Observed**	**Predicted**	**Std Err**	**Residual**	**T-test**
TP (µg/L)	57	35	13	0.22	1.19
Chl-a (µg/L)	37.3	11.7	7.8	0.5	1.61
Secchi (m)	1.5	1.8	0.8	-0.09	-0.46

F. MINLEAP Discussion:

The MINLEAP model has been demonstrated to perform well in the Northern Lake/Forest and Northern Central Hardwood Forest areas; however, it does not perform as well in lakes exhibiting high levels of internal loading or nutrient cycling. The documented presence and abundance of CLP within the JGC suggests that internal loading may play a large role in the nutrient cycling of these waterbodies. MINLEAP's predicted TP concentration was always less than the observed TP concentration, this difference between observed and predicted values was statistically significant on several lake basins (Table F). Based on these results, it can safely be concluded that all lake basins of the JGC are subjective to extensive nutrient loading. Certain lake basins are subjective to more extensive loading than other basins as indicated by the significant difference between observed and predicted values. Due to this fact, additional modeling (BATHTUB) was performed on the JGC.

Table F. MINLEAP model results.

Lake	Year	Parameters with a Significant Difference (P=0.05)
West Jefferson	2009	None
West Jefferson	2010	None
Middle Jefferson	2009	TP
Middle Jefferson	2010	TP, Chl-a
Swedes Bay	2009	TP
Swedes Bay	2010	TP
East Jefferson Lake	2009	TP
East Jefferson Lake	2010	TP, Chl-a
German Lake	2009	None
German Lake	2010	None

Appendix E: BATHTUB case files, computed October, 2012.

A. West Jefferson Lake:

1. Files for Existing Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km²	Depth m	Length km	Mixed Depth (m) Mean	Mixed Depth (m) CV	Hypol Depth Mean	Hypol Depth CV	Non-Algal Turb (m^{-1}) Mean	Non-Algal Turb (m^{-1}) CV	Internal Loads (mg/m2-day) Conserv. Mean	Conserv. CV	Total P Mean	Total P CV	Total N Mean
1	West Jefferson	0	1	1.77	2.9	2.906	2.9	0	4	0	0.14	0	0	0	0.463	0	0

Segment Observed Water Quality

Seg	Conserv Mean	Conserv CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV	TP - Ortho P (ppb) Mean	TP - Ortho P (ppb) CV	HOD (ppb/day) Mean	HOD (ppb/day) CV	MOD (ppb/day) Mean	MOD (ppb/day) CV
1	0	0	63.88889	0	0	0	35.61667	0	1.28056	0	0	0	0.1325	0	0	0	0	0

Segment Calibration Factors

Seg	Dispersion Rate Mean	Dispersion Rate CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV	TP - Ortho P (ppb) Mean	TP - Ortho P (ppb) CV	HOD (ppb/day) Mean	HOD (ppb/day) CV	MOD (ppb/day) Mean	MOD (ppb/day) CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km²	Flow (hm^3/yr) Mean	Flow CV	Conserv. Mean	Conserv. CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Ortho P (ppb) Mean	Ortho P (ppb) CV	Inorganic N (ppb) Mean	Inorganic N (ppb) CV
1	West Jefferson Watershed	1	2	2.42	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km²)

Trib	Trib Name	Land Use Category---> 1	2	3	4	5	6
1	West Jefferson Watershed	0.1139	0.966483	0.608	0.568	0.1584	0.0000

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	Runoff (m/yr) CV	Conserv. Subs. Mean	Conserv. Subs. CV	Total P (ppb) Mean
1	Forest	0.048	0	0	0	92.31
2	Agriculture	0.048	0	0	0	307.69
3	Urban	0.048	0	0	0	769.23
4	Grassland/Pasture	0.048	0	0	0	230.77
5	Wetland	0.048	0	0	0	76.92
6	Open Water	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	2	1	West Jefferson Watershed	2.42	0.12	0.00E+00	0.00	0.048
PRECIPITATION				1.77	1.75	0.00E+00	0.00	0.990
NONPOINT INFLOW				2.42	0.12	0.00E+00	0.00	0.048
***TOTAL INFLOW				4.19	1.87	0.00E+00	0.00	0.446
ADVECTIVE OUTFLOW				4.19	0.12	0.00E+00	0.00	0.028
***TOTAL OUTFLOW				4.19	0.12	0.00E+00	0.00	0.028
***EVAPORATION					1.75	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	2	1	West Jefferson Watershed	44.1	11.1%	0.00E+00		0.00	380.5	18.2
PRECIPITATION				53.1	13.4%	7.05E+02	100.0%	0.50	30.3	30.0
INTERNAL LOAD				299.3	75.5%	0.00E+00		0.00		
NONPOINT INFLOW				44.1	11.1%	0.00E+00		0.00	380.5	18.2
***TOTAL INFLOW				396.5	100.0%	7.05E+02	100.0%	0.07	212.3	94.6
ADVECTIVE OUTFLOW				7.4	1.9%	1.02E+01		0.43	63.9	1.8
***TOTAL OUTFLOW				7.4	1.9%	1.02E+01		0.43	63.9	1.8
***RETENTION				389.1	98.1%	7.01E+02		0.07		

Overflow Rate (m/yr)	0.1	Nutrient Resid. Time (yrs)	0.8272
Hydraulic Resid. Time (yrs)	44.2845	Turnover Ratio	1.2
Reservoir Conc (mg/m3)	64	Retention Coef.	0.981

2. Files for Modeled Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	West Jefferson	0	1	1.77	2.9	2.906	2.9	0	4	0	0.14	0	0	0	0.0926	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	36	0	0	0	14	0	1.4	0	0	0	0.1325	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	West Jefferson Watershed	1	2	2.42	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	West Jefferson Watershed	0.1139	0.966483	0.608	0.568	0.1584	0.0000

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)	
Categ	Land Use Name	Mean	CV	Mean	CV	Mean	CV
1	Forest	0.048	0	0	0	56.77	0
2	Agriculture	0.048	0	0	0	189.23	0
3	Urban	0.048	0	0	0	473.08	0
4	Grassland/Pasture	0.048	0	0	0	141.92	0
5	Wetland	0.048	0	0	0	47.31	0
6	Open Water	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	2	1	West Jefferson Watershed	2.42	0.12	0.00E+00	0.00	0.048
PRECIPITATION				1.77	1.75	0.00E+00	0.00	0.990
NONPOINT INFLOW				2.42	0.12	0.00E+00	0.00	0.048
***TOTAL INFLOW				4.19	1.87	0.00E+00	0.00	0.446
ADVECTIVE OUTFLOW				4.19	0.12	0.00E+00	0.00	0.028
***TOTAL OUTFLOW				4.19	0.12	0.00E+00	0.00	0.028
***EVAPORATION					1.75	0.00E+00	0.00	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**

Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	2	1	West Jefferson Watershed	27.1	19.4%	0.00E+00		0.00	234.0	11.2
PRECIPITATION				53.1	37.9%	7.05E+02	100.0%	0.50	30.3	30.0
INTERNAL LOAD				59.9	42.7%	0.00E+00		0.00		
NONPOINT INFLOW				27.1	19.4%	0.00E+00		0.00	234.0	11.2
***TOTAL INFLOW				140.1	100.0%	7.05E+02	100.0%	0.19	75.0	33.4
ADVECTIVE OUTFLOW				4.2	3.0%	3.32E+00		0.44	36.0	1.0
***TOTAL OUTFLOW				4.2	3.0%	3.32E+00		0.44	36.0	1.0
***RETENTION				135.9	97.0%	6.85E+02		0.19		

Overflow Rate (m/yr)	0.1	Nutrient Resid. Time (yrs)	1.3172
Hydraulic Resid. Time (yrs)	44.2845	Turnover Ratio	0.8
Reservoir Conc (mg/m3)	36	Retention Coef.	0.970

B. Middle Jefferson:

1. Files for Existing Conditions:

Global Variables

	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km²	Depth m	Length km	Mixed Depth (m) Mean	CV	Hypol Depth Mean	CV	Non-Algal Turb (m^{-1}) Mean	CV	Internal Loads (mg/m2-day) Conserv. Mean	CV	Total P Mean	CV	Total N Mean
1	Middle Jefferson Lake	0	1	2.688	1.4	3	1.4	0.12	0	0	0.08	0	0	0	0.837	0	0

Segment Observed Water Quality

Seg	Conserv Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Chl-a (ppb) Mean	CV	Secchi (m) Mean	CV	Organic N (ppb) Mean	CV	TP - Ortho P (ppb) Mean	CV	HOD (ppb/day) Mean	CV	MOD (ppb/day) Mean	CV
1	0	0	141.0556	0	0	0	70.625	0	0.96556	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

Seg	Dispersion Rate Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Chl-a (ppb) Mean	CV	Secchi (m) Mean	CV	Organic N (ppb) Mean	CV	TP - Ortho P (ppb) Mean	CV	HOD (ppb/day) Mean	CV	MOD (ppb/day) Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km²	Flow (hm^3/yr) Mean	CV	Conserv. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	West Jefferson Outflow	1	1	4.19576	0.115	0	0	0	60	0	0	0	0	0	0	0
2	TMDL Inflow Site JG9	1	1	1.090359	0.232	0	0	0	1616	0	0	0	0	0	0	0
3	Middle Jefferson Lake Watersh	1	2	3.36	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km²)

Land Use Category--->

Trib	Trib Name	1	2	3	4	5
1	West Jefferson Outflow	0	0	0	0	0
2	TMDL Inflow Site JG9	0	0	0	0	0
3	Middle Jefferson Lake Watersh	0.2097	2.06	0.5089	0.47797	0.109

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	CV	Conserv. Subs. Mean	CV	Total P (ppb) Mean
1	Forest	0.048	0	0	0	92.31
2	Agriculture	0.048	0	0	0	307.69
3	Urban	0.048	0	0	0	769.23
4	Grassland/Pasture	0.048	0	0	0	230.77
5	Wetland	0.048	0	0	0	76.92
6	Open Water	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	West Jefferson Outflow	4.20	0.115	0.00E+00	0.00	0.027
2	1	1	TMDL Inflow Site JG9	1.09	0.232	0.00E+00	0.00	0.213
3	2	1	Middle Jefferson Lake Water	3.36	0.162	0.00E+00	0.00	0.048
PRECIPITATION				2.69	2.661	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				5.29	0.347	0.00E+00	0.00	0.066
NONPOINT INFLOW				3.36	0.162	0.00E+00	0.00	0.048
***TOTAL INFLOW				11.33	3.170	0.00E+00	0.00	0.280
ADVECTIVE OUTFLOW				11.33	0.509	0.00E+00	0.00	0.045
***TOTAL OUTFLOW				11.33	0.509	0.00E+00	0.00	0.045
***EVAPORATION					2.661	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted — **Outflow & Reservoir Concentrations**

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	West Jefferson Outflow	6.9	0.5%	0.00E+00		0.00	60.0	1.6
2	1	1	TMDL Inflow Site JG9	374.9	28.0%	0.00E+00		0.00	1616.0	343.8
3	2	1	Middle Jefferson Lake Water	55.8	4.2%	0.00E+00		0.00	345.7	16.6
PRECIPITATION				80.6	6.0%	1.63E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				821.8	61.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				381.8	28.5%	0.00E+00		0.00	1100.3	72.2
NONPOINT INFLOW				55.8	4.2%	0.00E+00		0.00	345.7	16.6
***TOTAL INFLOW				1340.1	100.0%	1.63E+03	100.0%	0.03	422.8	118.2
ADVECTIVE OUTFLOW				71.8	5.4%	8.85E+02		0.41	141.1	6.3
***TOTAL OUTFLOW				71.8	5.4%	8.85E+02		0.41	141.1	6.3
***RETENTION				1268.3	94.6%	2.41E+03		0.04		

Overflow Rate (m/yr)	0.2	Nutrient Resid. Time (yrs)	0.3962
Hydraulic Resid. Time (yrs)	7.3999	Turnover Ratio	2.5
Reservoir Conc (mg/m3)	141	Retention Coef.	0.946

2. Files for Modeled Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Middle Jefferson Lake	0	1	2.688	1.4	3	1.4	0.12	0	0	0.08	0	0	0	0.0837	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	54	0	0	0	20	0	1	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	West Jefferson Outflow	1	1	4.19576	0.115	0	0	0	40	0	0	0	0	0	0	0
2	TMDL Inflow Site JG9	1	1	1.090359	0.232	0	0	0	220.13	0	0	0	0	0	0	0
3	Middle Jefferson Lake Watersh	1	2	3.36	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	West Jefferson Outflow	0	0	0	0	0	0
2	TMDL Inflow Site JG9	0	0	0	0	0	0
3	Middle Jefferson Lake Watersh	0.2097	2.06	0.5089	0.47797	0.109	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)	
Categ	Land Use Name	Mean	CV	Mean	CV	Mean	CV
1	Forest	0.048	0	0	0	58.79	0
2	Agriculture	0.048	0	0	0	195.94	0
3	Urban	0.048	0	0	0	489.86	0
4	Grassland/Pasture	0.048	0	0	0	146.96	0
5	Wetland	0.048	0	0	0	48.98	0
6	Open Water	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance | **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	West Jefferson Outflow	4.2	0.1	0.00E+00	0.00	0.03
2	1	1	TMDL Inflow Site JG9	1.1	0.2	0.00E+00	0.00	0.21
3	2	1	Middle Jefferson Lake Wa	3.4	0.2	0.00E+00	0.00	0.05
PRECIPITATION				2.7	2.7	0.00E+00	0.00	0.99
TRIBUTARY INFLOW				5.3	0.3	0.00E+00	0.00	0.07
NONPOINT INFLOW				3.4	0.2	0.00E+00	0.00	0.05
***TOTAL INFLOW				11.3	3.2	0.00E+00	0.00	0.28
ADVECTIVE OUTFLOW				11.3	0.5	0.00E+00	0.00	0.04
***TOTAL OUTFLOW				11.3	0.5	0.00E+00	0.00	0.04
***EVAPORATION					2.7	0.00E+00	0.00	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	West Jefferson Outflow	4.6	1.8%	0.00E+00		0.00	40.0	1.1
2	1	1	TMDL Inflow Site JG9	51.1	20.1%	0.00E+00		0.00	220.1	46.8
3	2	1	Middle Jefferson Lake Wa	35.6	14.0%	0.00E+00		0.00	220.1	10.6
PRECIPITATION				80.6	31.7%	1.63E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				82.2	32.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				55.7	21.9%	0.00E+00		0.00	160.4	10.5
NONPOINT INFLOW				35.6	14.0%	0.00E+00		0.00	220.1	10.6
***TOTAL INFLOW				254.0	100.0%	1.63E+03	100.0%	0.16	80.1	22.4
ADVECTIVE OUTFLOW				27.5	10.8%	1.22E+02		0.40	54.0	2.4
***TOTAL OUTFLOW				27.5	10.8%	1.22E+02		0.40	54.0	2.4
***RETENTION				226.6	89.2%	1.54E+03		0.17		

Overflow Rate (m/yr)	0.2	Nutrient Resid. Time (yrs)	0.7998
Hydraulic Resid. Time (yrs)	7.3999	Turnover Ratio	1.3
Reservoir Conc (mg/m3)	54	Retention Coef.	0.892

C. East Jefferson

1. Files for Existing Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Segname 1	0	1	2.616252	5.5	2.894	4.9	0.12	7	0	0.08	0	0	0	1.05	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	72.72222	0	0	0	35.86667	0	1.80556	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Swedes Bay Outflow	1	1	24.06	2.33	0	0	0	230	0	0	0	0	0	0	0
2	Middle Jefferson Outflow	1	1	11.335	0.115	0	0	0	111	0	0	0	0	0	0	0
3	East Jefferson Watershed	1	2	4.2	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	Swedes Bay Outflow	0	0	0	0	0	0
2	Middle Jefferson Outflow	0	0	0	0	0	0
3	East Jefferson Watershed	0.8484	1.4826	1.0836	0.1512	0.6342	0.0000

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)
Categ	Land Use Name	Mean	CV	Mean	CV	Mean
1	Forest	0.048	0	0	0	92.31
2	Agriculture	0.048	0	0	0	307.69
3	Urban	0.048	0	0	0	769.23
4	Grassland/Pasture	0.048	0	0	0	230.77
5	Wetland	0.048	0	0	0	76.92
6	Open Water	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Swedes Bay Outflow	24.06	2.33	0.00E+00	0.00	0.097
2	1	1	Middle Jefferson Outflow	11.34	0.12	0.00E+00	0.00	0.010
3	2	1	East Jefferson Watershed	4.20	0.20	0.00E+00	0.00	0.048
PRECIPITATION				2.62	2.59	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				35.40	2.44	0.00E+00	0.00	0.069
NONPOINT INFLOW				4.20	0.20	0.00E+00	0.00	0.048
***TOTAL INFLOW				42.21	5.24	0.00E+00	0.00	0.124
ADVECTIVE OUTFLOW				42.21	2.65	0.00E+00	0.00	0.063
***TOTAL OUTFLOW				42.21	2.65	0.00E+00	0.00	0.063
***EVAPORATION					2.59	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Swedes Bay Outflow	535.9	31.5%	0.00E+00		0.00	230.0	22.3
2	1	1	Middle Jefferson Outflow	12.8	0.8%	0.00E+00		0.00	111.0	1.1
3	2	1	East Jefferson Watershed	69.7	4.1%	0.00E+00		0.00	345.6	16.6
PRECIPITATION				78.5	4.6%	1.54E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				1003.4	59.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				548.7	32.3%	0.00E+00		0.00	224.4	15.5
NONPOINT INFLOW				69.7	4.1%	0.00E+00		0.00	345.6	16.6
***TOTAL INFLOW				1700.2	100.0%	1.54E+03	100.0%	0.02	324.7	40.3
ADVECTIVE OUTFLOW				192.4	11.3%	5.60E+03		0.39	72.7	4.6
***TOTAL OUTFLOW				192.4	11.3%	5.60E+03		0.39	72.7	4.6
***RETENTION				1507.8	88.7%	6.94E+03		0.06		

Overflow Rate (m/yr)	1.0	Nutrient Resid. Time (yrs)	0.6154
Hydraulic Resid. Time (yrs)	5.4369	Turnover Ratio	1.6
Reservoir Conc (mg/m3)	73	Retention Coef.	0.887

2. Files for Modeled Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Segname 1	0	1	2.616252	5.5	2.894	4.9	0.12	7	0	0.08	0	0	0	0.26033	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	36	0	0	0	14	0	1.4	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Swedes Bay Outflow	1	1	24.06	2.33	0	0	0	60	0	0	0	0	0	0	0
2	Middle Jefferson Outflow	1	1	11.335	0.115	0	0	0	60	0	0	0	0	0	0	0
3	East Jefferson Watershed	1	2	4.2	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	Swedes Bay Outflow	0	0	0	0	0	0
2	Middle Jefferson Outflow	0	0	0	0	0	0
3	East Jefferson Watershed	0.8484	1.4826	1.0836	0.1512	0.6342	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)	
Categ	Land Use Name	Mean	CV	Mean	CV	Mean	CV
1	Forest	0.048	0	0	0	80.13	0
2	Agriculture	0.048	0	0	0	267.07	0
3	Urban	0.048	0	0	0	667.69	0
4	Grassland/Pasture	0.048	0	0	0	200.31	0
5	Wetland	0.048	0	0	0	66.77	0
6	Open Water	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Swedes Bay Outflow	24.06	2.33	0.00E+00	0.00	0.097
2	1	1	Middle Jefferson Outflow	11.34	0.12	0.00E+00	0.00	0.010
3	2	1	East Jefferson Watershed	4.20	0.20	0.00E+00	0.00	0.048
PRECIPITATION				2.62	2.59	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				35.40	2.44	0.00E+00	0.00	0.069
NONPOINT INFLOW				4.20	0.20	0.00E+00	0.00	0.048
***TOTAL INFLOW				42.21	5.24	0.00E+00	0.00	0.124
ADVECTIVE OUTFLOW				42.21	2.65	0.00E+00	0.00	0.063
***TOTAL OUTFLOW				42.21	2.65	0.00E+00	0.00	0.063
***EVAPORATION					2.59	0.00E+00	0.00	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**
Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Swedes Bay Outflow	139.8	26.2%	0.00E+00		0.00	60.0	5.8
2	1	1	Middle Jefferson Outflow	6.9	1.3%	0.00E+00		0.00	60.0	0.6
3	2	1	East Jefferson Watershed	60.5	11.3%	0.00E+00		0.00	300.0	14.4
PRECIPITATION				78.5	14.7%	1.54E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				248.8	46.5%	0.00E+00		0.00		
TRIBUTARY INFLOW				146.7	27.4%	0.00E+00		0.00	60.0	4.1
NONPOINT INFLOW				60.5	11.3%	0.00E+00		0.00	300.0	14.4
***TOTAL INFLOW				534.4	100.0%	1.54E+03	100.0%	0.07	102.1	12.7
ADVECTIVE OUTFLOW				95.2	17.8%	1.20E+03		0.36	36.0	2.3
***TOTAL OUTFLOW				95.2	17.8%	1.20E+03		0.36	36.0	2.3
***RETENTION				439.2	82.2%	2.40E+03		0.11		

Overflow Rate (m/yr)	1.0	Nutrient Resid. Time (yrs)	0.9689
Hydraulic Resid. Time (yrs)	5.4369	Turnover Ratio	1.0
Reservoir Conc (mg/m3)	36	Retention Coef.	0.822

D. Swede's Bay

1. Files for Existing Conditions

Global Variables

	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km^2	Depth m	Length km	Mixed Depth (m) Mean	Mixed Depth (m) CV	Hypol Depth Mean	Hypol Depth CV	Non-Algal Turb (m^{-1}) Mean	Non-Algal Turb (m^{-1}) CV	Internal Loads (mg/m2-day) Conserv. Mean	Conserv. CV	Total P Mean	Total P CV	Total N Mean
1	Swedes Bay	0	1	1.99	0.9	0.002936	0.9	0.12	0	0	0.08	0	0	0	4.009	0	0

Segment Observed Water Quality

Seg	Conserv Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Chl-a (ppb) Mean	CV	Secchi (m) Mean	CV	Organic N (ppb) Mean	CV	TP - Ortho P (ppb) Mean	CV	HOD (ppb/day) Mean	CV	MOD (ppb/day) Mean	CV
1	0	0	303.6111	0	0	0	79.13333	0	0.79445	0	0	0	105	0	0	0	0	0

Segment Calibration Factors

Seg	Dispersion Rate Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Chl-a (ppb) Mean	CV	Secchi (m) Mean	CV	Organic N (ppb) Mean	CV	TP - Ortho P (ppb) Mean	CV	HOD (ppb/day) Mean	CV	MOD (ppb/day) Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km^2	Flow (hm^3/yr) Mean	CV	Conserv. Mean	CV	Total P (ppb) Mean	CV	Total N (ppb) Mean	CV	Ortho P (ppb) Mean	CV	Inorganic N (ppb) Mean	CV
1	JG6	1	1	12.21	1.625	0	0	0	255	0	16033	0	148	0	0	0
2	JG8	1	1	3.92	0.424	0	0	0	228	0	1467	0	120	0	0	0
3	Swedes Bay Watershed	1	2	5.9383	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

Trib	Trib Name	Land Use Category---> 1	2	3	4	5
1	JG6	0	0	0	0	0
2	JG8	0	0	0	0	0
3	Swedes Bay Watershed	0.5736	2.824	0.4252	1.801	0.3141

Non-Point Source Export Coefficients

Categ	Land Use Name	Runoff (m/yr) Mean	CV	Conserv. Subs. Mean	CV	Total P (ppb) Mean
1	Forest	0.048	0	0	0	92.31
2	Agriculture	0.048	0	0	0	307.69
3	Urban	0.048	0	0	0	769.23
4	Grassland/Pasture	0.048	0	0	0	230.77
5	Wetland	0.048	0	0	0	76.92
6	Open Water	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	JG6	12.21	1.63	0.00E+00	0.00	0.133
2	1	1	JG8	3.92	0.42	0.00E+00	0.00	0.108
3	2	1	Swedes Bay Watershed	5.94	0.29	0.00E+00	0.00	0.048
PRECIPITATION				1.99	1.97	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				16.13	2.05	0.00E+00	0.00	0.127
NONPOINT INFLOW				5.94	0.29	0.00E+00	0.00	0.048
***TOTAL INFLOW				24.06	4.30	0.00E+00	0.00	0.179
ADVECTIVE OUTFLOW				24.06	2.33	0.00E+00	0.00	0.097
***TOTAL OUTFLOW				24.06	2.33	0.00E+00	0.00	0.097
***EVAPORATION					1.97	0.00E+00	0.00	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**

Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	JG6	414.4	11.6%	0.00E+00		0.00	255.0	33.9
2	1	1	JG8	96.7	2.7%	0.00E+00		0.00	228.0	24.7
3	2	1	Swedes Bay Watershed	81.1	2.3%	0.00E+00		0.00	284.4	13.7
PRECIPITATION				59.7	1.7%	8.91E+02	100.0%	0.50	30.3	30.0
INTERNAL LOAD				2913.9	81.7%	0.00E+00		0.00		
TRIBUTARY INFLOW				511.0	14.3%	0.00E+00		0.00	249.4	31.7
NONPOINT INFLOW				81.1	2.3%	0.00E+00		0.00	284.4	13.7
***TOTAL INFLOW				3565.7	100.0%	8.91E+02	100.0%	0.01	828.4	148.2
ADVECTIVE OUTFLOW				708.7	19.9%	6.23E+04		0.35	303.6	29.5
***TOTAL OUTFLOW				708.7	19.9%	6.23E+04		0.35	303.6	29.5
***RETENTION				2857.1	80.1%	6.29E+04		0.09		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.1525
Hydraulic Resid. Time (yrs)	0.7673	Turnover Ratio	6.6
Reservoir Conc (mg/m3)	304	Retention Coef.	0.801

2. Files for Modeled Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Swedes Bay	0	1	1.99	0.9	0.002936	0.9	0.12	0	0	0.08	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	54	0	0	0	20	0	1	0	0	0	105	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	JG6	1	1	12.21	1.625	0	0	0	96.83	0	16033	0	148	0	0	0
2	JG8	1	1	3.92	0.424	0	0	0	96.83	0	1467	0	120	0	0	0
3	Swedes Bay Watershed	1	2	5.9383	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	JG6	0	0	0	0	0	0
2	JG8	0	0	0	0	0	0
3	Swedes Bay Watershed	0.5736	2.824	0.4252	1.801	0.3141	0

Non-Point Source Export Coefficients

	Runoff (m/yr)		Conserv. Subs.		Total P (ppb)	
Categ Land Use Name	Mean	CV	Mean	CV	Mean	CV
1 Forest	0.048	0	0	0	31.43	0
2 Agriculture	0.048	0	0	0	104.76	0
3 Urban	0.048	0	0	0	261.9	0
4 Grassland/Pasture	0.048	0	0	0	78.57	0
5 Wetland	0.048	0	0	0	26.19	0
6 Open Water	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	JG6	12.21	1.63	0.00E+00	0.00	0.133
2	1	1	JG8	3.92	0.42	0.00E+00	0.00	0.108
3	2	1	Swedes Bay Watershed	5.94	0.29	0.00E+00	0.00	0.048
PRECIPITATION				1.99	1.97	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				16.13	2.05	0.00E+00	0.00	0.127
NONPOINT INFLOW				5.94	0.29	0.00E+00	0.00	0.048
***TOTAL INFLOW				24.06	4.30	0.00E+00	0.00	0.179
ADVECTIVE OUTFLOW				24.06	2.33	0.00E+00	0.00	0.097
***TOTAL OUTFLOW				24.06	2.33	0.00E+00	0.00	0.097
***EVAPORATION					1.97	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: **Predicted TOTAL P** **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	JG6	157.3	55.1%	0.00E+00		0.00	96.8	12.9
2	1	1	JG8	41.1	14.4%	0.00E+00		0.00	96.8	10.5
3	2	1	Swedes Bay Watershed	27.6	9.7%	0.00E+00		0.00	96.8	4.6
PRECIPITATION				59.7	20.9%	8.91E+02	100.0%	0.50	30.3	30.0
TRIBUTARY INFLOW				198.4	69.4%	0.00E+00		0.00	96.8	12.3
NONPOINT INFLOW				27.6	9.7%	0.00E+00		0.00	96.8	4.6
***TOTAL INFLOW				285.7	100.0%	8.91E+02	100.0%	0.10	66.4	11.9
ADVECTIVE OUTFLOW				125.9	44.1%	1.07E+03		0.26	54.0	5.2
***TOTAL OUTFLOW				125.9	44.1%	1.07E+03		0.26	54.0	5.2
***RETENTION				159.8	55.9%	1.37E+03		0.23		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.3382
Hydraulic Resid. Time (yrs)	0.7673	Turnover Ratio	3.0
Reservoir Conc (mg/m3)	54	Retention Coef.	0.559

E. German Lake

1. Files for Existing Conditions:

Global Variables

	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	East Jefferson Outflow	42.21	2.64	0.00E+00	0.00	0.063
2	1	1	TMDL Inflow Site JG7	12.52	1.30	0.00E+00	0.00	0.104
3	2	1	German Lake Watershed	3.20	0.15	0.00E+00	0.00	0.048
PRECIPITATION				3.46	3.43	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				54.73	3.94	0.00E+00	0.00	0.072
NONPOINT INFLOW				3.20	0.15	0.00E+00	0.00	0.048
***TOTAL INFLOW				61.39	7.52	0.00E+00	0.00	0.122
ADVECTIVE OUTFLOW				61.39	4.09	0.00E+00	0.00	0.067
***TOTAL OUTFLOW				61.39	4.09	0.00E+00	0.00	0.067
***EVAPORATION					3.43	0.00E+00	0.00	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**

Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	East Jefferson Outflow	177.1	12.0%	0.00E+00		0.00	67.1	4.2
2	1	1	TMDL Inflow Site JG7	462.4	31.3%	0.00E+00		0.00	356.3	36.9
3	2	1	German Lake Watershed	41.5	2.8%	0.00E+00		0.00	270.3	13.0
PRECIPITATION				103.8	7.0%	2.70E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				691.6	46.8%	0.00E+00		0.00		
TRIBUTARY INFLOW				639.6	43.3%	0.00E+00		0.00	162.4	11.7
NONPOINT INFLOW				41.5	2.8%	0.00E+00		0.00	270.3	13.0
***TOTAL INFLOW				1476.5	100.0%	2.70E+03	100.0%	0.04	196.4	24.1
ADVECTIVE OUTFLOW				267.2	18.1%	9.27E+03		0.36	65.3	4.4
***TOTAL OUTFLOW				267.2	18.1%	9.27E+03		0.36	65.3	4.4
***RETENTION				1209.3	81.9%	1.14E+04		0.09		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.5818
Hydraulic Resid. Time (yrs)	3.2150	Turnover Ratio	1.7
Reservoir Conc (mg/m3)	65	Retention Coef.	0.819

2. Files for Modeled Conditions:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.99	0.0
Evaporation (m)	0.99	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Geman Lake	0	1	3.4616	3.8	2.31	3.7	0.12	8.5	0	0.08	0	0	0	0.0547	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	36	0	0	0	14	0	1.4	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	East Jefferson Outflow	1	1	42.2097	2.64	0	0	0	40	0	0	0	0	0	0	0
2	TMDL Inflow Site JG7	1	1	12.52	1.298	0	0	0	209.74	0	0	0	0	0	0	0
3	German Lake Watershed	1	2	3.1984	0	0	0	0	0	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->					
Trib	Trib Name	1	2	3	4	5	6
1	East Jefferson Outflow	0	0	0	0	0	0
2	TMDL Inflow Site JG7	0	0	0	0	0	0
3	German Lake Watershed	0.3995	0.8594	0.2847	1.4112	0.2437	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)	
Categ	Land Use Name	Mean	CV	Mean	CV	Mean	CV
1	Forest	0.048	0	0	0	71.62	0
2	Agriculture	0.048	0	0	0	238.71	0
3	Urban	0.048	0	0	0	596.79	0
4	Grassland/Pasture	0.048	0	0	0	179.04	0
5	Wetland	0.048	0	0	0	59.68	0
6	Open Water	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	East Jefferson Outflow	42.21	2.64	0.00E+00	0.00	0.063
2	1	1	TMDL Inflow Site JG7	12.52	1.30	0.00E+00	0.00	0.104
3	2	1	German Lake Watershed	3.20	0.15	0.00E+00	0.00	0.048
PRECIPITATION				3.46	3.43	0.00E+00	0.00	0.990
TRIBUTARY INFLOW				54.73	3.94	0.00E+00	0.00	0.072
NONPOINT INFLOW				3.20	0.15	0.00E+00	0.00	0.048
***TOTAL INFLOW				61.39	7.52	0.00E+00	0.00	0.122
ADVECTIVE OUTFLOW				61.39	4.09	0.00E+00	0.00	0.067
***TOTAL OUTFLOW				61.39	4.09	0.00E+00	0.00	0.067
***EVAPORATION					3.43	0.00E+00	0.00	

Overall Mass Balance Based Upon **Predicted** **Outflow & Reservoir Concentrations**
Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	East Jefferson Outflow	105.6	18.1%	0.00E+00		0.00	40.0	2.5
2	1	1	TMDL Inflow Site JG7	272.2	46.7%	0.00E+00		0.00	209.7	21.7
3	2	1	German Lake Watershed	32.2	5.5%	0.00E+00		0.00	209.7	10.1
PRECIPITATION				103.8	17.8%	2.70E+03	100.0%	0.50	30.3	30.0
INTERNAL LOAD				69.2	11.9%	0.00E+00		0.00		
TRIBUTARY INFLOW				377.8	64.8%	0.00E+00		0.00	95.9	6.9
NONPOINT INFLOW				32.2	5.5%	0.00E+00		0.00	209.7	10.1
***TOTAL INFLOW				583.1	100.0%	2.70E+03	100.0%	0.09	77.5	9.5
ADVECTIVE OUTFLOW				147.3	25.3%	2.42E+03		0.33	36.0	2.4
***TOTAL OUTFLOW				147.3	25.3%	2.42E+03		0.33	36.0	2.4
***RETENTION				435.7	74.7%	4.22E+03		0.15		

Overflow Rate (m/yr)	1.2	Nutrient Resid. Time (yrs)	0.8125
Hydraulic Resid. Time (yrs)	3.2150	Turnover Ratio	1.2
Reservoir Conc (mg/m3)	36	Retention Coef.	0.747

Appendix F. Monitoring Parameters

A. Phosphorus (P):

Phosphorus data was collected via grab samples at inflow/out flow sites using sterile bottles supplied through Minnesota Valley Testing Laboratories, Inc. (MVTL). Lake samples were taken two meters below the water surface at a geo-located position using a two meter long integrated sampler. Additional in-lake samples were taken below the thermocline during periods of thermal stratification on three deepest lake basins (West Jefferson, East Jefferson, and German) using a Van Dorn sampler. The P samples were then delivered to MVTL in New Ulm and analyzed for both TP and OP concentrations (Table F.1).

B. Nitrogen(N):

Nitrogen data was collected very similarly to the P data; using grab samples at the inflow/outflow sites, in-lake water quality samples were not analyzed for their N content. The N samples were analyzed for nitrate-nitrite (Table F.1).

C. Chlorophyll-a (Chl-a) (with phaeophytin correction):

Chl-a data was also collected at the JGC sites using the below surface sample method. Chl-a was not sampled at the inflow/outflow sites. All samples were collected, and then temporarily stored in an opaque plastic or amber glass bottle to prevent any additional development or breakdown of the Chl-a within the sample (Table F.1).

D. Temperature, Dissolved Oxygen (DO), Specific Conductance (SCond), and pH:

Temperature, DO, SCond, and pH data were collected using a YSI 6820 V2 Data Sonde connected to a YSI 650 multiparameter handheld display unit. This unit was equipped with a 23 m (75 ft.) cable that allowed vertical profiles to be taken of the entire water column at 1 meter wed to equilibrate at each depth interval until a constant reading was achieved (Table F.1).

E. Secchi Depth:

The Secchi disk is a flat, circular object used to measure water transparency in oceans and lakes. The disc is divided into four evenly spaced sections alternating with colors of black and white. The disc is mounted on a pole or line, and lowered down in the water. The depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity (Table 4.2).

Table F.1. Sample method information.

Analyte	Sample Quantity	Sample Container	Preservative	Holding Time	Analytical Method
Chlorophyll a	1 L	Amber glass	Cool to 4°C	4 H[†]	SM* 10200 H
Total Phosphorus	500 mL	Plastic	H_2SO_4 to pH <2, Cool to 4°C	28 D	EPA 365.1 Rev 2.0
Ortho- Phosphorus	500 mL	Plastic	Cool to 4°C	2 D	EPA 365.1 Rev 2.0
Nitrate + Nitrite	250 mL	Plastic	H_2SO_4 to pH <2, Cool to 4°C	28 D	EPA 353.2 Rev 2.0
Total Suspended Solids	500 mL	Plastic	Cool to 4°C	7 D	USGS I-3765-85

[†]May be stored on ice in the dark for up to 48 hrs. prior to analysis, otherwise, filter within 48 hrs. and store frozen at ≤ -20