2013-03-20

A Trophic State Analysis of Lakes in Yellowstone National Park

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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March 2013

ABSTRACT

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Eutrophication is of interest in the field of water quality. Eutrophic lakes, when used as sources for drinking water, can cause problems during the treatment process, for example algae blooms can clog filters, requiring more water and energy to be used during the cleaning and backwashing of the filters. Excess nutrient loading and eutrophication can also harm fish and aquatic life habitats. Certain species of algae and cyanobacteria can be toxic to humans as well.

Since 1998, Dr. A. Woodruff Miller has collected water samples from 46 lakes and ponds in Yellowstone National Park. The Carlson Trophic State Index, the Vollenweider Model, the Larsen Mercier Model, the Burns Trophic Level Index, and the Naumann Trophic Scale were then used to assign each lake or pond to a trophic state classification (Oligotrophic, Mesotrophic, Eutrophic, and Hyper-Eutrophic).

Of the 46 total lakes and ponds that have been tested over the past 14 years, five lakes are classified as slightly oligotrophic, implying that the waters are relatively clear and free from nutrient pollution. Of the 46 lakes, 19 are classified as slightly mesotrophic, mesotrophic, or strongly mesotrophic. These classifications imply that the waters are moderately clear and contain some nutrient pollution. Of the 46 lakes, 14 are classified as slightly eutrophic, eutrophic, or strongly eutrophic. This implies that the waters have high turbidity and nutrient content. Of the 46 lakes, 8 are classified as slightly hyper-eutrophic or hyper-eutrophic. These lakes are noticeable for their high algae content with very high nutrient content. These classifications are based on the most recent year sampled.

Keywords: Yellowstone National Park, eutrophication, trophic state

ACKNOWLEDGMENTS

I would like to start off by thanking my graduate committee, Dr. Gus P. Williams and M. Brett Borup, as well as my committee chair, Dr. A. Woodruff Miller. They all played a significant role in the successful completion of this thesis. Dr. Miller allowed me to bounce all my random ideas off of him with a fair amount of encouragement. I would also like to thank the US Bureau of Reclamation, Regional Laboratory in Boise, ID for the analysis and results for chlorophyll-a concentrations. Lastly I would like to thank my wonderful wife, Jamie, for allowing me to put in long nights at the school. I could not have done it without her.

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1 INTRODUCTION

The purpose of this document is to compare and analyze the nutrient levels of a number of lakes and ponds located in Yellowstone National Park, and to then classify them according to their trophic state. Dr. Woodruff Miller, since 1998, has collected water samples from 46 lakes or ponds and their inlets where applicable. These water samples were then tested for phosphorus and chlorophyll-a concentrations. These values are used as parameters to determine the corresponding trophic states of the lakes and ponds under analysis.

Trophic state analyses have become an area of interest in the field of water quality. This is primarily due to the effects certain nutrients have on the biosphere and the biodynamic cycle of a lake. As nutrients, such as phosphorus and nitrogen, enter lakes and streams, existing algae, phytoplankton, and other forms of life begin to react and multiply. The algae and other forms of life grow until there are no longer sufficient nutrients in the water. They then die and settle to the bottom of the lake where they are digested by worms and other microorganisms. After digestion, the nutrients solubilize and rise back to the surface, thus rendering themselves available for further algae and phytoplankton growth. This process is called the biodynamic cycle and is shown in Figure 1.1 (Sawyer 1966).

The biodynamic cycle and the effects surplus nutrients have on the lake biosphere are significant. In cases of a high level of nutrients (phosphorus primarily), algae tends to grow in large colonies called blooms. These blooms, when incorporated in water to be treated, have the tendency to clog water treatment filters, clog intake structures, and cause taste and odor problems in the water (Mines and Lackey 2009).

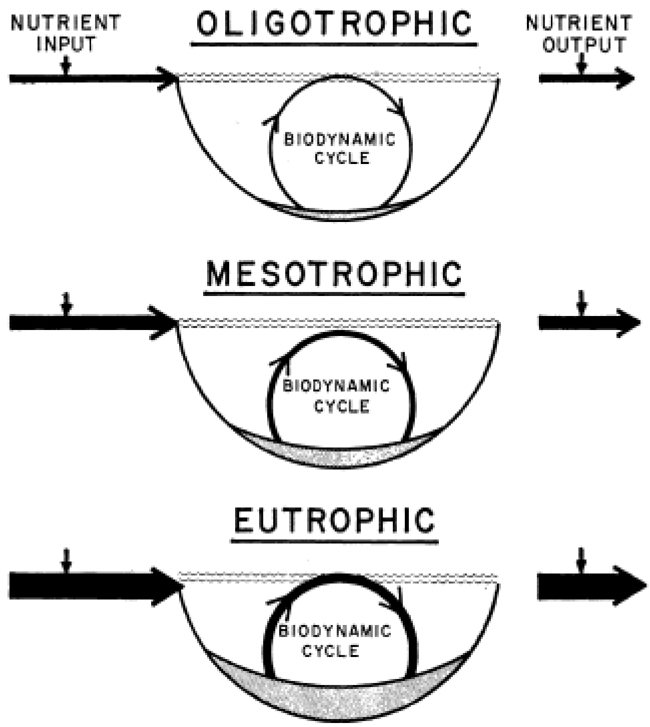

Figure 1.1: Biodynamic cycle (Sawyer 1966)

This particular analysis involved the application of five different eutrophication models in order to determine an overall average trophic state classification. These models were the Carlson Model, the Vollenweider Model, the Larsen-Mercier Model, the Burns Model, and the Naumann Model. All five models look at total phosphorus (TP) as one of the determining parameters. The Carlson and Burns Models also use Secchi depth and chlorophyll-a concentration. The Vollenweider and Larsen-Mercier Models are based on a mass balance approach. They look at inlet phosphorus and the time or concentration of TP that remains inlake. These parameters will be described more in depth later in this document.

1.1 **Eutrophication**

It is necessary to define eutrophication and why efforts have been made in attenuating this process. Eutrophication is defined as the process in which, “Over time, a build up of nutrients, organics, and sediments leads to natural aging or eutrophication of a lake or body of water (Mines and Lackey 2009).” In short, eutrophication is the process in which a lake or pond progresses from a clear body of water to a swamp or marsh and then ultimately dry land. This quote describes eutrophication as the natural aging of a lake; while that is true, there are two sources of eutrophication that are of importance in the discussion of water quality: natural and anthropogenic. The natural process is one that tends to require a long time period, whereas the anthropogenic process occurs at an accelerated rate.

It was proposed by Rìos that the chemical composition of particulate organic matter is:

$$C_{106}H_{177}O_{59}N_{15}Si_{6}P_{1.2} \tag{1-1}$$

This composition is up for debate as others have proposed different ratios (Tanoue 1985, Armas 1981), but the elemental makeup is the same. According to Sawyer, “…the principal components of all aquatic life are carbon, hydrogen, oxygen, nitrogen, and phosphorus (Sawyer 1966).” In addition to Sawyer’s statement the above equation also refers to silicon in the composition. While carbon, hydrogen, and oxygen come from water, photosynthesis and the atmosphere, nitrogen and phosphorus may derive from other external sources. Some of these sources can include agriculture, stormwater, wastewater, fossil fuels, and, in urban settings, yard and pet waste (EPA, Sources and Solutions 2012).

Eutrophication is of interest in the field of water quality. Eutrophic lakes, when used as sources for drinking water, can cause problems during the treatment process, for example algae blooms can clog filters, requiring more water and energy to be used during the cleaning and backwashing of the filters (Lund 1972). Excess nutrient loading and eutrophication can also harm fish and aquatic life habitats (EPA, The Problem 2013). Certain species of algae and cyanobacteria can be toxic to humans as well (Sharpley, et al. 2003).

1.2 Trophic State Classifications

As eutrophication is increasingly becoming an area of interest, it is necessary to develop methods for monitoring and classifying the eutrophication process. The EPA has created four classifications based on nutrient concentration and biological productivity (EPA, Classifications n.d.). These classifications are oligotrophic, mesotrophic, eutrophic, and hyper-eutrophic.

Table 1.1: Characteristics of the trophic state classifications (EPA, Classifications n.d.)

Lake Trophic Classification	Nutrient Concentration	Biological Productivity
Oligotrophic	Low	Low
Mesotrophic	Moderate	Moderate
Eutrophic	High	High
Hyper-eutrophic	Very High	Very High

Eutrophication can also be described as the process in which a body of water progresses from Oligotrophic, to Mesotrophic, to Eutrophic, and eventually to extinction (Sawyer 1966). Oligotrophic lakes though clear, beautiful, and serve well as a water source, are not always the ideal habitat for fish and other aquatic biota. Eutrophic and hyper-eutrophic lakes are also not ideal as they greatly reduce or eliminate the oxygen in the water. A mesotrophic state seems to be ideal for plant, animal, and human life (EPA, The Problem 2013).

1.2.1 Carlson Trophic State Index

In February of 1975, Robert E. Carlson proposed an index method for determining the trophic state of a lake based on the Secchi depth, chlorophyll-a concentration, and total phosphorus concentration. This system was designed in order to simplify some of the more complex multi-parametered models that are sometimes used in the field. While these models are beneficial, they are sometimes avoided due to the number of parameters that must be measured. For this reason Carlson developed an index based on just a few parameters. His model was tried and tested on many lakes located in Minnesota (Carlson 1977).

The Carlson Trophic State Index (TSI) is calculated by using three empirical equations, each based on one of the parameters listed above, and then taking the average of those three equations. The empirical equations used are defined below:

$$TSI_{SD} = 60 - 14.41LN(SD) \quad (1\text{-}2)$$

$$TSI_{Chla} = 9.81LN(Chla) + 30.6 \quad (1\text{-}3)$$

$$TSI_{TP} = 14.42LN(TP) + 4.15 \quad (1\text{-}4)$$

$$TSI_{tot} = \frac{(TSI_{SD}+TSI_{Chla}+TSI_{TP})}{3} \quad (1\text{-}5)$$

where: Chla = Chlorophyll-a concentration (µg/L)

SD = Secchi disk depth (meters)

TP = Total phosphorus concentration (µg/L)

TSI = Trophic State Index

The Carlson Model was implemented in this study for all inlake samples. As a method was not specified in Carlson's document (Carlson 1977), analysis of the inlet and outlet is omitted. The TSI was then used to determine the trophic state classification based on the following criteria:

Table 1.2: Trophic state classifications based on Carlson TSI

Classification	Sub-Classification	Trophic State Index
Oligotrophic	Strongly Oligotrophic	0-25
	Oligotrophic	26-32
	Slightly Oligotrophic	33-37
Mesotrophic	Slightly Mesotrophic	38-42
	Mesotrophic	43-48
	Strongly Mesotrophic	49-53
Eutrophic	Slightly Eutrophic	54-57
	Eutrophic	58-61
	Strongly Eutrophic	62-64
Hyper-eutrophic	Hyper-eutrophic	65+

1.2.2 Vollenweider Model

The Vollenweider Model was created as the result of a study performed on many lakes in Europe and the Scandinavian countries. The purpose of the study was to monitor the effect of nitrogen and phosphorus in the eutrophication process. It was concluded that "nitrogen and phosphorus appear to be the most important among the nutrients responsible for eutrophication. Phosphorus is usually the initiating factor while other substances including potassium, magnesium, sulphates, and trace elements (cobalt, molybdenum, copper, zinc, boron, iron, manganese, etc.), together with organic growth factors, probably also play a part (Vollenweider 1970)."

The Vollenweider Model uses total phosphorus measured at the lake inlets and hydraulic residence time as parameters. The hydraulic residence time is a calculated value used to represent how long a drop of water remains in storage within the lake. This value is used to determine an approximation of the time the phosphorus remains in the lake. The hydraulic residence time is calculated by:

$$\theta = \frac{V}{Q} \tag{1-6}$$

where: θ = Hydraulic Residence Time (years)

V = total volume of the lake (ft^3)

Q = total inlet flow (ft^3/yr)

The trophic state classifications were then determined by plotting the inlet phosphorus concentration versus the hydraulic residence time on a log-log scale. The lakes are then classified based on the plot location.

1.2.3 Larsen Mercier Model

The Larsen Mercier Model uses the hydrodynamics of the lake in order to determine its trophic state. The phosphorus retention coefficient (PRC) is calculated by Equation (1-11).

$$PRC = \frac{(P_{Inlet} - P_{Outlet})}{P_{Inlet}} \tag{1-7}$$

where: PRC = phosphorus retention coefficient

P_{Inlet} = Inlet phosphorus concentration (mg/L)

P_{Outlet} = Outlet phosphorus concentration (mg/L)

It is important to note that, in the case of the lack of an outlet sample, the inlake phosphorus concentration was used as this has been the method in previous years' studies

(Albrecht 2012). The trophic state classification was then selected by plotting the inlet phosphorus concentration versus the PRC. The location of the plot determined the classification.

1.2.4 Burns Trophic Level Index

A study was performed from February 1992 to June 1996 by Noel M. Burns as part of the New Zealand Lakes Water Quality Monitoring Programme (NZLMP). This study involved the sampling of 23 New Zealand lakes, 17 of the 23 under close monitoring for 3 to 4 years. A variety of lake types were tested in this study in order to obtain a wide range of sampling (size, depth).

Equations were developed as a product of this study (Burns, Rutherford and Clayton 2009). These equations are shown below.

$$TL_c = 2.22 + 2.54\log(Chla) \tag{1-8}$$

$$TL_s = 5.10 + 2.27\log\left(\frac{1}{SD} - \frac{1}{40}\right) \tag{1-9}$$

$$TL_p = 0.218 + 2.92\, log(TP) \tag{1-10}$$

$$TLI = \frac{1}{3}\left(TL_c + TL_p + TL_s\right) \tag{1-11}$$

where: Chla = Chlorophyll-a concentration (µg/L)

SD = Secchi depth (meters)

TP = Total Phosphorus concentration (µg/L)

TLI = Trophic Level Index

Table 1.2 shows the trophic state classifications based on the trophic level index (TLI) (Earthsoft 2012). A higher TLI indicates a higher nutrient activity and thus a higher trophic classification. The analysis of Yellowstone lakes required a normalization of Table 1.2, so as to facilitate the comparison of classifications used in other models. The seven lake classifications depicted in Table 1.2 were re-divided to four classifications, each with three sub-classifications. The results are shown in Table 1.3.

Table 1.3: Trophic state classifications based on Burns TLI (Earthsoft 2012)

Lake Classification	Trophic Level
Ultra-microtrophic	0.0-1.0
Microtrophic	1.0-2.0
Oligotrophic	2.0-3.0
Mesotrophic	3.0-4.0
Eutrophic	4.0-5.0
Supertrophic	5.0-6.0
Hypertrophic	6.0-7.0

Table 1.4: Sub-classifications of Burns TLI (Albrecht 2012)

Classification	Sub-Classification	Trophic Level
Oligotrophic	Strongly Oligotrophic	0.0-2.0
	Oligotrophic	2.0-2.7
	Slightly Oligotrophic	2.7-3.0
Mesotrophic	Slightly Mesotrophic	3.0-3.3
	Mesotrophic	3.3-3.7
	Strongly Mesotrophic	3.7-4.0
Eutrophic	Slightly Eutrophic	4.0-4.5
	Eutrophic	4.5-5.0
	Strongly Eutrophic	5.0-5.5
Hyper-eutrophic	Slightly Hyper-eutrophic	5.5-6.0
	Hyper-eutrophic	6.0-6.5

1.2.5 Naumann Trophic Scale

The 2011 sampling year was the first year in which the Naumann trophic scale was applied to analyze the trophic state of the lakes in Yellowstone. The Naumann trophic scale was developed as a result of a study performed on the Great Lakes. This study was completed by Steven C. Chapra and Hugh F. H. Dobson. The purpose of the study was to determine a method of relating surface water quality and hypolimnetic dissolved oxygen depletion with overall trophic state. The surface water portion was inspired by the work of Einar Naumann. The method uses Secchi depth, chlorophyll-a concentration, total phosphorus concentration, and primary production as parameters for determining the trophic state classification. The primary production parameter is one that represents the carbon reduction at the surface of the water, and the areal oxygen depletion. Primary production is calculated by equation (1-12).

$$Pr = 420(1 - e^{-0.148Chla}) \tag{1-12}$$

where: Pr = primary production

Chla = chlorophyll-a concentration (µg/L)

The Naumann trophic scale is then calculated by the following equations:

$$TI_P = 0.461p \tag{1-13}$$

$$TI_{Chla} = 1.78Chla \tag{1-14}$$

$$TI_{Pr} = 12.0ln\frac{420}{420-Pr} \tag{1-15}$$

$$TI_S = \frac{36.8}{S} - 2.27 \tag{1-16}$$

where: S = Secchi depth (meters)

TI = Naumann Trophic Index

P = phosphorus concentrations (ppb)

As this is the first year in which this method has been used for the lakes in Yellowstone, it is uncertain if it will provide a good representation of the overall trophic state trends.

2 2011 RESULTS FROM YELLOWSTONE NATIONAL PARK SAMPLING

2.1 Beaver Lake

Beaver Lake is a relatively small lake located just west of Highway 89 (Grand Loop Rd). In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. All measurements were made in the month of August.

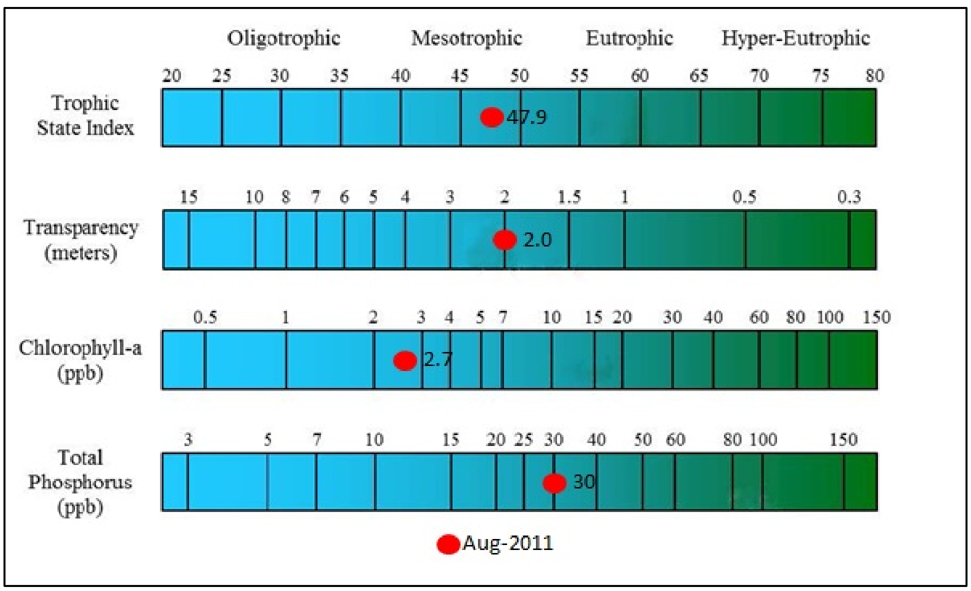

Figure 2.1: 2011 Carlson TSI results for Beaver Lake

Figure 2.1 shows the results from the Carlson TSI Model for Beaver Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 47.9, which represents a mesotrophic classification according to the Carlson TSI Model.

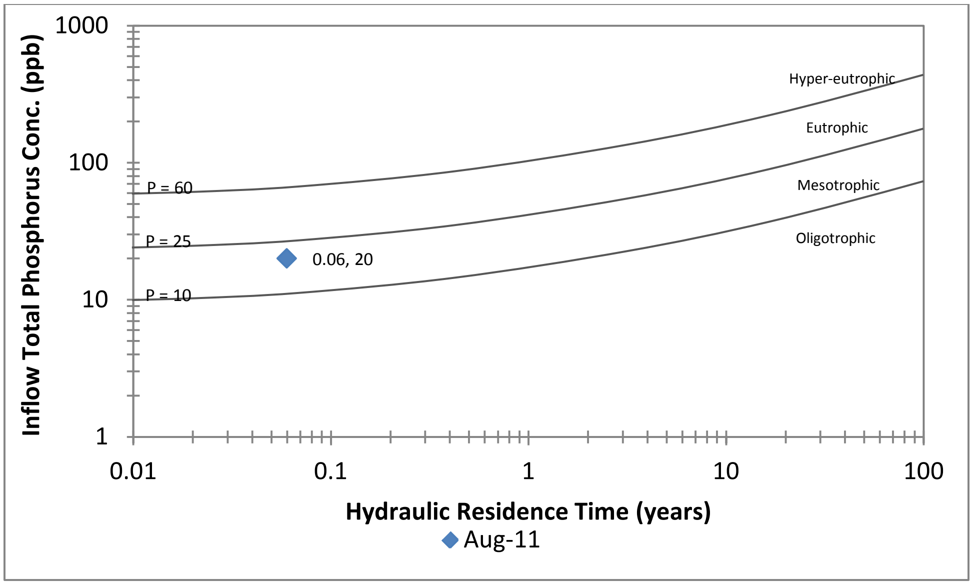

Figure 2.2: 2011 Vollenweider Model results for Beaver Lake

Figure 2.2 shows the results from the Vollenweider Model for Beaver Lake. The hydraulic residence time was calculated to be 0.06 years and the inflow total phosphorus concentration was measured to be 20 ppb. As can be seen from the figure, these values represent a mesotrophic classification based on the Vollenweider Model.

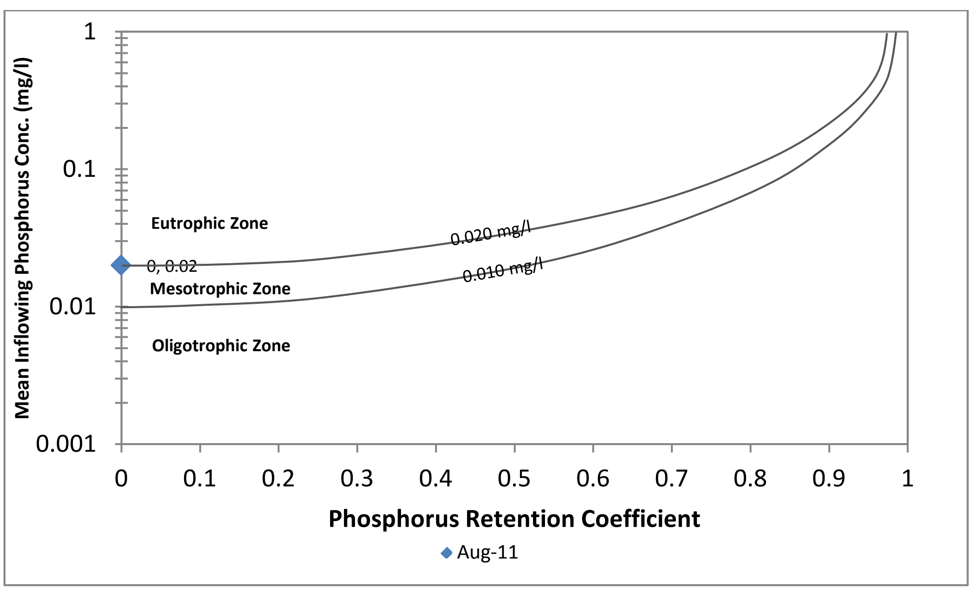

Figure 2.3: 2011 Larsen Mercier Model results for Beaver Lake

Figure 2.3 depicts the results from the Larsen Mercier Model for Beaver Lake. A PRC value of zero was used as the inlake phosphorus measured higher than the inlet phosphorus. This could be due to the particular inlake sample location or for some other reason. It is beyond the scope of this paper to give an explanation for this phenomenon. The inlet phosphorus concentration was measured to be 0.02 mg/L. As can be seen from the figure, these values represent a strongly mesotrophic classification based on the Larsen Mercier Model.

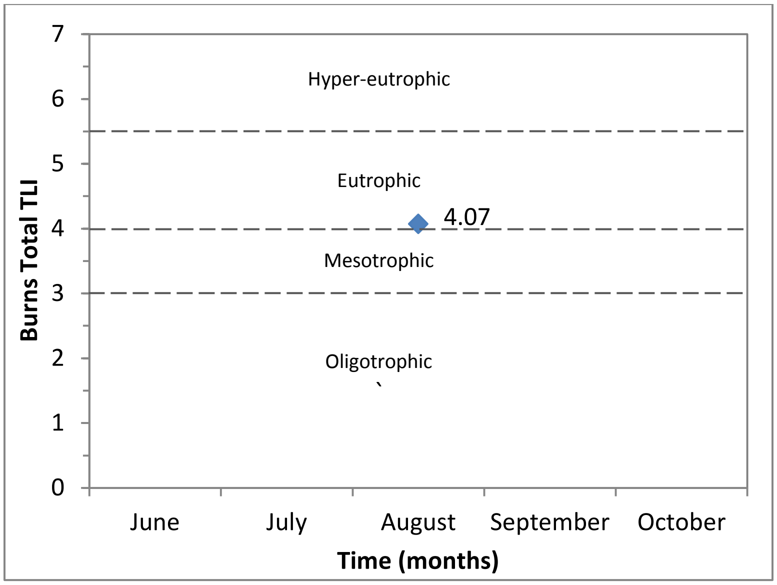

Figure 2.4: 2011 Burns TLI results for Beaver Lake

Figure 2.4 shows the results from the Burns TLI Model for Beaver Lake. For the month of August, the Burns TLI value was calculated to be 4.07. This value falls within the slightly eutrophic classification according to the Burns TLI Model.

Figure 2.5 depicts the Naumann Trophic Scale results for Beaver Lake for the month of August. The Naumann Trophic Scale was calculated to be 9.89 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value classifies Beaver Lake as strongly mesotrophic based on the Naumann Trophic Scale Model.

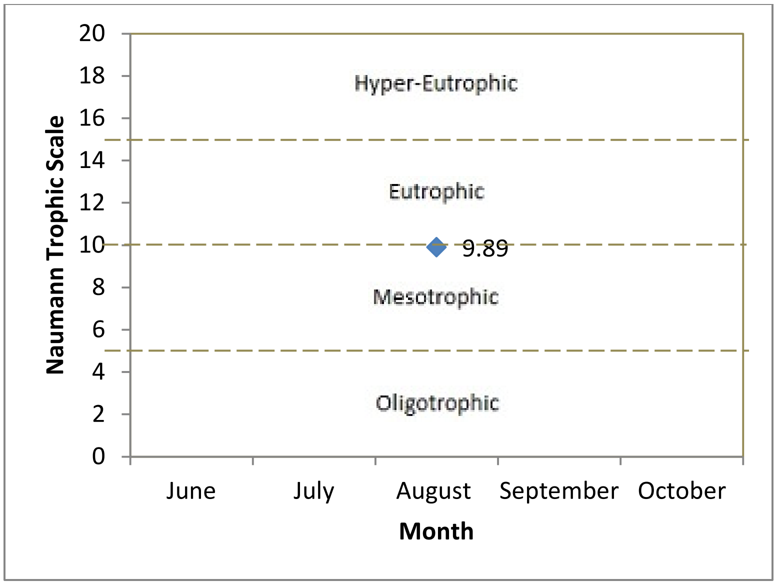

Figure 2.5: 2011 Naumann Trophic Scale results for Beaver Lake

Table 2.1: 2011 results for Beaver Lake

Model	*June*	*July*	*August*	*October*	*Four-Month Average*
Carlson	-	-	Mesotrophic	-	Mesotrophic
Vollenweider	-	-	Mesotrophic	-	Mesotrophic
Larsen-Mercier	-	-	Strongly Mesotrophic	-	Strongly Mesotrophic
Burns	-	-	Slightly Eutrophic	-	Slightly Eutrophic
Naumann	-	-	Strongly Mesotrophic	-	Strongly Mesotrophic
Monthly-Average	-	-	Strongly Mesotrophic	-	**Strongly Mesotrophic**

Table 2.1 summarizes the results for Beaver Lake. As each model was used to classify Beaver Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Beaver Lake as strongly mesotrophic.

2.2 **Blacktail Pond**

Blacktail Pond is a relatively small pond located just north of Highway 212 (Grand Loop Rd) near Mammoth, Wyoming. In 2011, phosphorus, chlorophyll-a, and Secchi depth were measured at only an inlake location. All measurements were made in the month of August.

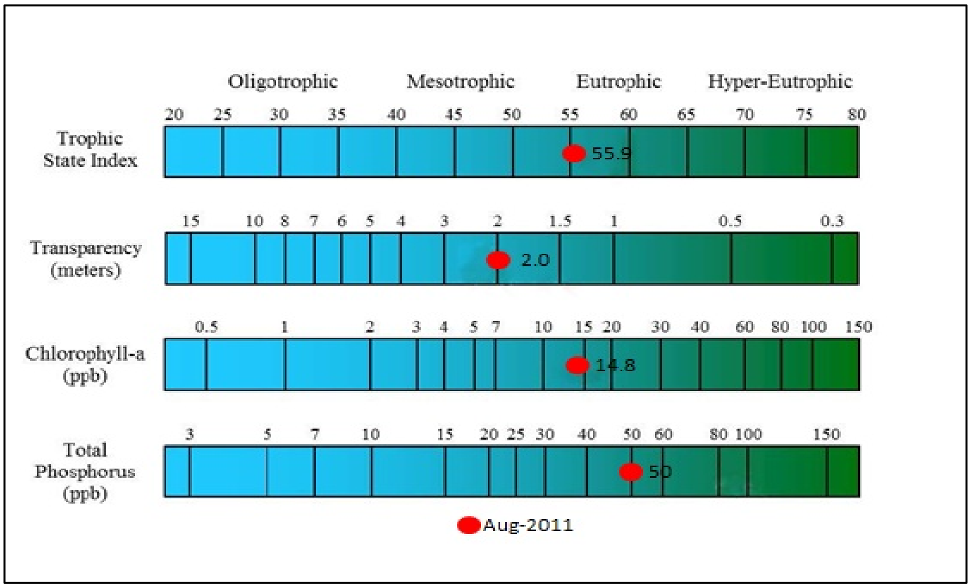

Figure 2.6: 2011 Carlson TSI results for Blacktail Pond

Figure 2.6 shows the results from the Carlson TSI Model for Blacktail Pond. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 55.9, which represents a slightly eutrophic classification according to the Carlson TSI Model.

The trophic state according to the Vollenweider and Larsen Mercier Models were not analyzed as no inlet data were available for Blacktail Pond in 2011. Figure 2.7 shows the results from the Burns TLI Model for Blacktail Pond. For the month of August, the Burns TLI value was calculated to be 4.91. This value falls within the eutrophic classification according to the Burns TLI Model.

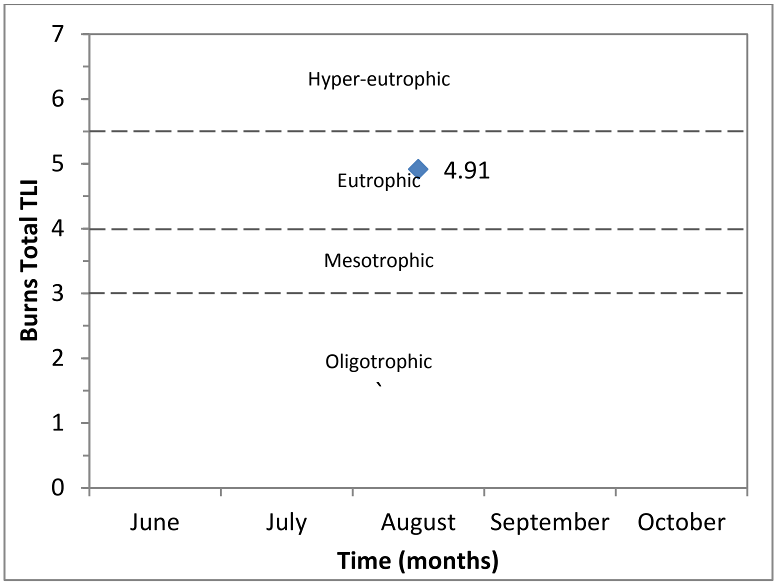

Figure 2.7: 2011 Burns TLI results for Blacktail Pond

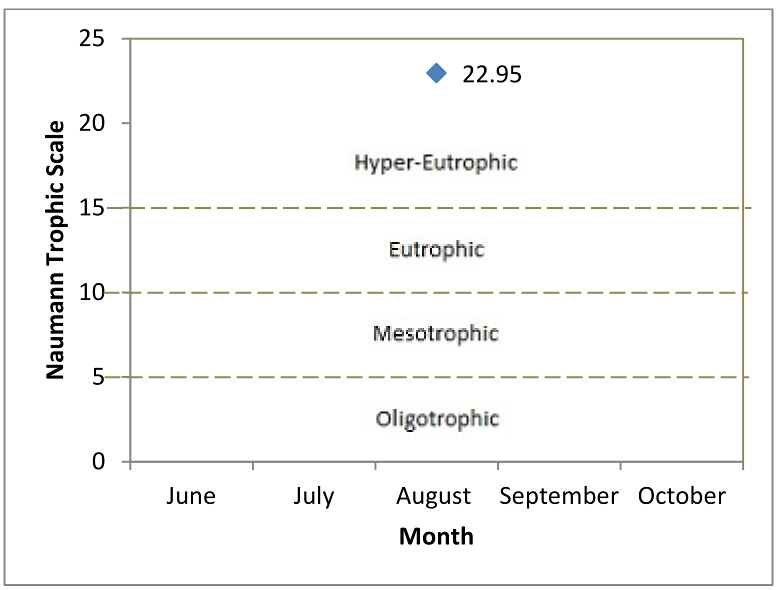

Figure 2.8: 2011 Naumann Trophic Scale results for Blacktail Pond

Figure 2.8 depicts the Naumann Trophic Scale results for Blacktail Pond for the month of August. The Naumann Trophic Scale was calculated to be 22.95 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value classifies Blacktail Pond as hyper-eutrophic based on the Naumann Trophic Scale Model.

Table 2.2: 2011 results for Blacktail Pond

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	Slightly Eutrophic	-	Slightly Eutrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	Eutrophic	-	Eutrophic
Naumann	-	-	Hyper-Eutrophic		Hyper-Eutrophic
Monthly-Average	-	-	Strongly Eutrophic	-	**Strongly Eutrophic**

Table 2.2 summarizes the results for Blacktail Pond. As each model was used to classify Blacktail Pond into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Blacktail Pond as strongly eutrophic. It is important to note that the Naumann Trophic Scale value of hyper-eutrophic may be a potential outlier as both the Burns and Carlson Models classified Blacktail Pond as eutrophic.

2.3 Buck Lake

Buck Lake is a relatively small lake located just west of Highway 212 near the NE Entrance. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June, July, August, and October.

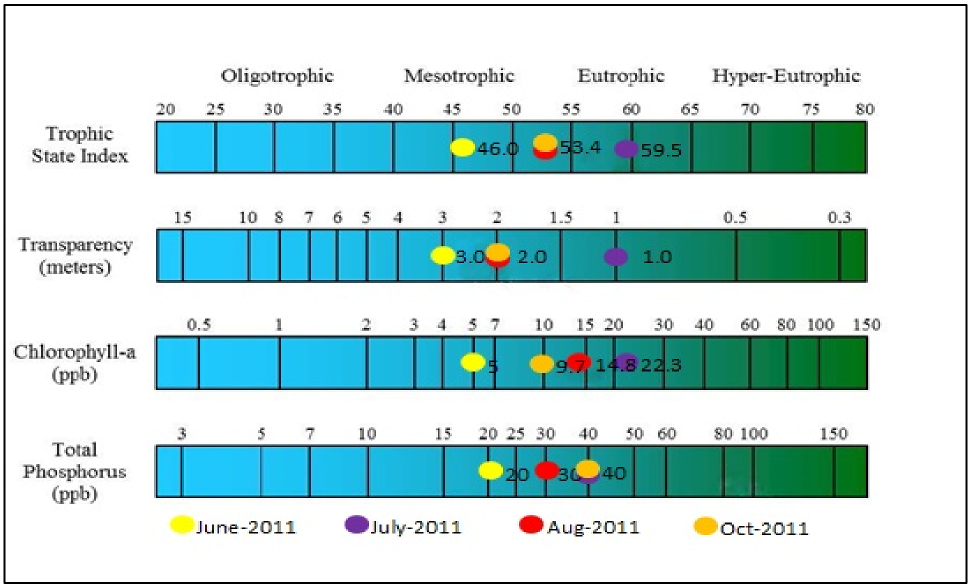

Figure 2.9: 2011 Carlson TSI results for Buck Lake

Figure 2.9 shows the results from the Carlson TSI Model for Buck Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 46.0 for the month of June, 53.4 for the months of October and August, and 59.5 for the month of July. The four-month average TSI was calculated to be 52.3 which falls under the strongly mesotrophic classification according to the Carlson TSI Model.

Figure 2.10 shows the results from the Vollenweider Model for Buck Lake. The hydraulic residence time was calculated to be 0.25 years for the months of June, July, August, and October. The inflow total phosphorus concentration was measured to be 80 ppb for the month of July, 90 ppb for the months of August and October, and 110 ppb for the month of June. As can be seen from the figure, these values represent an overall classification of slightly hyper-eutrophic based on the Vollenweider Model.

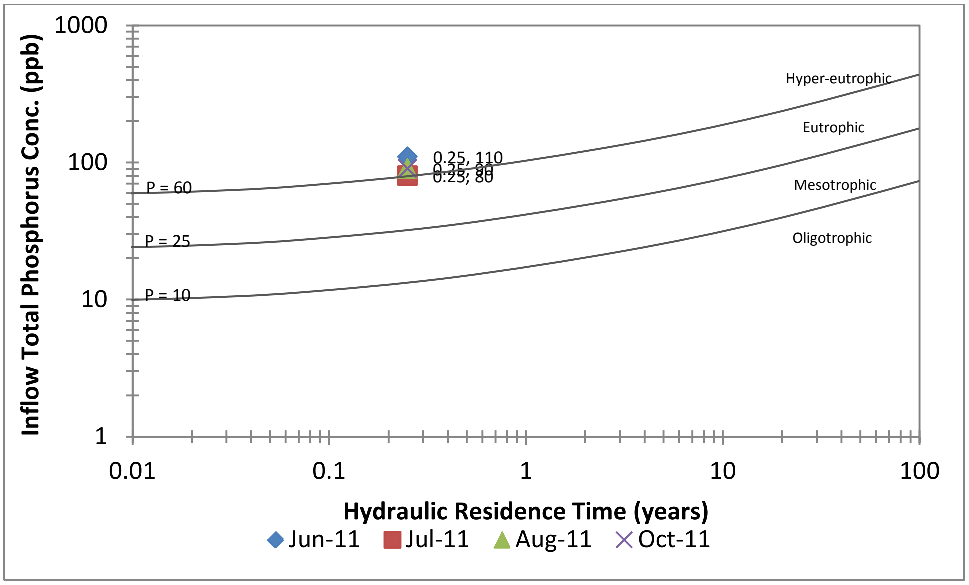

Figure 2.10: 2011 Vollenweider Model results for Buck Lake

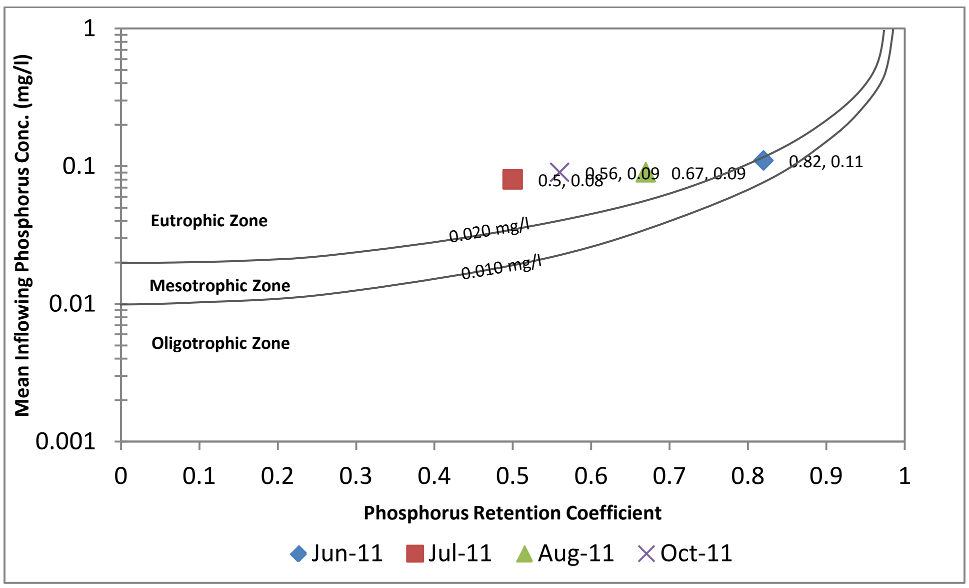

Figure 2.11: 2011 Larsen Mercier Model results for Buck Lake

Figure 2.11 depicts the results from the Larsen Mercier Model for Buck Lake. PRC values of 0.82, 0.5, 0.67, and 0.56 were calculated for the months of June, July, August, and October respectively. The inlet phosphorus concentrations were measured to be 0.11, 0.08, 0.09, and 0.09 mg/L for the months of June, July, August, and October respectively. Table 2.3 depicts that these values represent an overall classification of strongly eutrophic based on the Larsen Mercier Model.

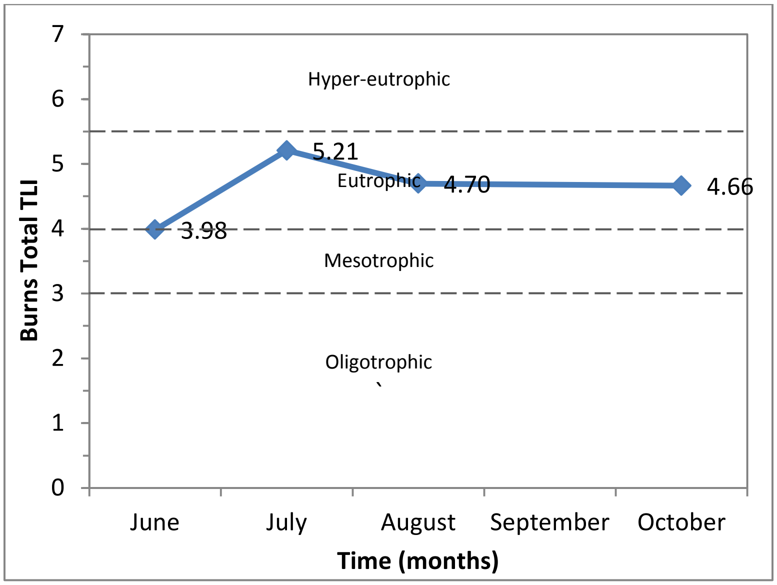

Figure 2.12: 2011 Burns TLI results for Buck Lake

Figure 2.12 shows the results from the Burns TLI Model for Buck Lake. For the months of June, July, August, and October the Burns TLI values were calculated to be 3.98, 5.21, 4.70, and 4.66 respectively. The four-month average TLI was calculated to be 4.58 which falls under the eutrophic classification according to the Burns TLI Model.

Figure 2.13 depicts the Naumann Trophic Scale results for Buck Lake for the months of June, July, August, and October. The Naumann Trophic Scale was calculated to be 9.25, 33.07, 20.65, and 17.27 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The four-month average trophic scale was calculated to be 20.06 which falls under the hyper-eutrophic classification according to the Naumann Trophic Scale Model.

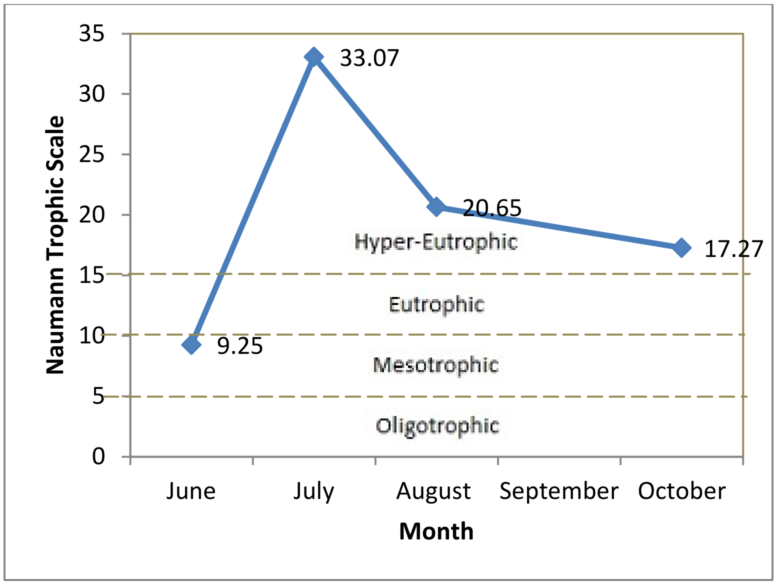

Figure 2.13: 2011 Naumann Trophic Scale results for Buck Lake

Table 2.3: 2011 results for Buck Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Mesotrophic	Eutrophic	Strongly Mesotrophic	Strongly Mesotrophic	Strongly Mesotrophic
Vollenweider	Slightly Hyper-eutrophic	Slightly Hyper-eutrophic	Slightly Hyper-eutrophic	Slightly Hyper-eutrophic	Slightly Hyper-eutrophic
Larsen-Mercier	Strongly Mesotrophic	Slightly Hyper-eutrophic	Strongly Eutrophic	Slightly Hyper-eutrophic	Strongly Eutrophic
Burns	Strongly Mesotrophic	Strongly Eutrophic	Eutrophic	Eutrophic	Eutrophic
Naumann	Strongly Mesotrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic
Monthly-Average	Eutrophic	Strongly Eutrophic	Eutrophic	Strongly Eutrophic	**Strongly Eutrophic**

Table 2.3 summarizes the results for Buck Lake. As each model was used to classify Buck Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Buck Lake as strongly eutrophic.

2.4 **Cascade Lake**

Cascade Lake is a medium sized lake located east of Grebe Lake and northwest of the Norris Canyon Rd/Grand Loop Rd intersection. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the month of August.

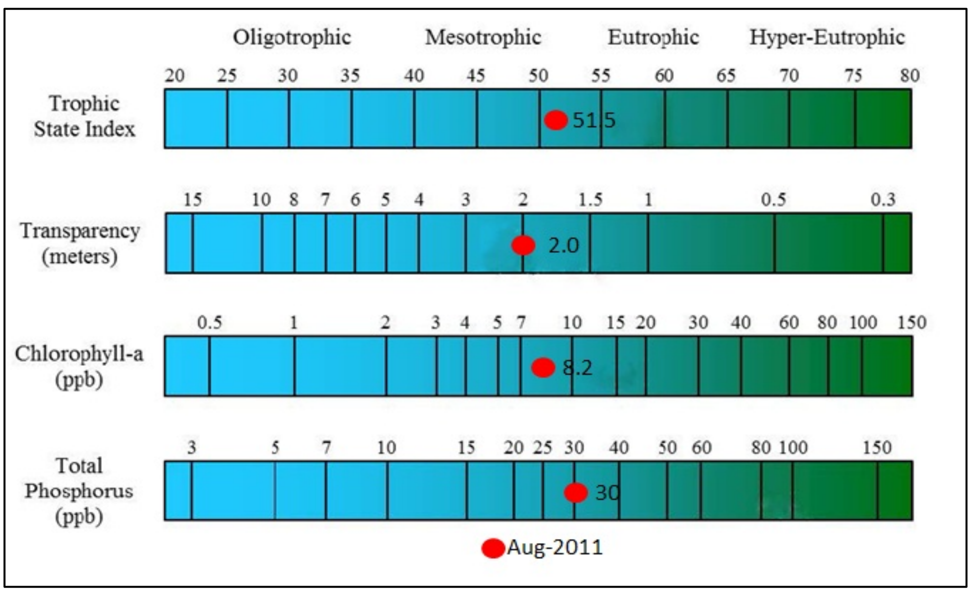

Figure 2.14: 2011 Carlson TSI results for Cascade Lake

Figure 2.14 shows the results from the Carlson TSI Model for Cascade Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 51.5 for the month of August. Table 2.4 shows that the four-month average classification was determined to be strongly mesotrophic according to the Carlson TSI Model.

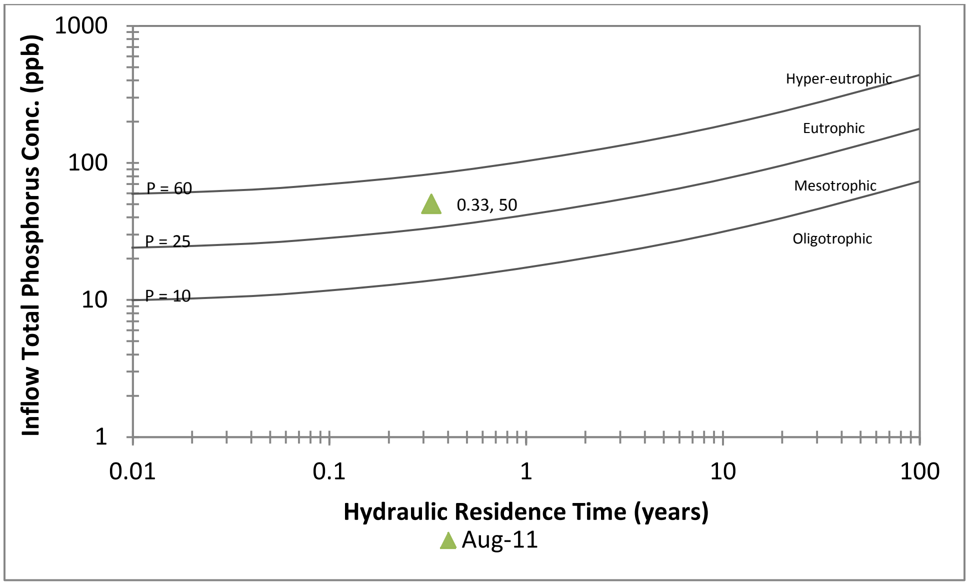

Figure 2.15: 2011 Vollenweider Model results for Cascade Lake

Figure 2.15 shows the results from the Vollenweider Model for Cascade Lake. The hydraulic residence time was calculated to be 0.33 years for the month of August. The inflow total phosphorus concentration was measured to be 50 ppb also for the month of August. As can be seen from the figure, these values represent an overall classification of eutrophic based on the Vollenweider Model.

Figure 2.16 depicts the results from the Larsen Mercier Model for Cascade Lake. A PRC value of 0.4 was calculated for the month August. The inlet phosphorus concentration was measured to be 0.05 mg/L for the month of August. Table 2.4 depicts that this value represents an overall classification of eutrophic based on the Larsen Mercier Model.

Figure 2.17 shows the results from the Burns TLI Model for Cascade Lake. For the month of August the Burns TLI value was calculated to be 4.48. Table 2.4 shows that this value represents an overall classification of slightly eutrophic according to the Burns TLI Model.

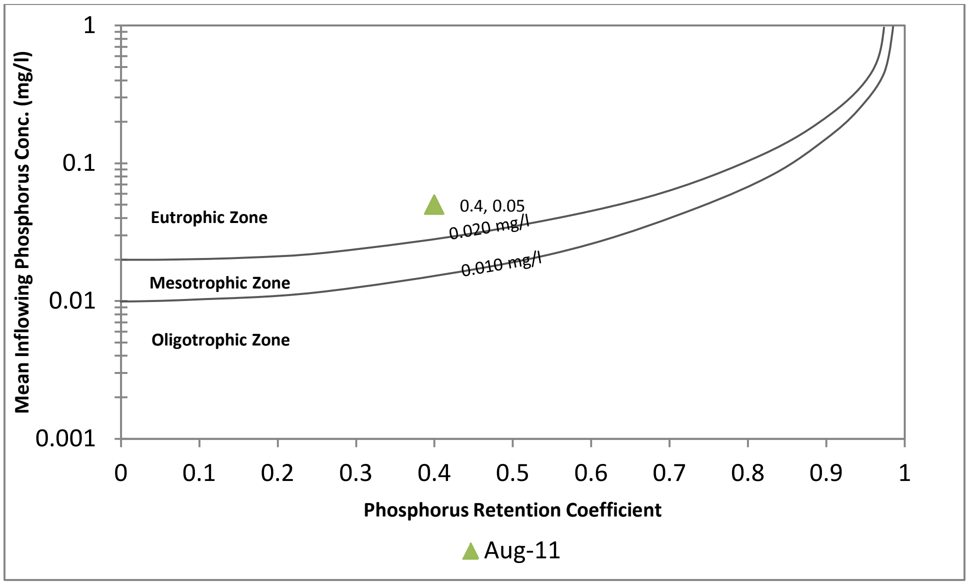

Figure 2.16: 2011 Larsen Mercier Model results for Cascade Lake

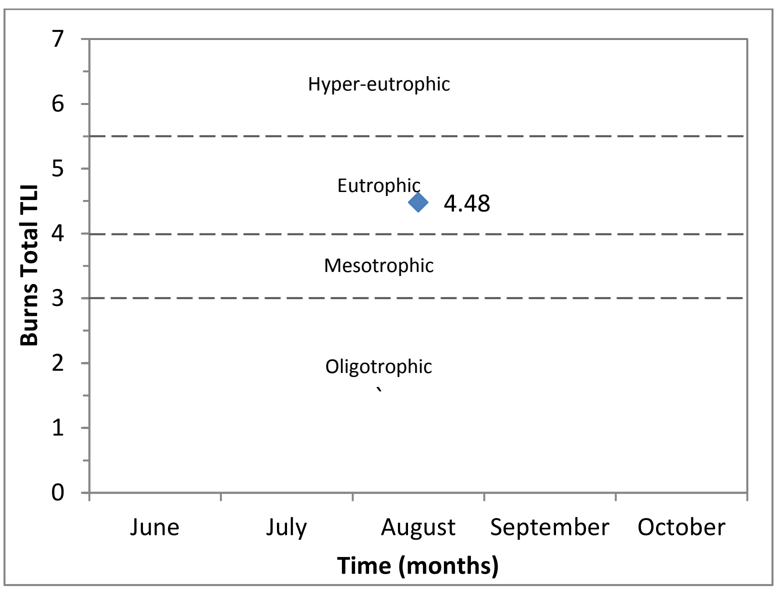

Figure 2.17: 2011 Burns TLI results for Cascade Lake

Figure 2.18 depicts the Naumann Trophic Scale results for Cascade Lake for the month of August. The Naumann Trophic Scale was calculated to be 14.78 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Cascade Lake as strongly eutrophic based on the Naumann Trophic Scale Model.

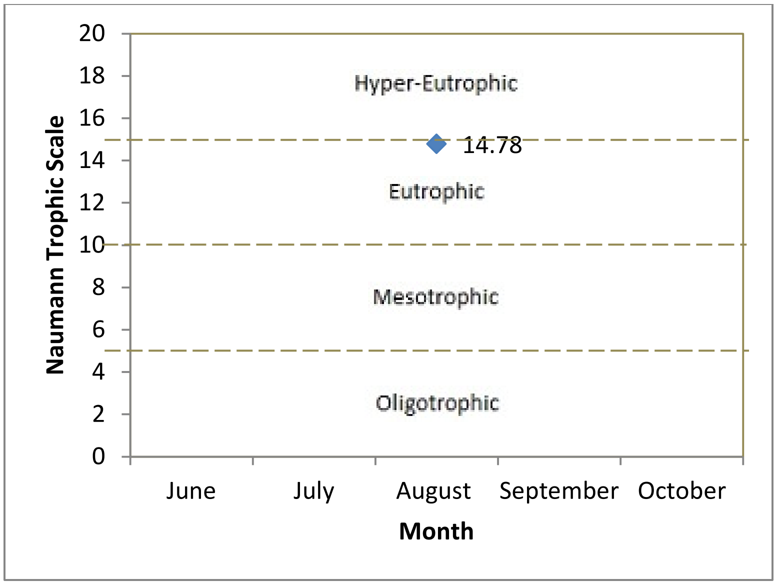

Figure 2.18: 2011 Naumann Trophic Scale results for Cascade Lake

Table 2.4: 2011 results for Cascade Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	Strongly Mesotrophic	-	Strongly Mesotrophic
Vollenweider	-	-	Eutrophic	-	Eutrophic
Larsen-Mercier	-	-	Eutrophic	-	Eutrophic
Burns	-	-	Slightly Eutrophic	-	Slightly Eutrophic
Naumann	-	-	Strongly Eutrophic		Strongly Eutrophic
Monthly-Average	-	-	Eutrophic	-	**Eutrophic**

Table 2.4 summarizes the results for Cascade Lake. As each model was used to classify Cascade Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Cascade Lake as eutrophic.

2.5 Clear Lake

Clear Lake is a very small lake located east of Grand Loop Rd. and South Rim Dr near Canyon. In June of 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June and October.

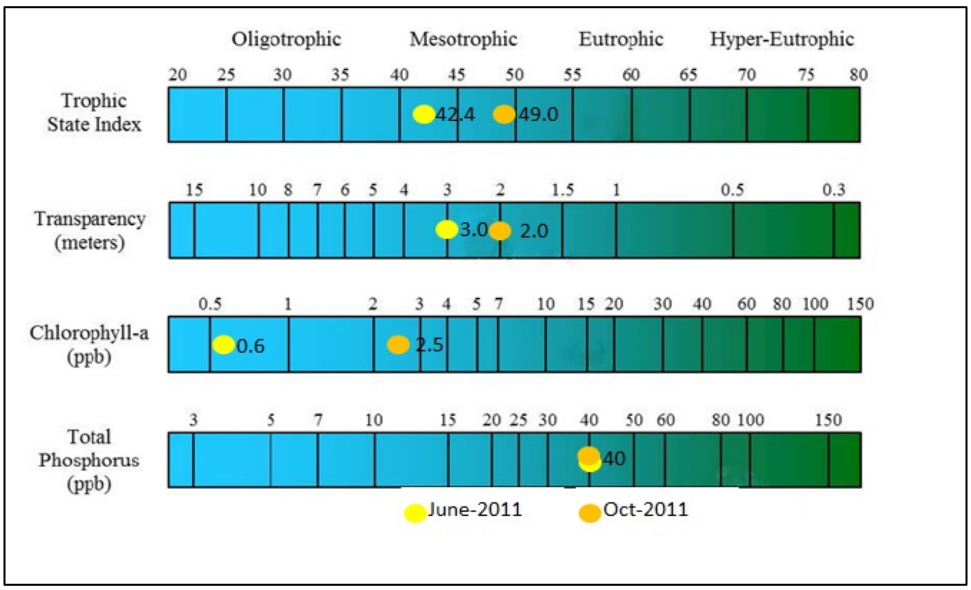

Figure 2.19: 2011 Carlson TSI results for Clear Lake

Figure 2.19 shows the results from the Carlson TSI Model for Clear Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 42.4 for the month of June and 49.0 for the month of October. The two-month average TSI was calculated to be 45.1 which falls under the mesotrophic classification according to the Carlson TSI Model.

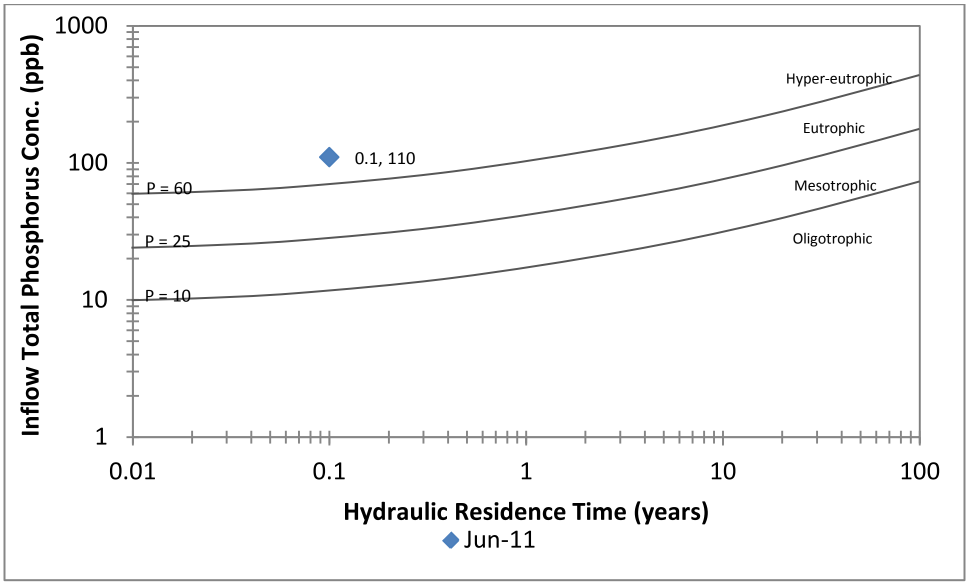

Figure 2.20: 2011 Vollenweider Model results for Clear Lake

Figure 2.20 shows the results from the Vollenweider Model for Clear Lake. The hydraulic residence time was calculated to be 0.1 years for the month of June. The inflow total phosphorus concentration was measured to be 110 ppb for the month of June. As can be seen from the figure, this value represents an overall classification of hyper-eutrophic based on the Vollenweider Model.

Figure 2.21 depicts the results from the Larsen Mercier Model for Clear Lake. A PRC value of 0.64 was calculated for the month of June. The inlet phosphorus concentration was measured to be 0.11 mg/L. Table 2.5 depicts that this value represents an overall classification of strongly eutrophic based on the Larsen Mercier Model.

Figure 2.23 depicts the Naumann Trophic Scale results for Clear Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 7.64 and 10.87 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 9.26 which falls under the strongly mesotrophic classification according to the Naumann Trophic Scale Model.

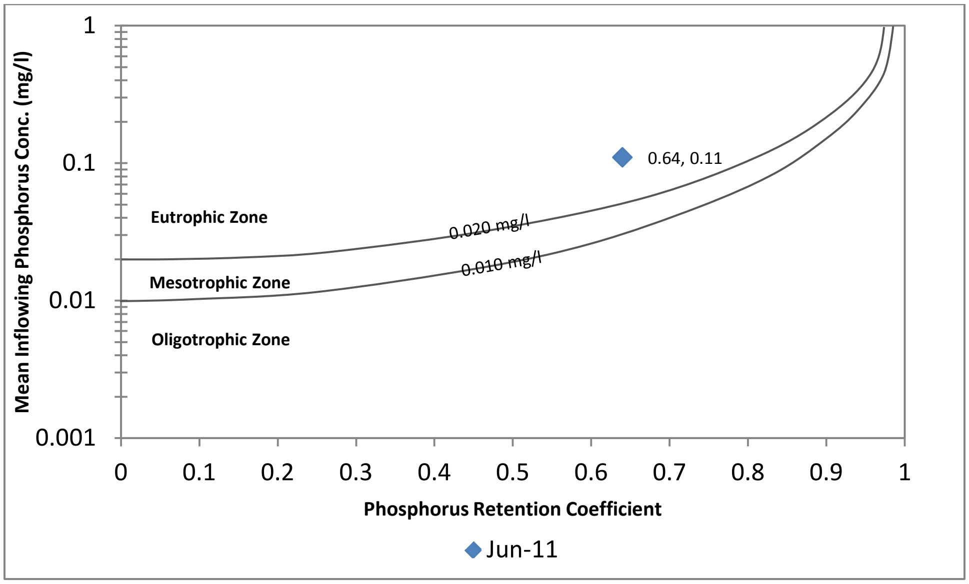

Figure 2.21: 2011 Larsen Mercier Model results for Clear Lake

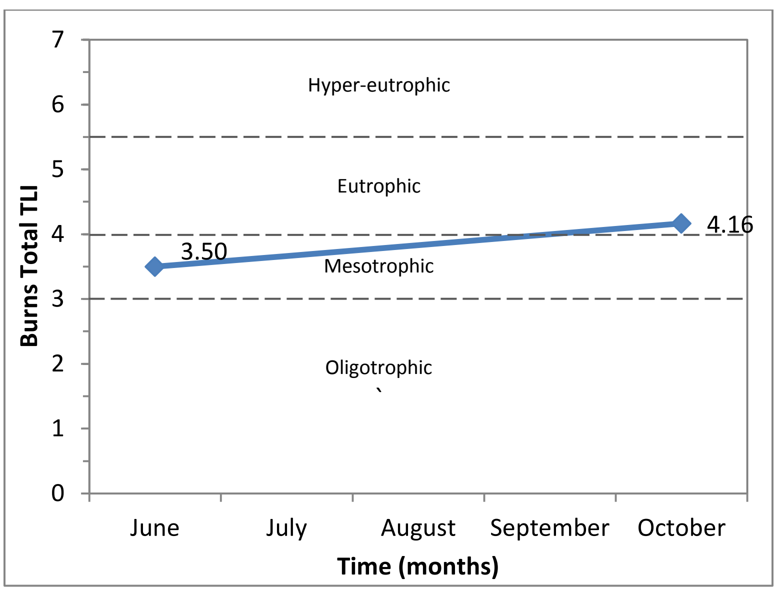

Figure 2.22: 2011 Burns TLI results for Clear Lake

Figure 2.22 shows the results from the Burns TLI Model for Clear Lake. For the months of June and October the Burns TLI values were calculated to be 3.50 and 4.16 respectively. The two-month average TLI was calculated to be 3.79 which falls under the strongly mesotrophic classification according to the Burns TLI Model.

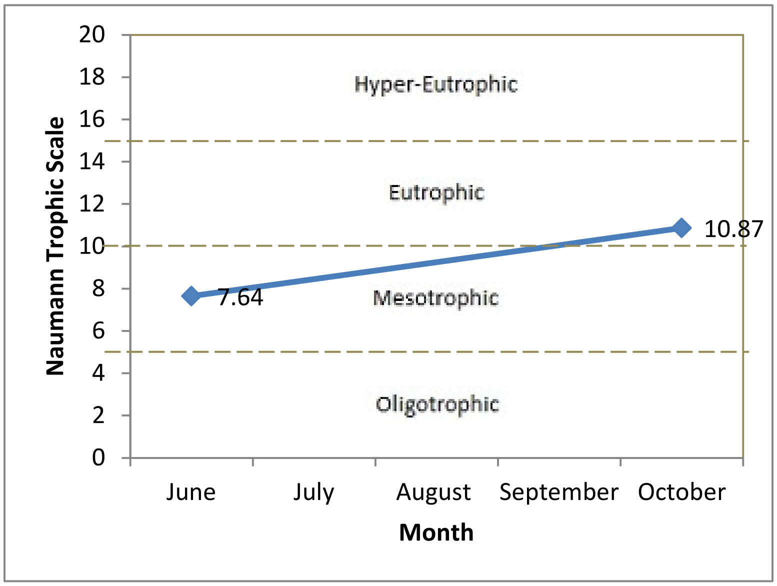

Figure 2.23: 2011 Naumann Trophic Scale results for Clear Lake

Table 2.5. 2011 results for Clear Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Mesotrophic	-	-	Strongly Mesotrophic	Mesotrophic
Vollenweider	Hyper-Eutrophic	-	-	-	Hyper-Eutrophic
Larsen-Mercier	Strongly Eutrophic	-	-	-	Strongly Eutrophic
Burns	Mesotrophic	-	-	Slightly Eutrophic	Strongly Mesotrophic
Naumann	Mesotrophic	-	-	Slightly Eutrophic	Strongly Mesotrophic
Monthly-Average	Eutrophic	-	-	Strongly Mesotrophic	**Slightly Eutrophic**

Table 2.5 summarizes the results for Clear Lake. As each model was used to classify Clear Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Clear Lake as slightly eutrophic.

2.6 **Druid Lake**

Druid Lake is a relatively small lake located just west of the NE Entrance Rd near Soda Butte. In 2011, inlake samples were taken for phosphorus, chlorophyll-a, and Secchi depth. Measurements were made in the months of June and October.

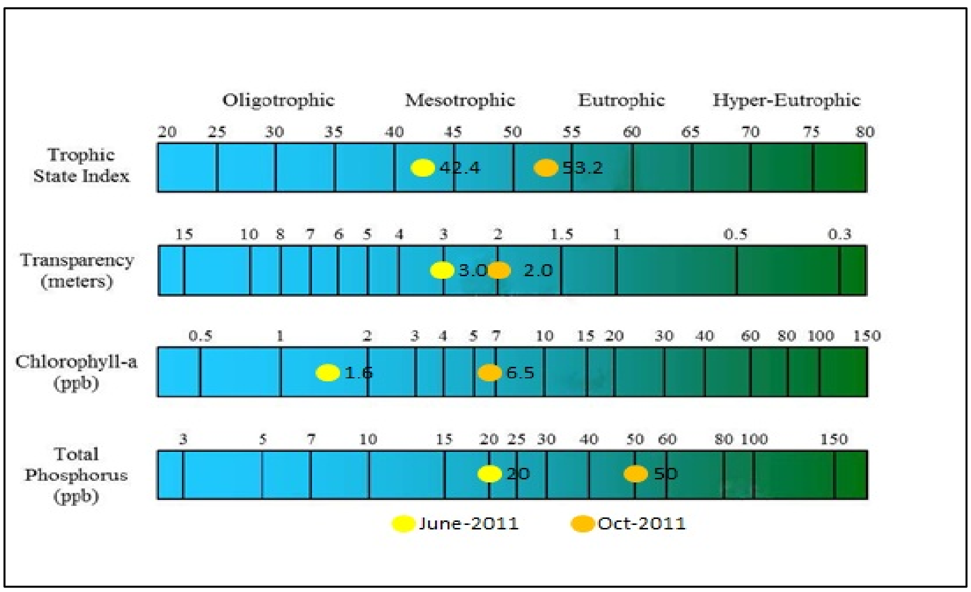

Figure 2.24: 2011 Carlson TSI results for Druid Lake

Figure 2.24 shows the results from the Carlson TSI Model for Druid Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 42.4 for the month of June and 53.2 for the month of October. The two-month average TSI was calculated to be 46.8 which falls under the mesotrophic classification according to the Carlson TSI Model.

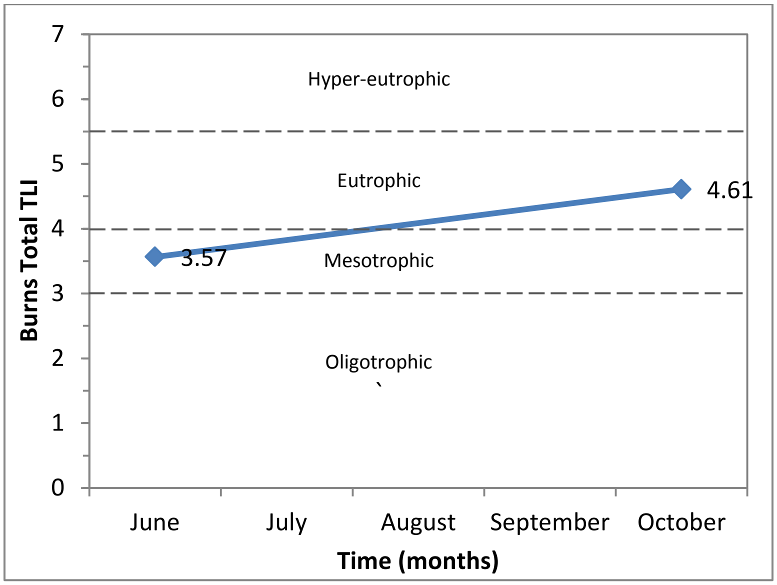

Figure 2.25: 2011 Burns TLI results for Druid Lake

Figure 2.25 shows the results from the Burns TLI Model for Druid Lake. For the months of June and October the Burns TLI values were calculated to be 3.57 and 4.61 respectively. The two-month average TLI was calculated to be 4.02 which falls under the slightly eutrophic classification according to the Burns TLI Model.

Figure 2.26 depicts the Naumann Trophic Scale results for Druid Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 6.23 and 15.57 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 10.9 which falls under the slightly eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.6 summarizes the results for Druid Lake. As each model was used to classify Druid Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Druid Lake as strongly mesotrophic.

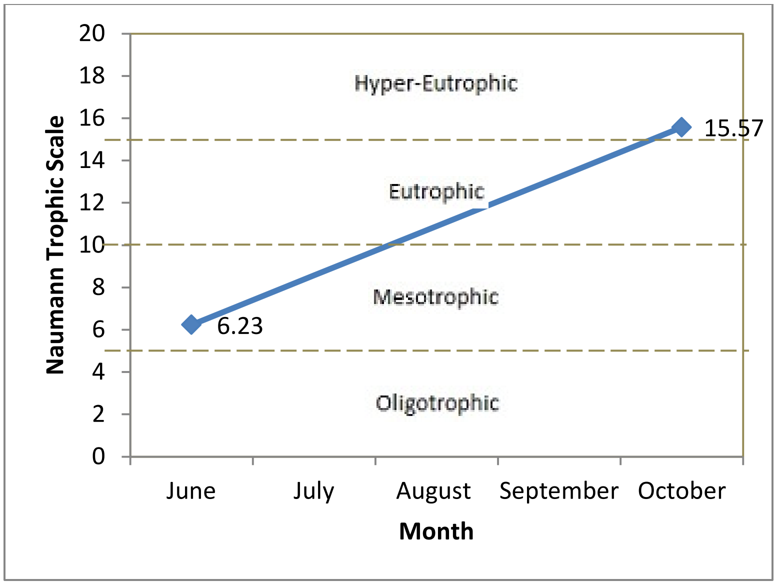

Figure 2.26: 2011 Naumann Trophic Scale results for Druid Lake

Table 2.6: 2011 results for Druid Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Mesotrophic	-	-	Strongly Mesotrophic	Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Mesotrophic	-	-	Eutrophic	Slightly Eutrophic
Naumann	Slightly Mesotrophic			Slightly Hyper-Eutrophic	Slightly Eutrophic
Monthly-Average	Mesotrophic	-	-	Eutrophic	**Strongly Mesotrophic**

2.7 **Duck Lake**

Duck Lake is a relatively small lake located just north of the South Entrance Rd/Grand Loop Rd intersection near West Thumb. In 2011, phosphorus, chlorophyll-a, and Secchi depth were measured at an inlake location. Measurements were made in the months of June and August.

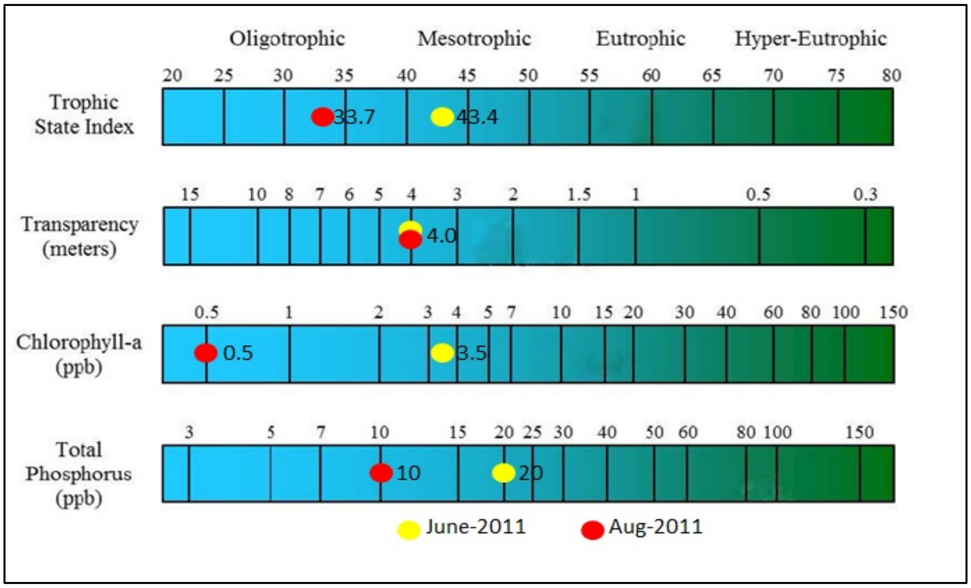

Figure 2.27: 2011 Carlson TSI results for Duck Lake

Figure 2.27 shows the results from the Carlson TSI Model for Duck Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 33.7 for the month of June and 43.4 for the month of August. The two-month average TSI was calculated to be 38.6 which falls under the slightly mesotrophic classification according to the Carlson TSI Model.

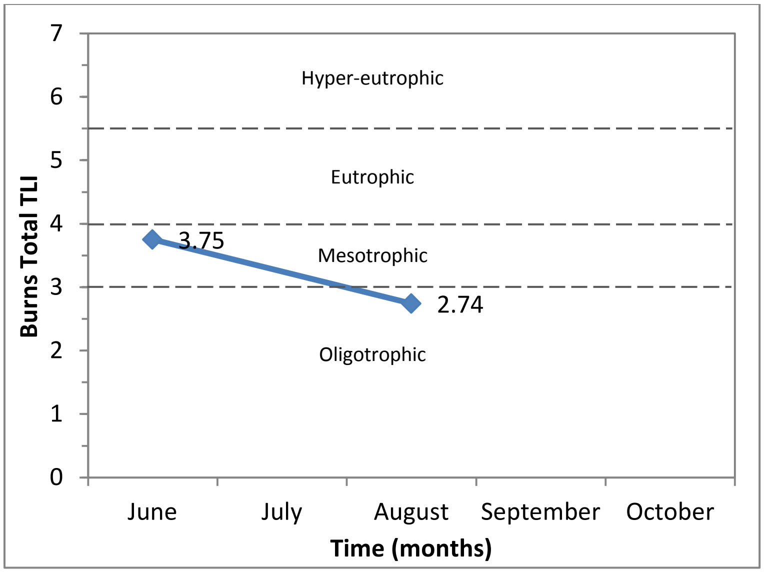

Figure 2.28: 2011 Burns TLI results for Duck Lake

Figure 2.28 shows the results from the Burns TLI Model for Duck Lake. For the months of June and August the Burns TLI values were calculated to be 3.75 and 2.74 respectively. The two-month average TLI was calculated to be 3.25 which falls under the slightly mesotrophic classification according to the Burns TLI Model.

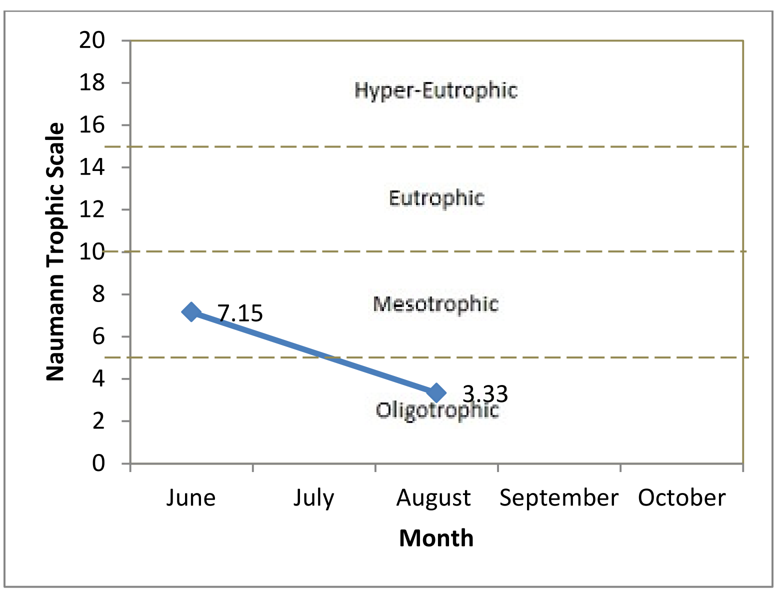

Figure 2.29: 2011 Naumann Trophic Scale results for Duck Lake

Figure 2.29 depicts the Naumann Trophic Scale results for Duck Lake for the months of June and August. The Naumann Trophic Scale was calculated to be 7.15 and 3.33 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 5.24 which falls under the slightly mesotrophic classification according to the Naumann Trophic Scale.

Table 2.7: 2011 results for Duck Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Mesotrophic	-	Slightly Oligotrophic	-	Slightly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Strongly Mesotrophic	-	Slightly Oligotrophic	-	Slightly Mesotrophic
Naumann	Mesotrophic	-	Oligotrophic		Slightly Mesotrophic
Monthly-Average	Mesotrophic	-	Slightly Oligotrophic	-	**Slightly Mesotrophic**

Table 2.7 summarizes the results for Duck Lake. As each model was used to classify Duck Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Duck Lake as slightly mesotrophic.

2.8 **Eleanor Lake**

Eleanor Lake is a relatively small lake located just south of the East Entrance Rd near Sylvan Lake. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were taken at an inlake location. Measurements were made in the month July.

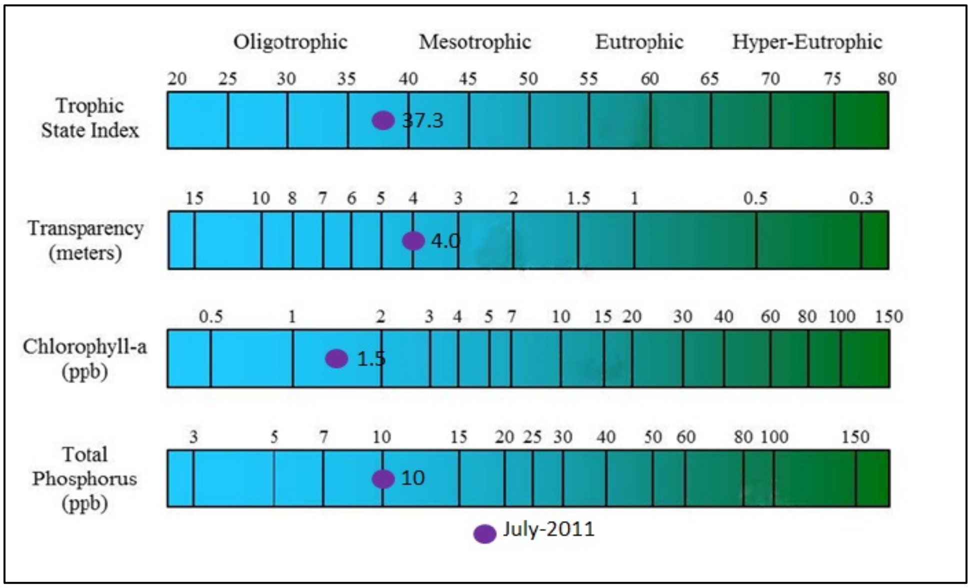

Figure 2.30: 2011 Carlson TSI results for Eleanor Lake

Figure 2.30 shows the results from the Carlson TSI Model for Eleanor Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 37.3 for the month of July. Table 2.8 shows that the four-month average classification was determined to be slightly oligotrophic according to the Carlson TSI Model.

Figure 2.31 shows the results from the Burns TLI Model for Eleanor Lake. For the month of July the Burns TLI value was calculated to be 3.03. Table 2.8 shows that this value represents an overall classification of slightly mesotrophic according to the Burns TLI Model.

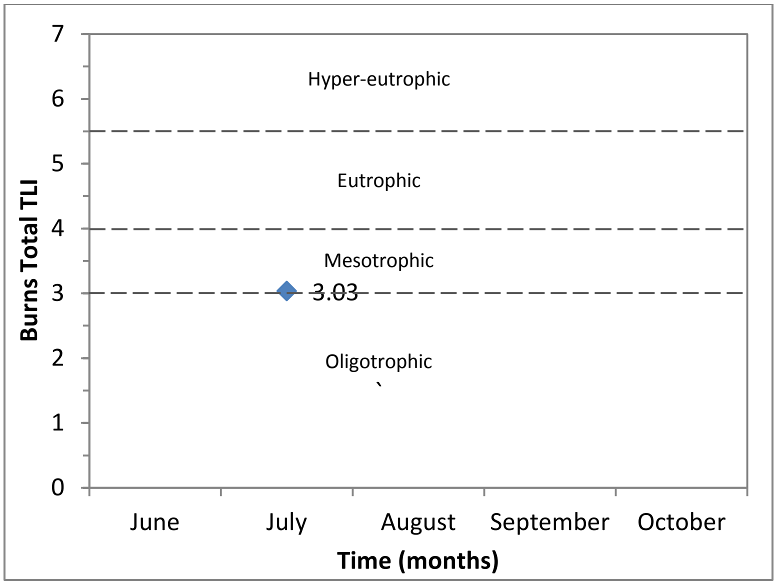

Figure 2.31: 2011 Burns TLI results for Eleanor Lake

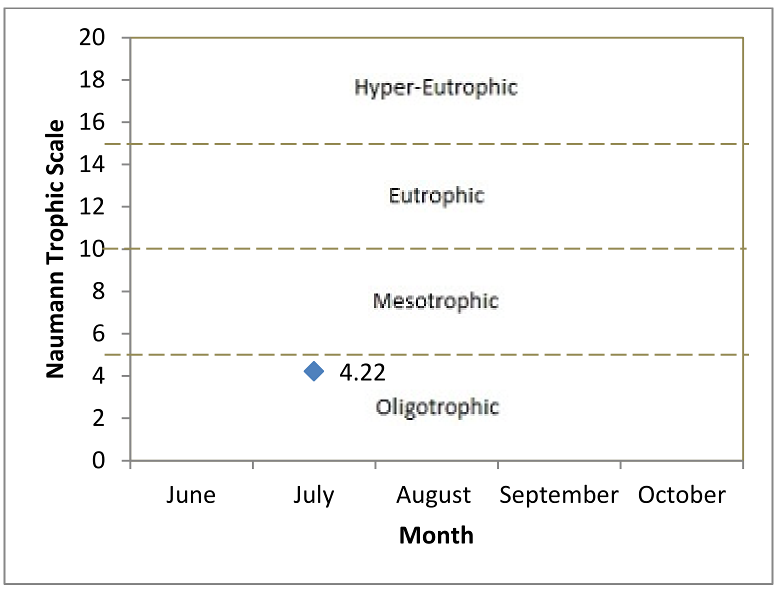

Figure 2.32: 2011 Naumann Trophic Scale results for Eleanor Lake

Figure 2.32 depicts the Naumann Trophic Scale results for Eleanor Lake for the month of July. The Naumann Trophic Scale was calculated to be 4.22 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Eleanor Lake as slightly oligotrophic based on the Naumann Trophic Scale Model.

Table 2.8: 2011 results for Eleanor Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Slightly Oligotrophic	-	-	Slightly Oligotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	Slightly Mesotrophic	-	-	Slightly Mesotrophic
Naumann	-	Slightly Oligotrophic	-	-	Slightly Oligotrophic
Monthly-Average	-	Slightly Oligotrophic	-	-	**Slightly Oligotrophic**

Table 2.8 summarizes the results for Eleanor Lake. As each model was used to classify Eleanor Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Eleanor Lake as slightly oligotrophic.

2.9 **Feather Lake**

Feather Lake is a relatively small lake located west of Grand Loop Rd and east of Goose Lake near Midway Geyser Basin. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were taken at an inlake location. Measurements were made in the month of October.

Figure 2.33 shows the results from the Carlson TSI Model for Feather Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 63.7 for the month of October. Table 2.9 shows that the four-month average classification was determined to be strongly eutrophic according to the Carlson TSI Model.

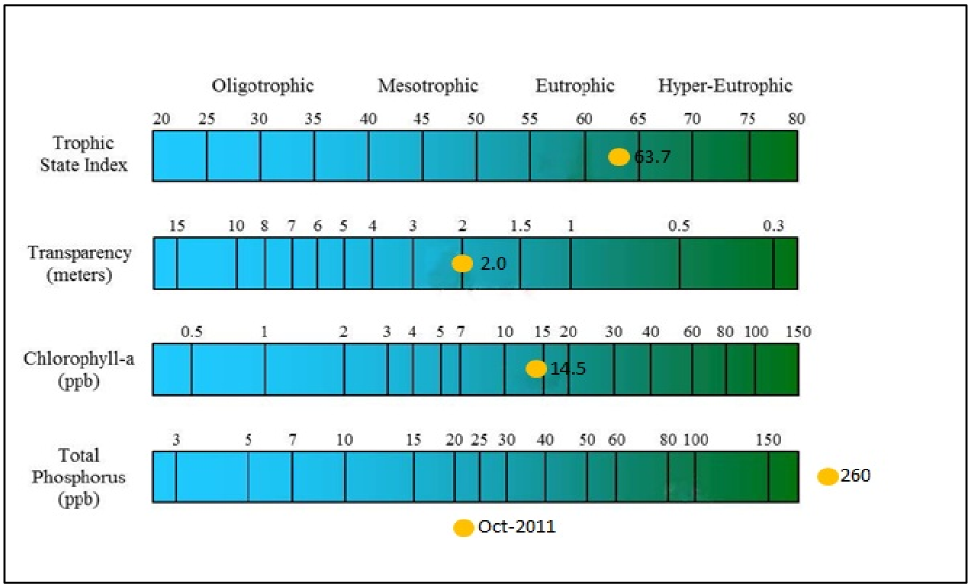

Figure 2.33: 2011 Carlson TSI results for Feather Lake

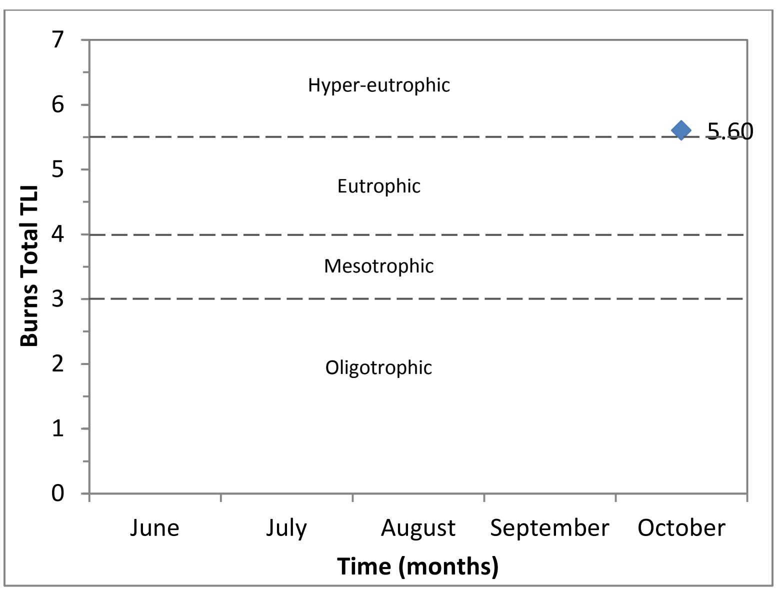

Figure 2.34: 2011 Burns TLI results for Feather Lake

Figure 2.34 shows the results from the Burns TLI Model for Feather Lake. For the month of October the Burns TLI value was calculated to be 5.60. Table 2.9 shows that this value represents an overall classification of slightly hyper-eutrophic according to the Burns TLI Model.

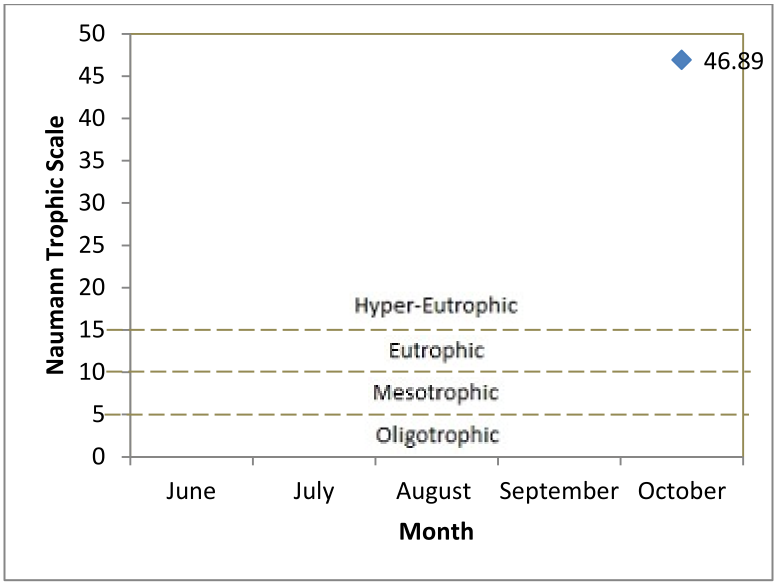

Figure 2.35: 2011 Naumann Trophic Scale results for Feather Lake

Figure 2.35 depicts the Naumann Trophic Scale results for Feather Lake for the month of October. The Naumann Trophic Scale was calculated to be 46.89 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Feather Lake as hyper-eutrophic based on the Naumann Trophic Scale Model.

Table 2.9: 2011 results for Feather Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	-	Strongly Eutrophic	Strongly Eutrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	-	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic

Table 2.9 continued: 2011 results for Feather Lake

Naumann	-	-	-	Hyper-Eutrophic	Hyper-Eutrophic
Monthly-Average	-	-	-	Slightly Hyper-Eutrophic	**Slightly Hyper-Eutrophic**

Table 2.9 summarizes the results for Feather Lake. As each model was used to classify Feather Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Feather Lake as slightly hyper-eutrophic.

2.10 **Floating Island Lake**

Floating Island Lake is a very small lake located just west Grand Loop Rd north of Roosevelt Lodge. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were taken at an inlake location. Measurements were made in the month of July.

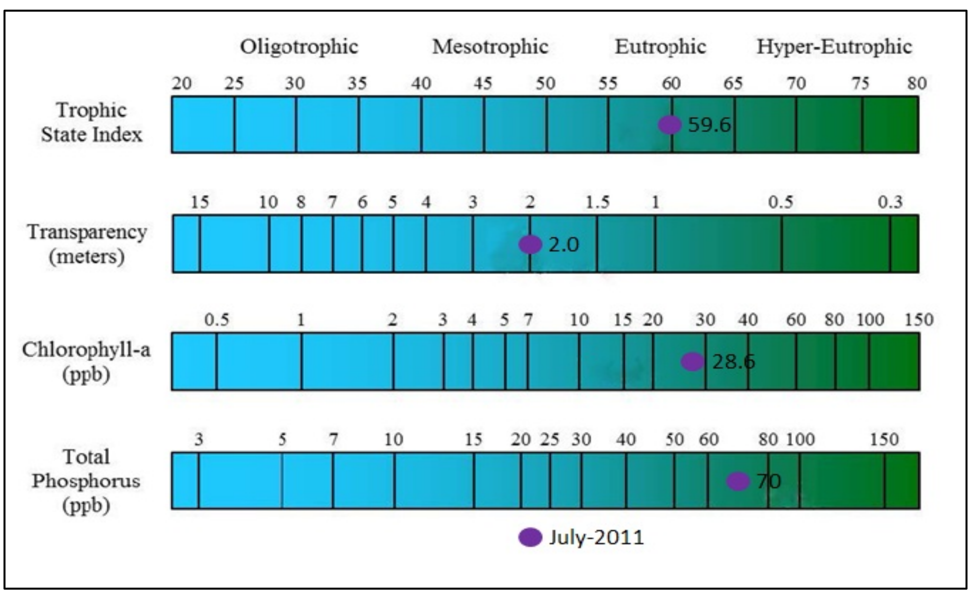

Figure 2.36: 2011 Carlson TSI results for Floating Island Lake

Figure 2.36 shows the results from the Carlson TSI Model for Floating Island Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 59.6 for the month of July. Table 2.10 shows that the four-month average classification was determined to be eutrophic according to the Carlson TSI Model.

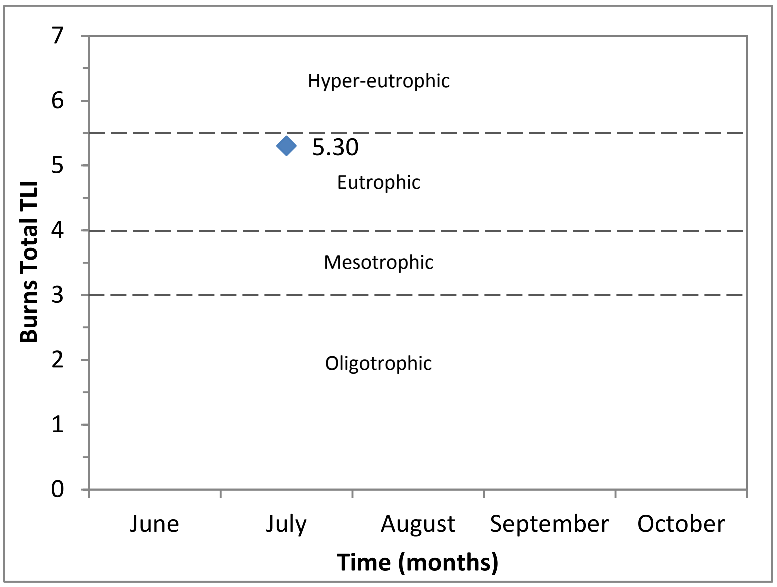

Figure 2.37: 2011 Burns TLI results for Floating Island Lake

Figure 2.37 shows the results from the Burns TLI Model for Floating Island Lake. For the month of July the Burns TLI value was calculated to be 5.30. Table 2.10 shows that this value represents an overall classification of strongly eutrophic according to the Burns TLI Model.

Figure 2.38 depicts the Naumann Trophic Scale results for Floating Island Lake for the month of July. The Naumann Trophic Scale was calculated to be 37.53 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Floating Island Lake as hyper-eutrophic based on the Naumann Trophic Scale Model.

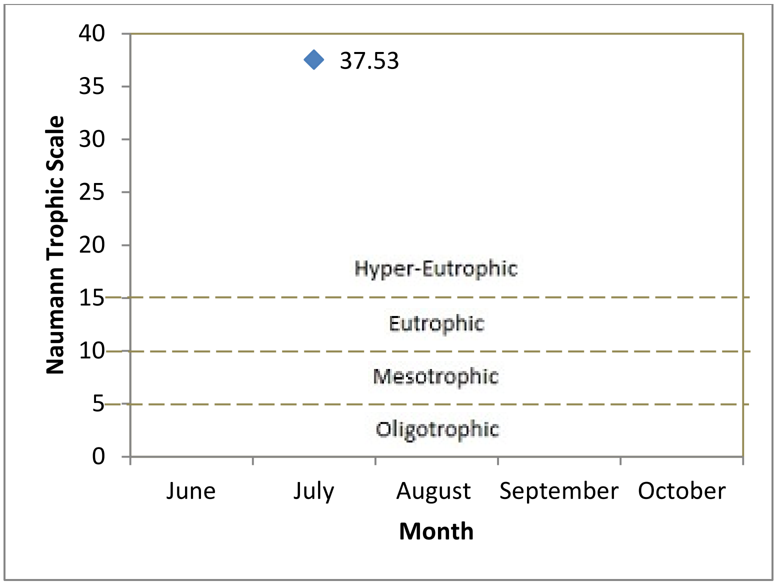

Figure 2.38: 2011 Naumann Trophic Scale results for Floating Island Lake

Table 2.10: 2011 results for Floating Island Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Eutrophic	-	-	Eutrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	Strongly Eutrophic	-	-	Strongly Eutrophic
Naumann	-	Hyper-Eutrophic	-	-	Hyper-Eutrophic
Monthly-Average	-	Slightly Hyper-Eutrophic	-	-	**Slightly Hyper-Eutrophic**

Table 2.10 summarizes the results for Floating Island Lake. As each model was used to classify Floating Island Lake into a generic trophic state, a qualitative average was used in order

to determine an overall trophic state classification. The 2011 results classify Floating Island Lake as slightly hyper-eutrophic.

2.11 Goose Lake

Goose Lake is a relatively small lake located just west of Feather Lake and Grand Loop Rd near Midway Geyser Basin. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June and October.

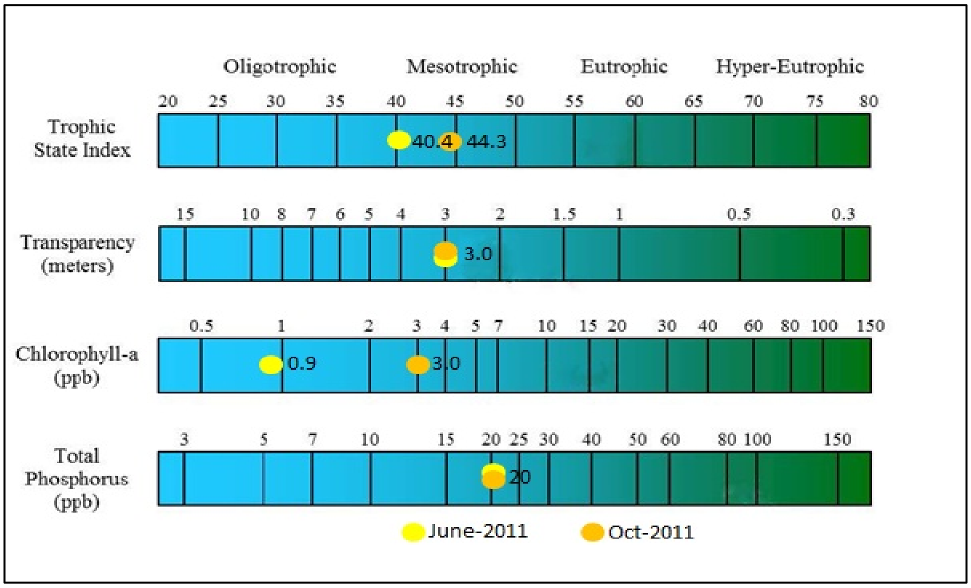

Figure 2.39: 2011 Carlson TSI results for Goose Lake

Figure 2.39 shows the results from the Carlson TSI Model for Goose Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 40.4 for the month of June and 44.3 for the month of October. The two-month average TSI was calculated to be 43.2 which falls under the mesotrophic classification according to the Carlson TSI Model.

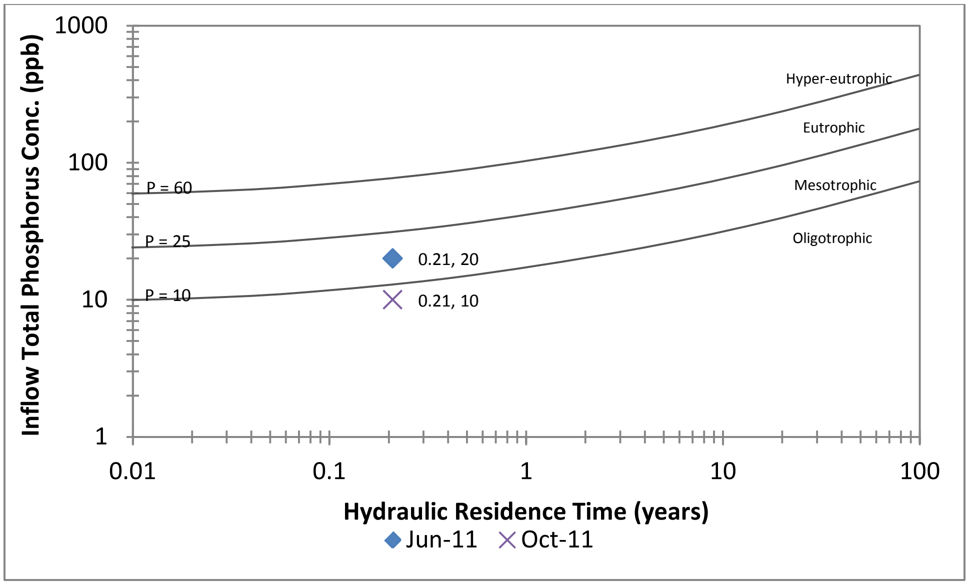

Figure 2.40: 2011 Vollenweider Model results for Goose Lake

Figure 2.40 shows the results from the Vollenweider Model for Goose Lake. The hydraulic residence time was calculated to be 0.21 years for the months of June and October. The inflow total phosphorus concentration was measured to be 20 ppb for the month of June and 10 ppb for the month of October. As can be seen from the figure, these values represent an overall classification of slightly mesotrophic based on the Vollenweider Model.

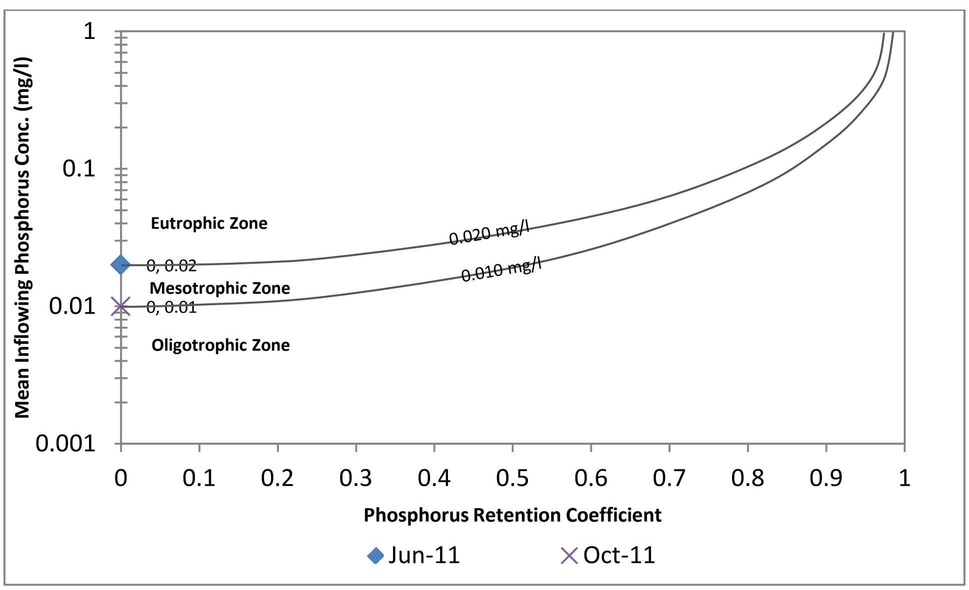

Figure 2.41: 2011 Larsen Mercier Model results for Goose Lake

Figure 2.41 depicts the results from the Larsen Mercier Model for Goose Lake. PRC values of 0.0 were used for both June and October. This is due to the fact that the inlake sample measured a higher phosphorus concentration than the inlet sample. The inlet phosphorus concentrations were measured to be 0.02 and 0.01 mg/L for the months of June and October respectively. Table 2.11 depicts that these values represent an overall classification of mesotrophic based on the Larsen Mercier Model.

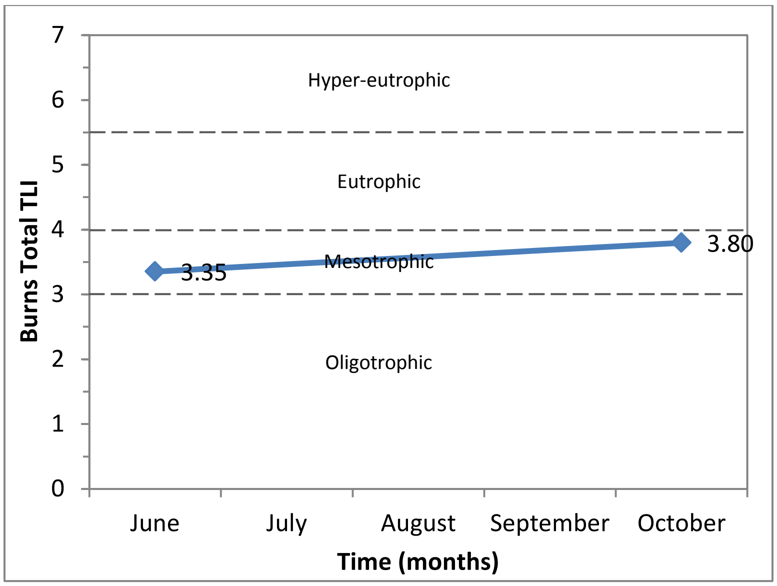

Figure 2.42: 2011 Burns TLI results for Goose Lake

Figure 2.42 shows the results from the Burns TLI Model for Goose Lake. For the months of June and October the Burns TLI values were calculated to be 3.35 and 3.80 respectively. The two-month average TLI was calculated to be 3.64 which falls under the mesotrophic classification according to the Burns TLI Model.

Figure 2.43 depicts the Naumann Trophic Scale results for Goose Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 5.60 and 7.47 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 6.54 which falls under the mesotrophic classification according to the Naumann Trophic Scale Model.

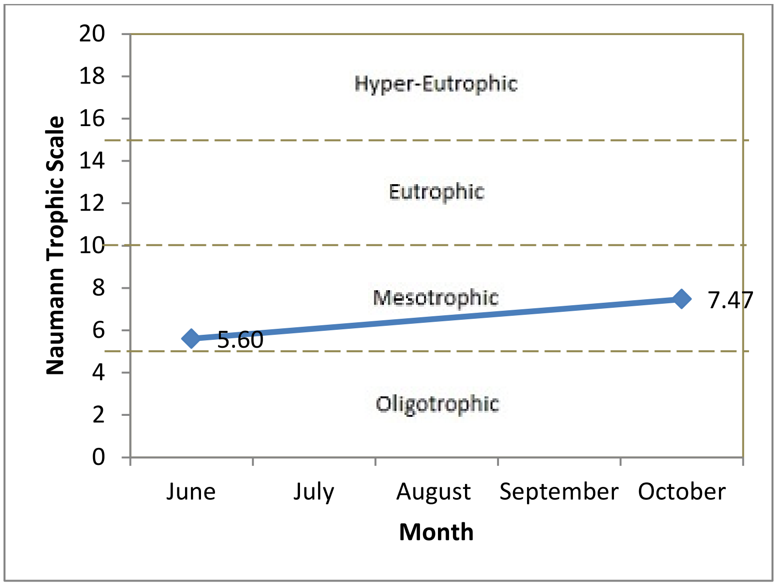

Figure 2.43: 2011 Naumann Trophic Scale results for Goose Lake

Table 2.11: 2011 results for Goose Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Mesotrophic	-	-	Mesotrophic	Mesotrophic
Vollenweider	Mesotrophic	-	-	Slightly Oligotrophic	Slightly Mesotrophic
Larsen-Mercier	Slightly Eutrophic	-	-	Slightly Mesotrophic	Mesotrophic
Burns	Mesotrophic	-	-	Strongly Mesotrophic	Mesotrophic
Naumann	Slightly Mesotrophic	-	-	Mesotrophic	Mesotrophic
Monthly-Average	Mesotrophic	-	-	Mesotrophic	**Mesotrophic**

Table 2.11 summarizes the results for Goose Lake. As each model was used to classify Goose Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Goose Lake as mesotrophic.

2.12 **Harlequin Lake**

Harlequin Lake is a relatively small lake located just north of the West Entrance Rd near Madison Junction. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were taken at an inlake location. Measurements were made in the month of July.

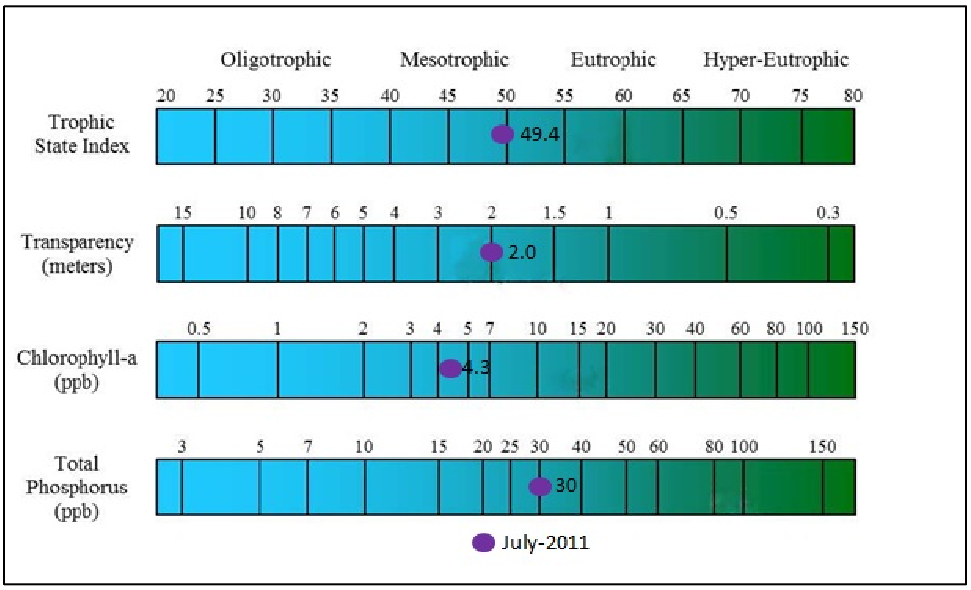

Figure 2.44: 2011 Carlson TSI results for Harlequin Lake

Figure 2.44 shows the results from the Carlson TSI Model for Harlequin Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 49.4 for the month of July. Table 2.12 shows that the average classification was determined to be strongly mesotrophic according to the Carlson TSI Model.

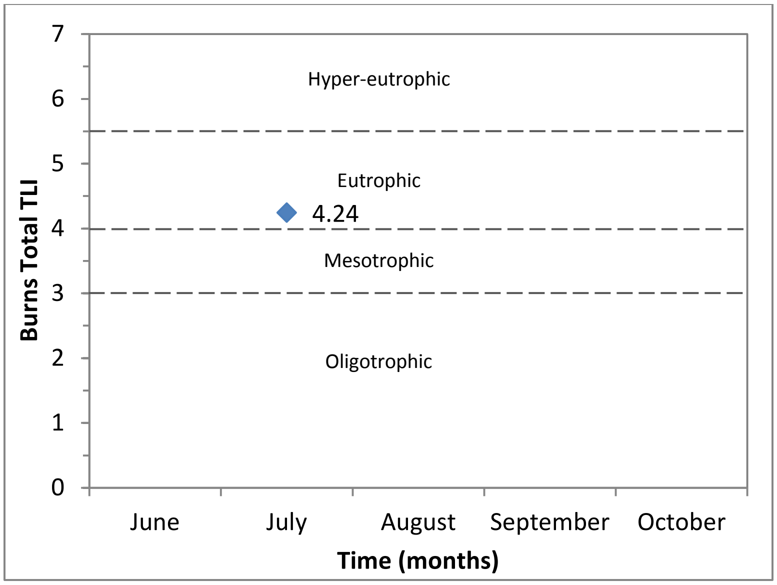

Figure 2.45: 2011 Burns TLI results for Harlequin Lake

Figure 2.45 shows the results from the Burns TLI Model for Harlequin Lake. For the months of July the Burns TLI value was calculated to be 4.24. Table 2.12 shows that this value represents an overall classification of slightly eutrophic according to the Burns TLI Model.

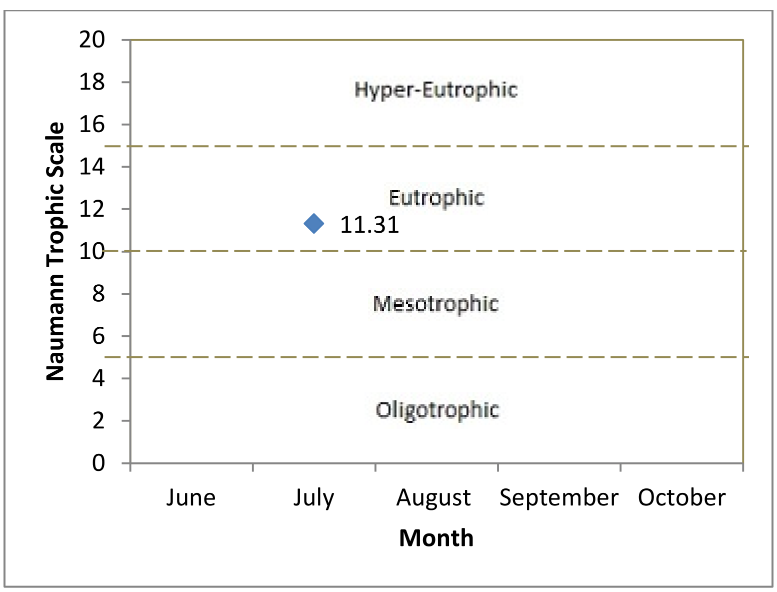

Figure 2.46: 2011 Naumann Trophic Scale results for Harlequin Lake

Figure 2.46 depicts the Naumann Trophic Scale results for Harlequin Lake for the month of July. The Naumann Trophic Scale was calculated to be 11.31 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Harlequin Lake as slightly eutrophic based on the Naumann Trophic Scale Model.

Table 2.12: 2011 results for Harlequin Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Strongly Mesotrophic	-	-	Strongly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	Slightly Eutrophic	-	-	Slightly Eutrophic
Naumann	-	Slightly Eutrophic	-	-	Slightly Eutrophic
Monthly-Average	-	Slightly Eutrophic	-	-	**Slightly Eutrophic**

Table 2.12 summarizes the results for Harlequin Lake. As each model was used to classify Harlequin Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Harlequin Lake as slightly eutrophic.

2.13 **Hazle Lake**

Hazle Lake is a very small lake located just south of Nymph Lake and west of Grand Loop Rd. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June and July.

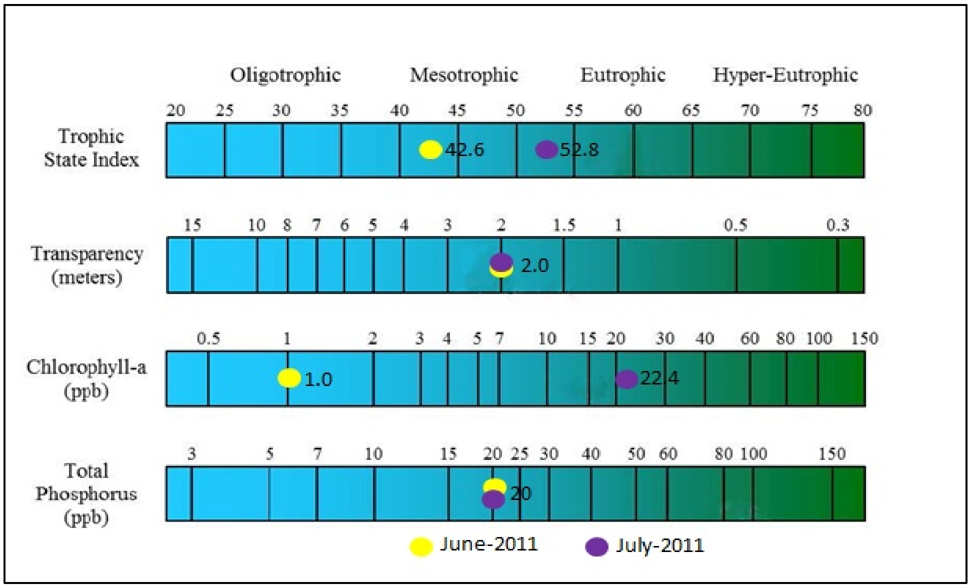

Figure 2.47: 2011 Carlson TSI results for Hazle Lake

Figure 2.47 shows the results from the Carlson TSI Model for Hazle Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 42.6 for the month of June and 52.8 for the month of July. The two-month average TSI was calculated to be 47.9 which falls under the mesotrophic classification according to the Carlson TSI Model.

Figure 2.48 shows the results from the Vollenweider Model for Hazle Lake. The hydraulic residence time was calculated to be 0.019 years for the months of June and July. The inflow total phosphorus concentration was measured to be 30 ppb for the month of June and 40 ppb for the month of July. As can be seen from the figure, these values represent an overall classification of eutrophic based on the Vollenweider Model.

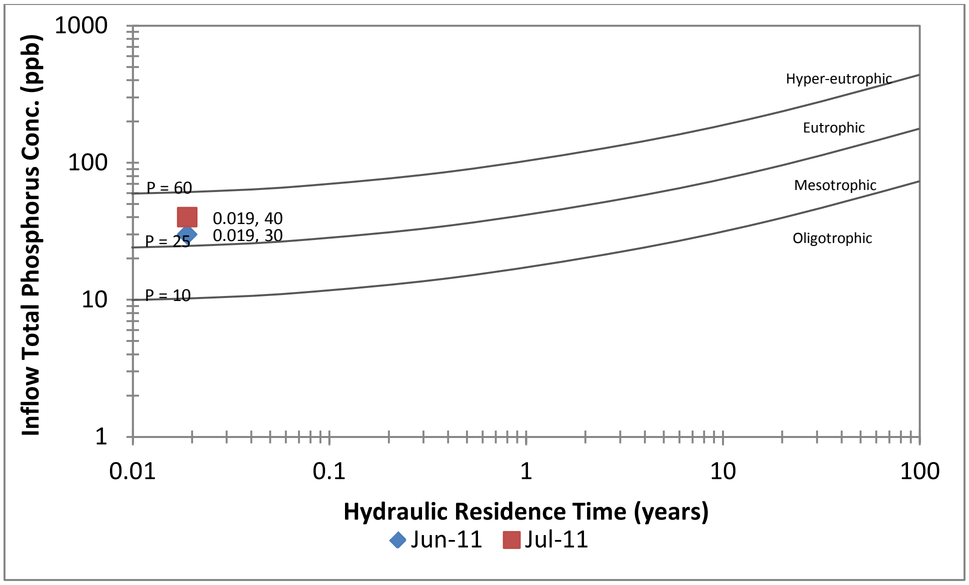

Figure 2.48: 2011 Vollenweider Model results for Hazle Lake

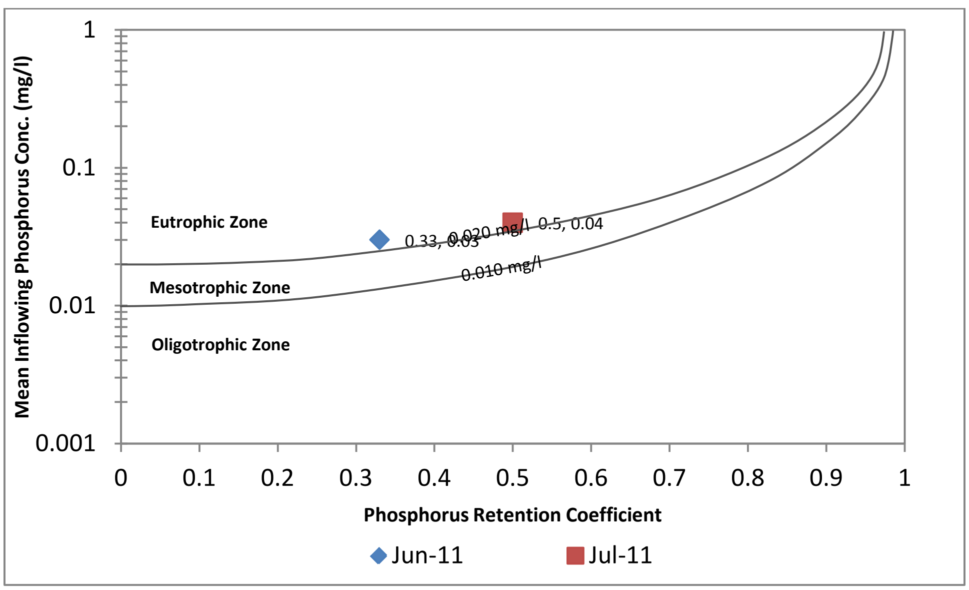

Figure 2.49: 2011 Larsen Mercier Model results for Hazle Lake

Figure 2.49 depicts the results from the Larsen Mercier Model for Hazle Lake. PRC values of 0.33 and 0.5 were calculated for the months of June and July respectively. The inlet phosphorus concentrations were measured to be 0.03 and 0.04 mg/L for the months of June and July respectively. Table 2.13 depicts that these values represent an overall classification of slightly eutrophic based on the Larsen Mercier Model.

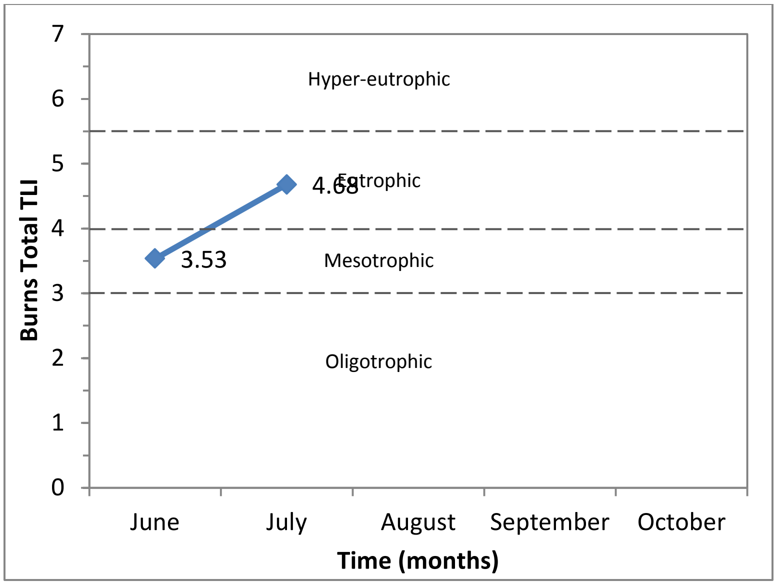

Figure 2.50: 2011 Burns TLI results for Hazle Lake

Figure 2.50 shows the results from the Burns TLI Model for Hazle Lake. For the months of June and July the Burns TLI values were calculated to be 3.53 and 4.68 respectively. The two-month average TLI was calculated to be 4.12 which falls under the slightly eutrophic classification according to the Burns TLI Model.

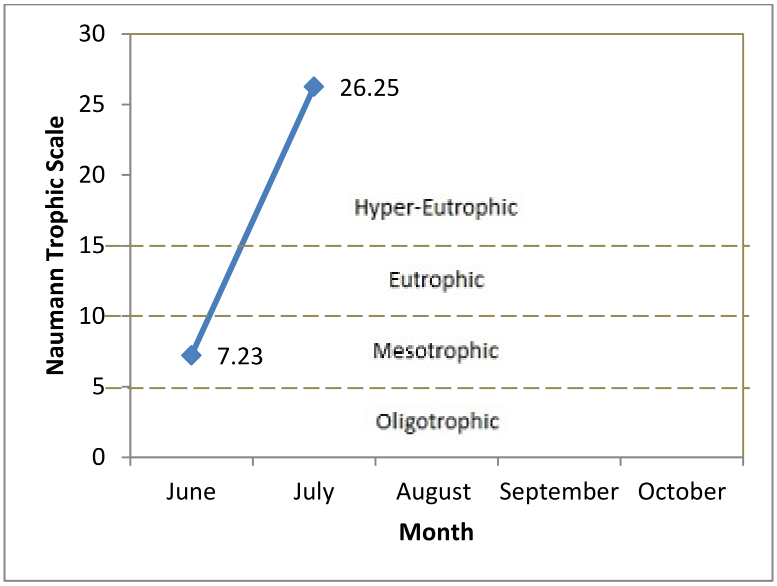

Figure 2.51: 2011 Naumann Trophic Scale results for Hazle Lake

Figure 2.51 depicts the Naumann Trophic Scale results for Hazle Lake for the months of June and July. The Naumann Trophic Scale was calculated to be 7.23 and 26.25 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 16.74 which falls under the slightly hyper-eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.13: 2011 results for Hazle Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Mesotrophic	Strongly Mesotrophic	-	-	Mesotrophic
Vollenweider	Slightly Eutrophic	Eutrophic	-	-	Eutrophic
Larsen-Mercier	Slightly Eutrophic	Slightly Eutrophic	-	-	Slightly Eutrophic
Burns	Mesotrophic	Eutrophic	-	-	Slightly Eutrophic
Naumann	Mesotrophic	Hyper-Eutrophic	-	-	Slightly Hyper-Eutrophic
Monthly-Average	Strongly Mesotrophic	Strongly Eutrophic	-	-	**Slightly Eutrophic**

Table 2.13 summarizes the results for Hazle Lake. As each model was used to classify Hazle Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Hazle Lake as slightly eutrophic.

2.14 **Hot Beach Pond**

Hot Beach Pond is a small pond located just north of Yellowstone Lake and the East Entrance Rd. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of October.

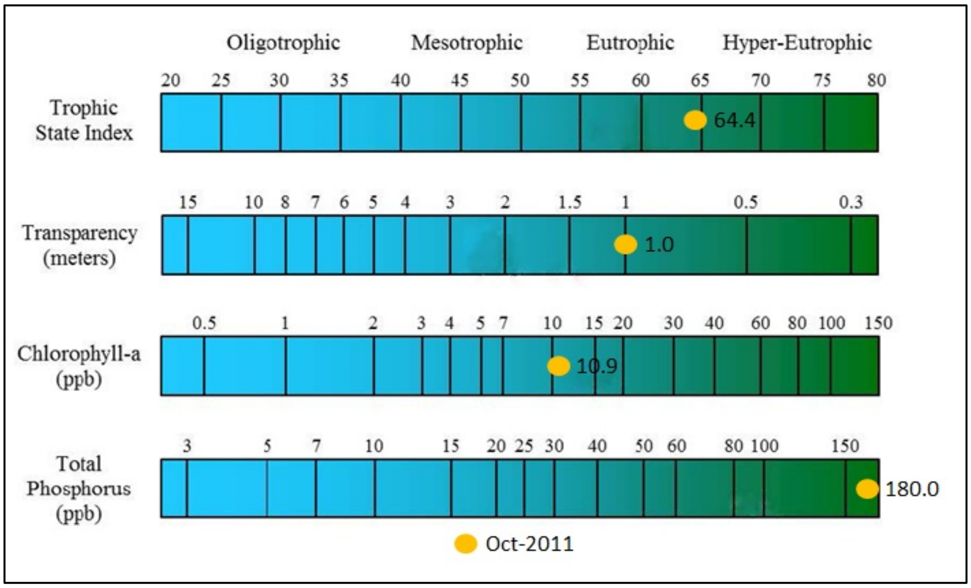

Figure 2.52: 2011 Carlson TSI results for Hot Beach Pond

Figure 2.52 shows the results from the Carlson TSI Model for Hot Beach Pond. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 64.4 for the month of October. Table 2.14 shows that the four-month average classification was determined to be strongly eutrophic according to the Carlson TSI Model.

Figure 2.53 shows the results from the Burns TLI Model for Hot Beach Pond. For the month of October the Burns TLI value was calculated to be 5.58. Table 2.14 shows that these values represent an overall classification of slightly hyper-eutrophic according to the Burns TLI Model.

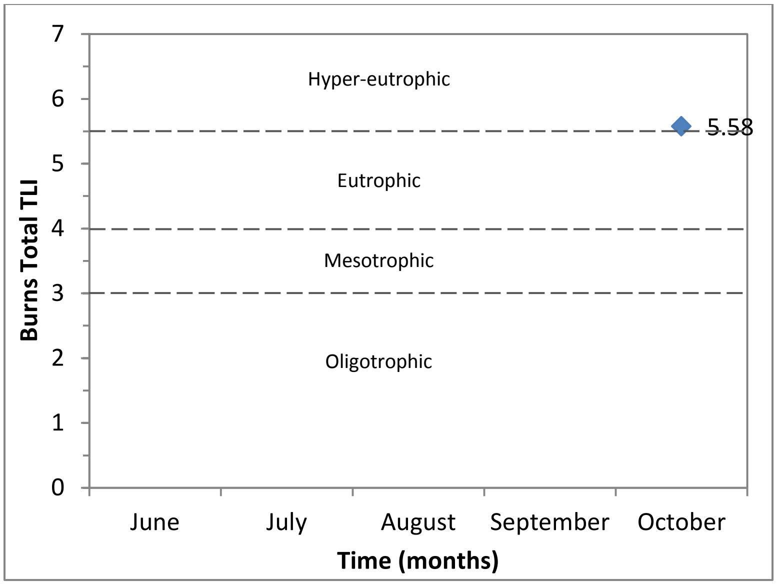

Figure 2.53: 2011 Burns TLI results for Hot Beach Pond

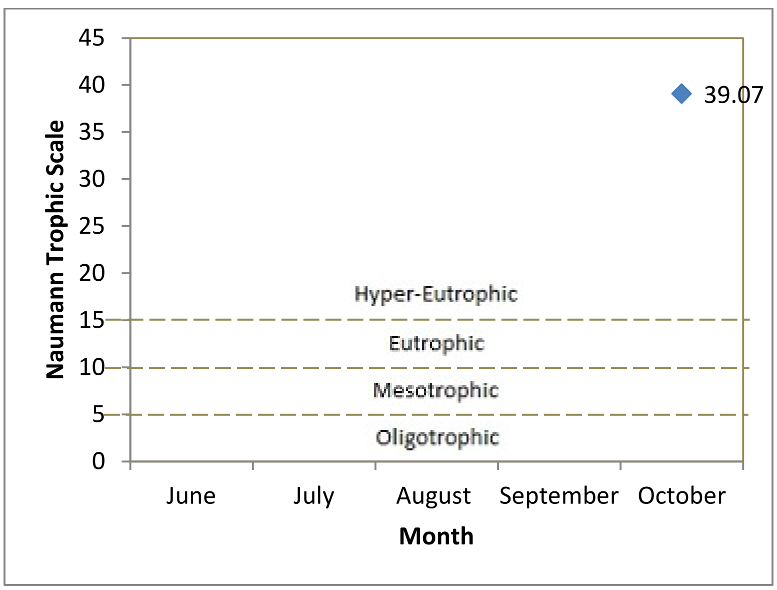

Figure 2.54: 2011 Naumann Trophic Scale results for Hot Beach Pond

Figure 2.54 depicts the Naumann Trophic Scale results for Hot Beach Pond for the month of October. The Naumann Trophic Scale was calculated to be 39.07 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Hot Beach Pond as hyper-eutrophic based on the Naumann Trophic Scale Model.

Table 2.14: 2011 results for Hot Beach Pond

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	-	Strongly Eutrophic	Strongly Eutrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	-	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic
Naumann	-	-	-	Hyper-Eutrophic	Hyper-Eutrophic
Monthly-Average	-	-	-	Hyper-Eutrophic	**Hyper-Eutrophic**

Table 2.14 summarizes the results for Hot Beach Pond. As each model was used to classify Hot Beach Pond into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Hot Beach Pond as hyper-eutrophic.

2.15 **Ice Lake**

Ice Lake is a medium sized lake located just north of Norris Canyon Rd. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of August.

Figure 2.55 shows the results from the Carlson TSI Model for Ice Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 41.6 in for the month of August. Table 2.15 shows that the four-month average classification was determined to be slightly mesotrophic according to the Carlson TSI Model.

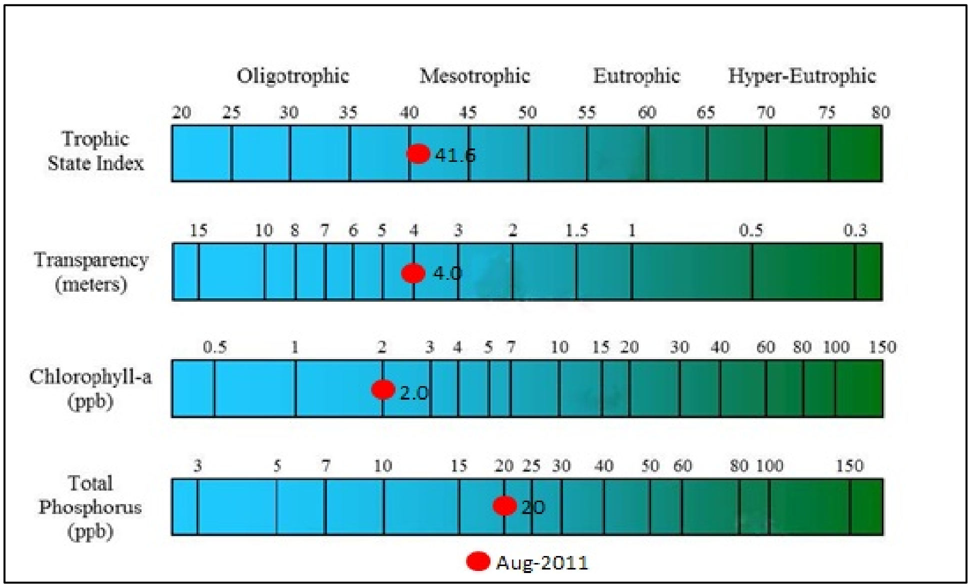

Figure 2.55: 2011 Carlson TSI results for Ice Lake

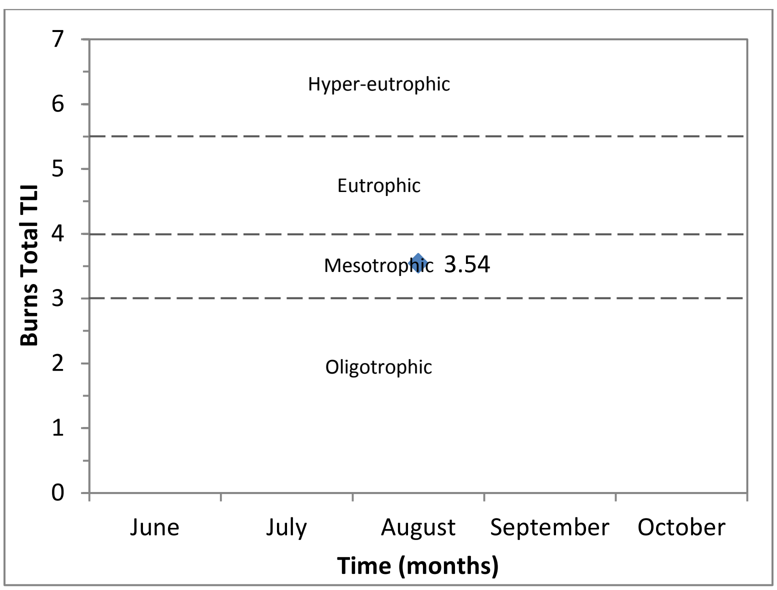

Figure 2.56: 2011 Burns TLI results for Ice Lake

Figure 2.56 shows the results from the Burns TLI Model for Ice Lake. For the month of August the Burns TLI value was calculated to be 3.54. Table 2.15 shows that this value represents an overall classification of mesotrophic according to the Burns TLI Model.

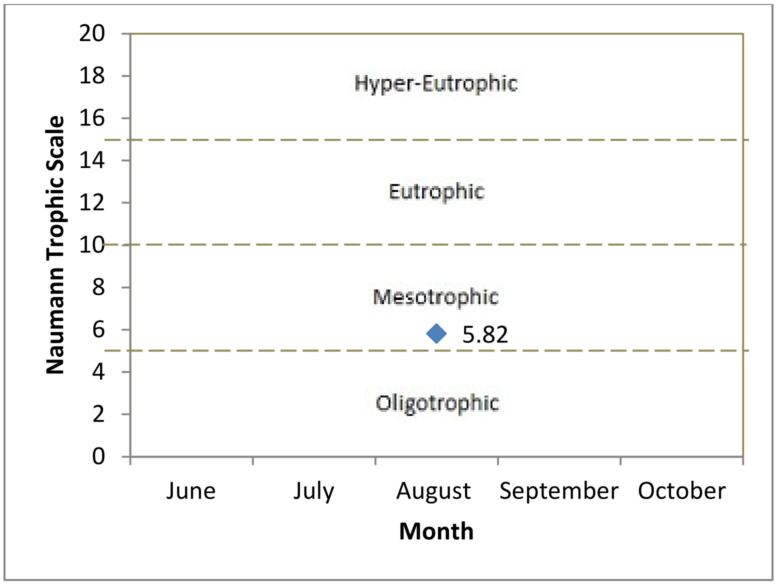

Figure 2.57: 2011 Naumann Trophic Scale results for Ice Lake

Figure 2.57 depicts the Naumann Trophic Scale results for Ice Lake for the month of August. The Naumann Trophic Scale was calculated to be 5.82 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Ice Lake as slightly mesotrophic based on the Naumann Trophic Scale Model.

Table 2.15: 2011 results for Ice Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	Slightly Mesotrophic	-	Sightly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	Mesotrophic	-	Mesotrophic
Naumann	-	-	Slightly Mesotrophic	-	Slightly Mesotrophic

Table 2.15 continued: 2011 results for Ice Lake

Monthly-Average	-	-	Slightly Mesotrophic	-	**Slightly Mesotrophic**

Table 2.15 summarizes the results for Ice Lake. As each model was used to classify Ice Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Ice Lake as slightly mesotrophic.

2.16 **Indian Pond**

Indian Pond is a relatively small pond located just off the north shore of Yellowstone Lake and just south of the East Entrance Rd. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of July, August, and October.

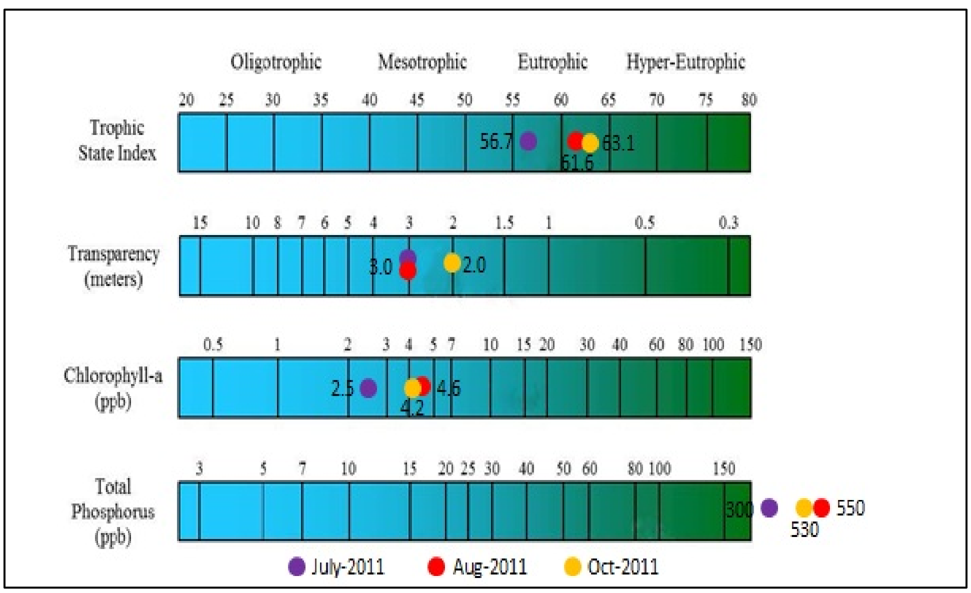

Figure 2.58: 2011 Carlson TSI results for Indian Pond

Figure 2.58 shows the results from the Carlson TSI Model for Indian Pond. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the

Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 56.7, 61.6, and 63.1 for the months of July, August, and October respectively. The three-month average TSI was calculated to be 61.1 which falls under the eutrophic classification according to the Carlson TSI Model.

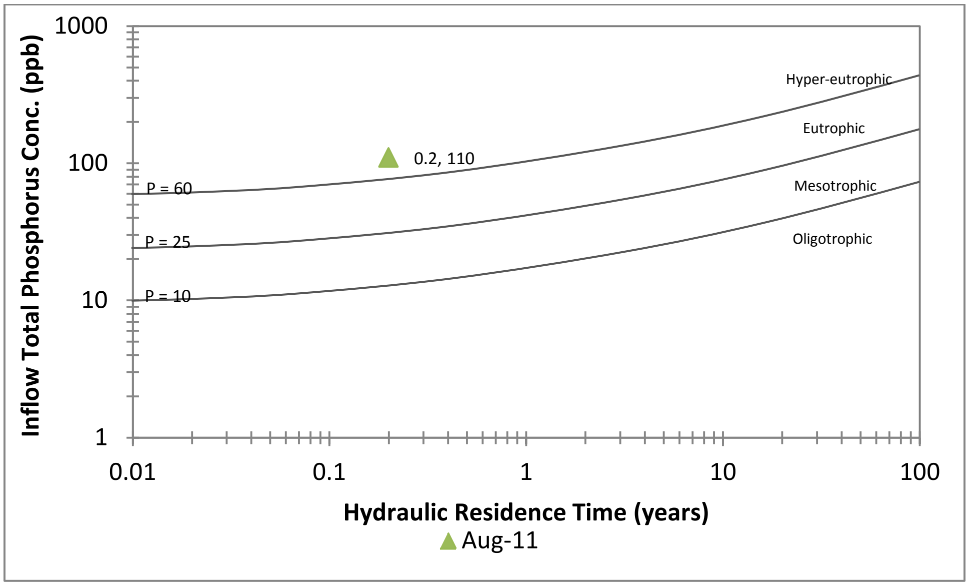

Figure 2.59: 2011 Vollenweider Model results for Indian Pond

Figure 2.59 shows the results from the Vollenweider Model for Indian Pond. The hydraulic residence time was calculated to be 0.2 years for the month of August. The inflow total phosphorus concentration was measured to be 110 ppb also for the month of August. As can be seen from the figure, these values represent an overall classification of slightly hyper-eutrophic based on the Vollenweider Model.

Figure 2.60 depicts the results from the Larsen Mercier Model for Indian Pond. A PRC value of 0.0 was used for the month of August. This is due to the inlake phosphorus concentration being greater than the inlet concentration. The inlet phosphorus concentrations were measured to be 0.11 mg/L. Table 2.16 depicts that this value represents an overall classification of hyper-eutrophic based on the Larsen Mercier Model.

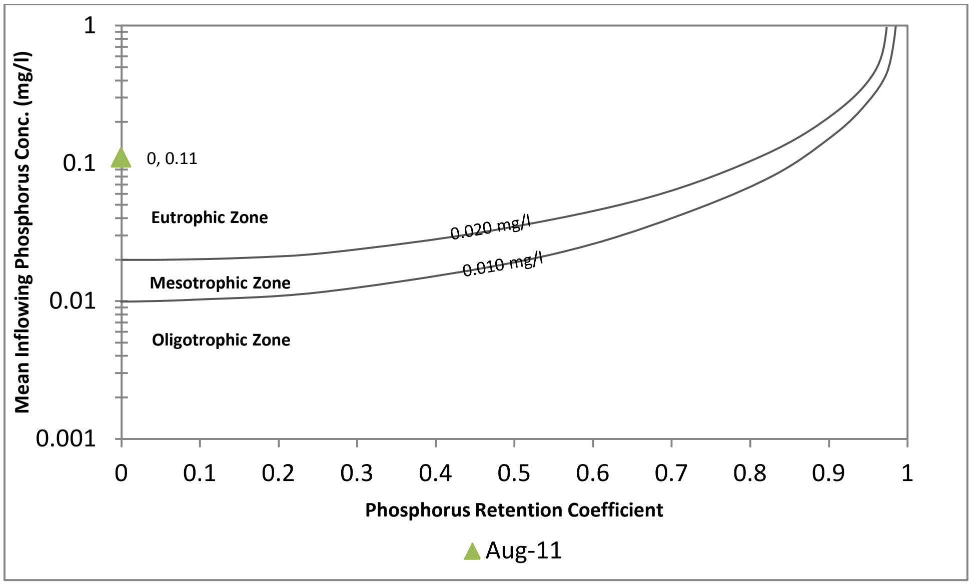

Figure 2.60: 2011 Larsen Mercier Model results for Indian Pond

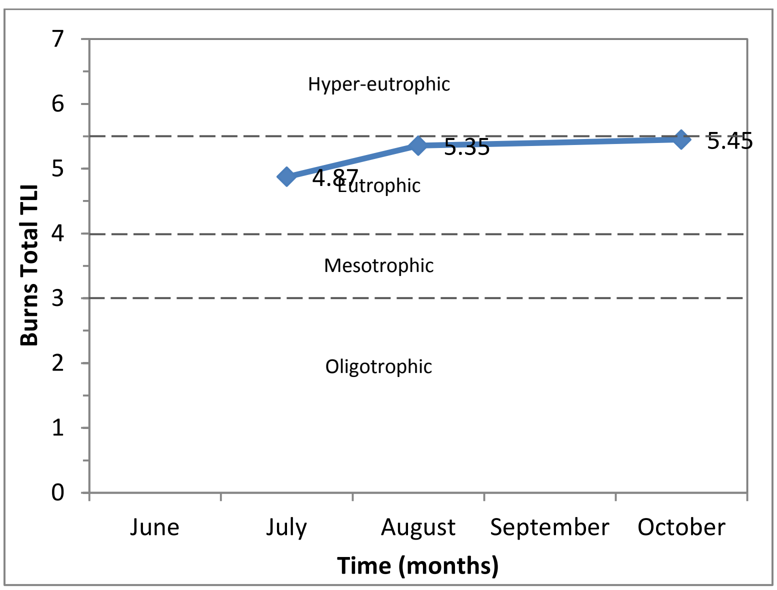

Figure 2.61: 2011 Burns TLI results for Indian Pond

Figure 2.61 shows the results from the Burns TLI Model for Indian Pond. For the months of July, August, and October the Burns TLI values were calculated to be 4.87, 5.35, and 5.45 respectively. The three-month average TLI was calculated to be 5.27 which falls under the strongly eutrophic classification according to the Burns TLI Model.

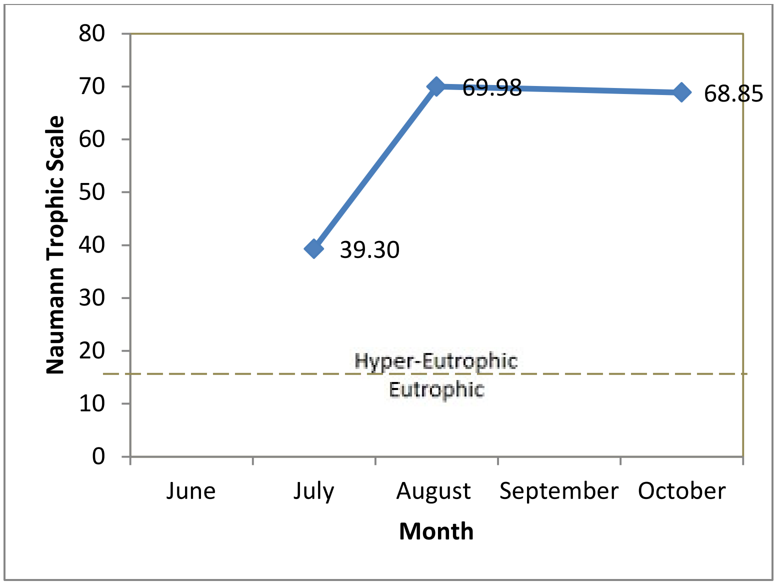

Figure 2.62: 2011 Naumann Trophic Scale results for Indian Pond

Figure 2.62 depicts the Naumann Trophic Scale results for Indian Pond for the months of July, August, and October. The Naumann Trophic Scale was calculated to be 39.30, 69.98, and 68.85 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The three-month average trophic scale was calculated to be 59.38 which falls under the hyper-eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.16: 2011 results for Indian Pond

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Slightly Eutrophic	Strongly Eutrophic	Strongly Eutrophic	Eutrophic
Vollenweider	-	-	Hyper-Eutrophic	-	Slightly Hyper-Eutrophic
Larsen-Mercier	-	-	Hyper-Eutrophic	-	Hyper-Eutrophic
Burns	-	Eutrophic	Strongly Eutrophic	Strongly Eutrophic	Strongly Eutrophic

Table 2.16 continued: 2011 results for Indian Pond

Naumann		Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic
Monthly-Average	-	Strongly Eutrophic	Slightly Hyper-Eutrophic	Strongly Eutrophic	**Strongly Eutrophic**

Table 2.16 summarizes the results for Indian Pond. As each model was used to classify Indian Pond into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Indian Pond as strongly eutrophic.

2.17 Isa Lake

Isa Lake is a very small lake located just north Grand Loop Rd and east of Old Faithful. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of October.

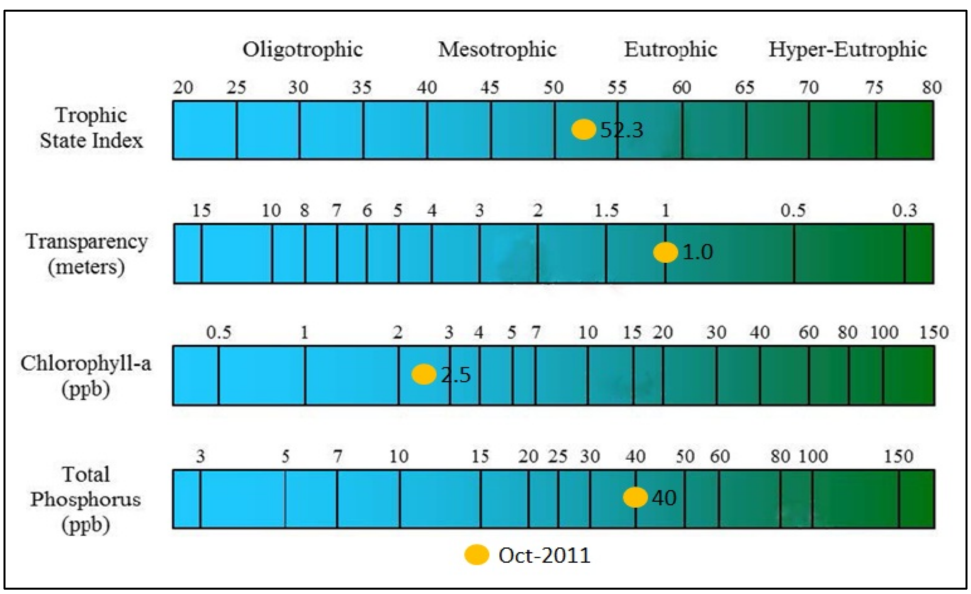

Figure 2.63: 2011 Carlson TSI results for Isa Lake

Figure 2.63 shows the results from the Carlson TSI Model for Isa Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 52.3 for the month of October. Table 2.17 shows that the four-month average classification was determined to be strongly mesotrophic according to the Carlson TSI Model.

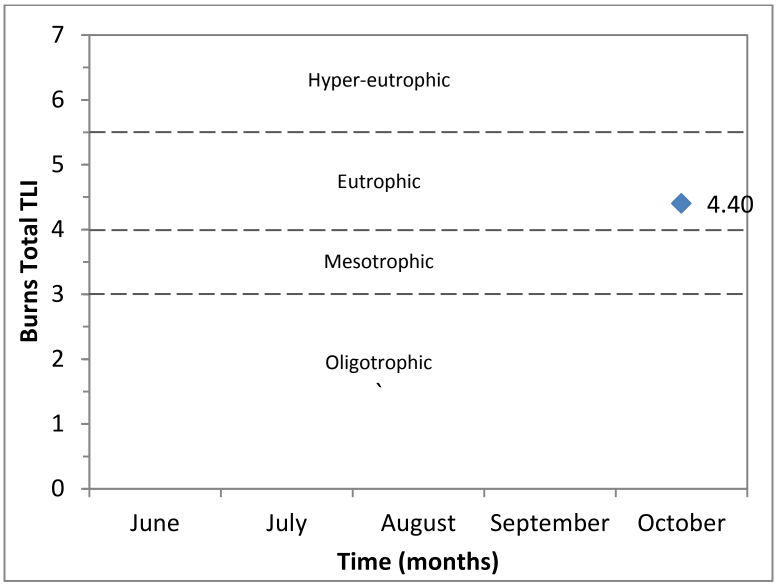

Figure 2.64: 2011 Burns TLI results for Isa Lake

Figure 2.64 shows the results from the Burns TLI Model for Isa Lake. For the month of October the Burns TLI value was calculated to be 4.40. Table 2.17 shows that this value represents an overall classification of slightly eutrophic according to the Burns TLI Model.

Figure 2.65 depicts the Naumann Trophic Scale results for Isa Lake for the month of October. The Naumann Trophic Scale was calculated to be 15.47 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Isa Lake as slightly hyper-eutrophic based on the Naumann Trophic Scale Model.

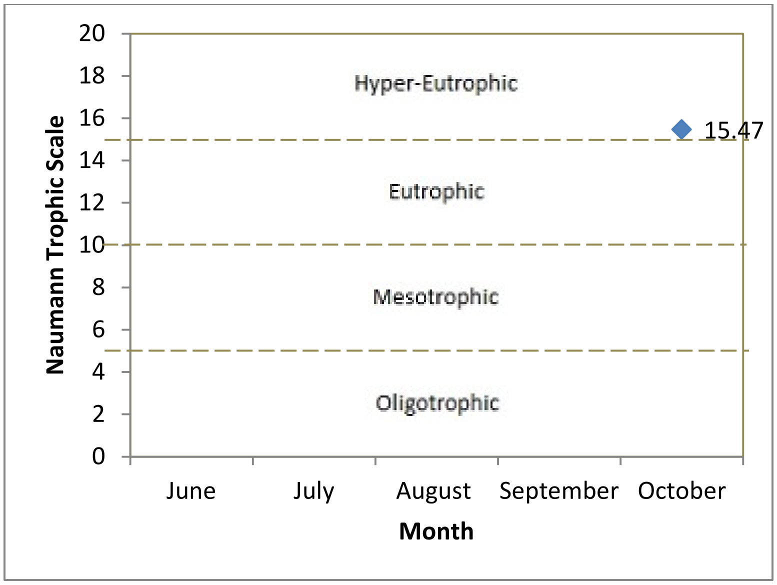

Figure 2.65: 2011 Naumann Trophic Scale results for Isa Lake

Table 2.17: 2011 results for Isa Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	-	Strongly Mesotrophic	Strongly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	-	Slightly Eutrophic	Slightly Eutrophic
Naumann	-	-	-	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic
Monthly-Average	-	-	-	Eutrophic	**Eutrophic**

Table 2.17 summarizes the results for Isa Lake. As each model was used to classify Isa Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Isa Lake as eutrophic.

2.18 **Lewis Lake**

Lewis Lake is a relatively large lake located along the South Entrance Rd. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the months of June and August.

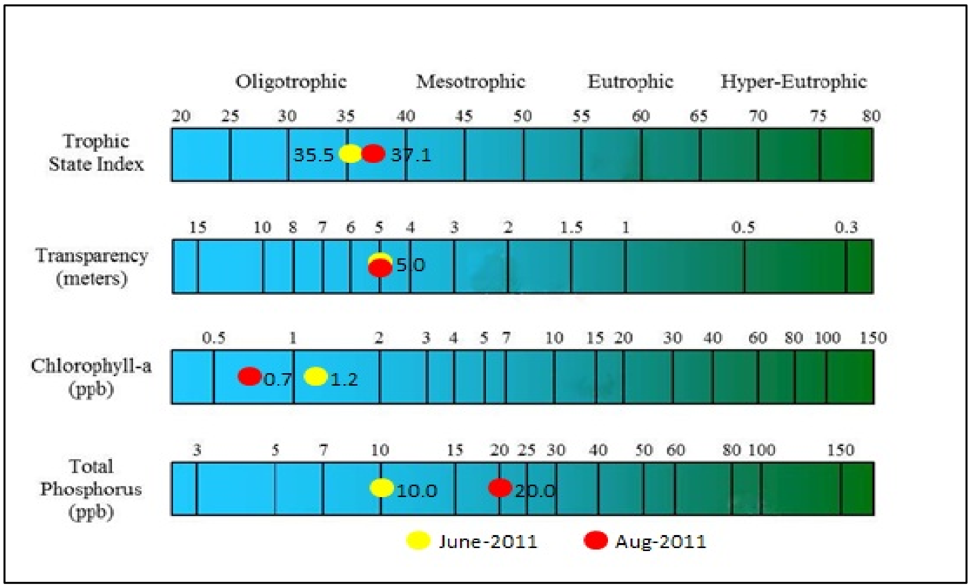

Figure 2.66: 2011 Carlson TSI results for Lewis Lake

Figure 2.66 shows the results from the Carlson TSI Model for Lewis Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 35.5 for the month of June and 37.1 for the month of August. The two-month average TSI was calculated to be 36.8 which falls under the slightly oligotrophic classification according to the Carlson TSI Model.

Figure 2.67 shows the results from the Burns TLI Model for Lewis Lake. For the months of June and August the Burns TLI values were calculated to be 2.98 and 3.08 respectively. The two-month average TLI was calculated to be 3.07 which falls under the slightly mesotrophic classification according to the Burns TLI Model.

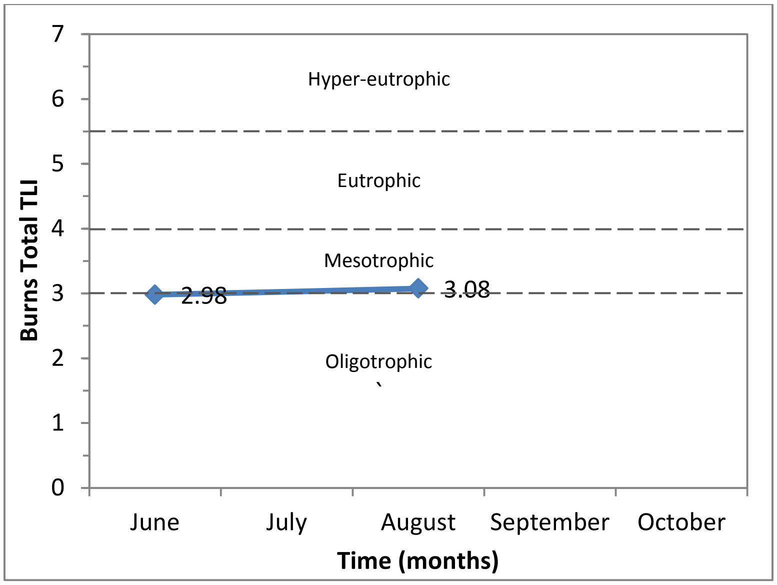

Figure 2.67: 2011 Burns TLI results for Lewis Lake

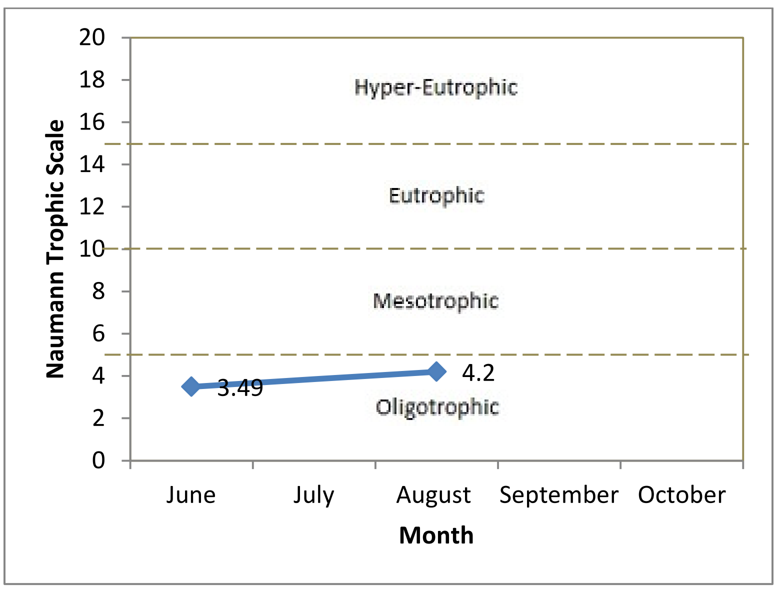

Figure 2.68: 2011 Naumann Trophic Scale results for Lewis Lake

Figure 2.68 depicts the Naumann Trophic Scale results for Lewis Lake for the months of June and August. The Naumann Trophic Scale was calculated to be 3.49 and 4.20 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 3.85 which falls under the slightly oligotrophic classification according to the Naumann Trophic Scale Model.

Table 2.18: 2011 results for Lewis Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Oligotrophic	-	Slightly Oligotrophic	-	Slightly Oligotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Slightly Oligotrophic	-	Slightly Mesotrophic	-	Slightly Mesotrophic
Naumann	Oligotrophic	-	Slightly Oligotrophic	-	Slightly Oligotrophic
Monthly-Average	Slightly Oligotrophic	-	Slightly Oligotrophic	-	**Slightly Oligotrophic**

Table 2.18 summarizes the results for Lewis Lake. As each model was used to classify Lewis Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Lewis Lake as slightly oligotrophic.

2.19 **Lily Pad Lake**

Lily Pad Lake is a very small lake located just east of Clear Lake and near Canyon. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the months of June and October.

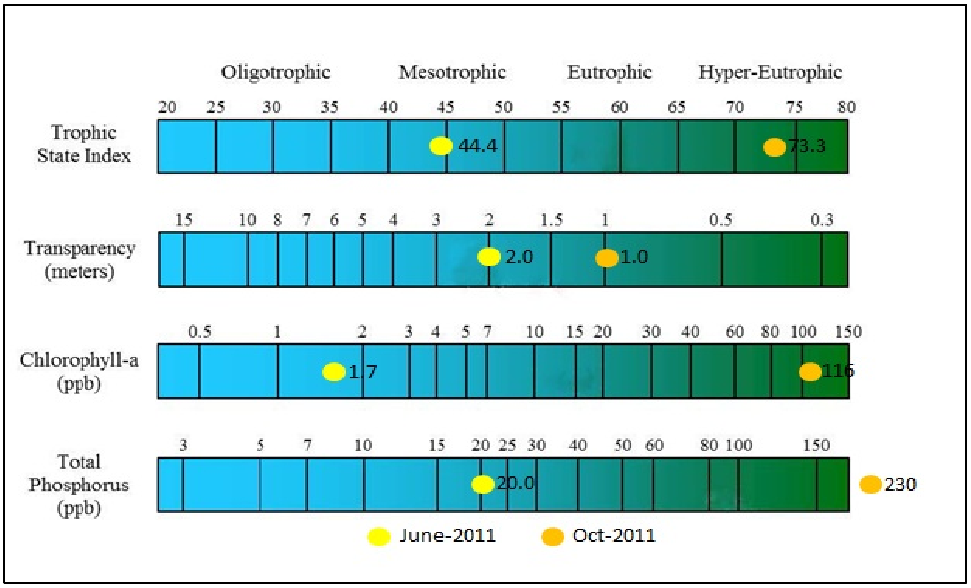

Figure 2.69: 2011 Carlson TSI results for Lily Pad Lake

Figure 2.69 shows the results from the Carlson TSI Model for Lily Pad Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 44.4 for the month of June and 73.3 for the month of October. This seems to be a significant increase over the summer of 2011. The two-month average TSI was calculated to be 59.5 which falls under the eutrophic classification according to the Carlson TSI Model.

Figure 2.70 shows the results from the Burns TLI Model for Lily Pad Lake. For the months of June and October the Burns TLI values were calculated to be 3.73 and 6.55 respectively. The two-month average TLI was calculated to be 5.19 which falls under the strongly eutrophic classification according to the Burns TLI Model.

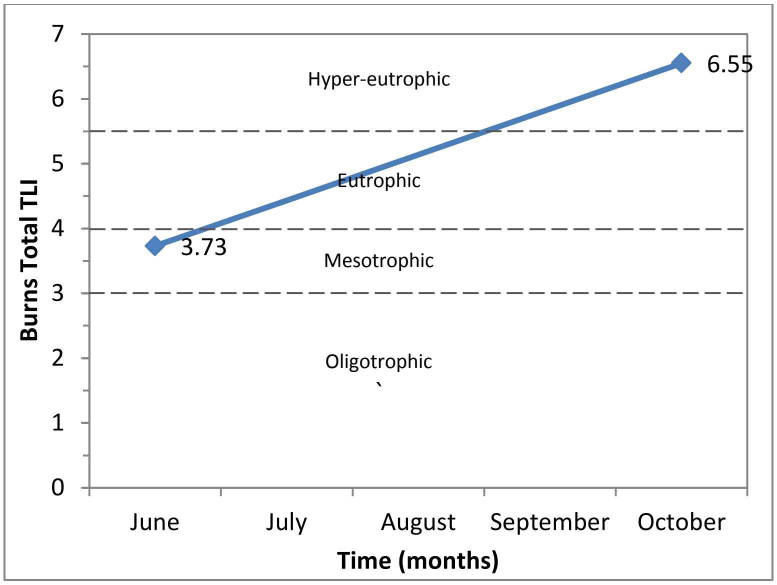

Figure 2.70: 2011 Burns TLI results for Lily Pad Lake

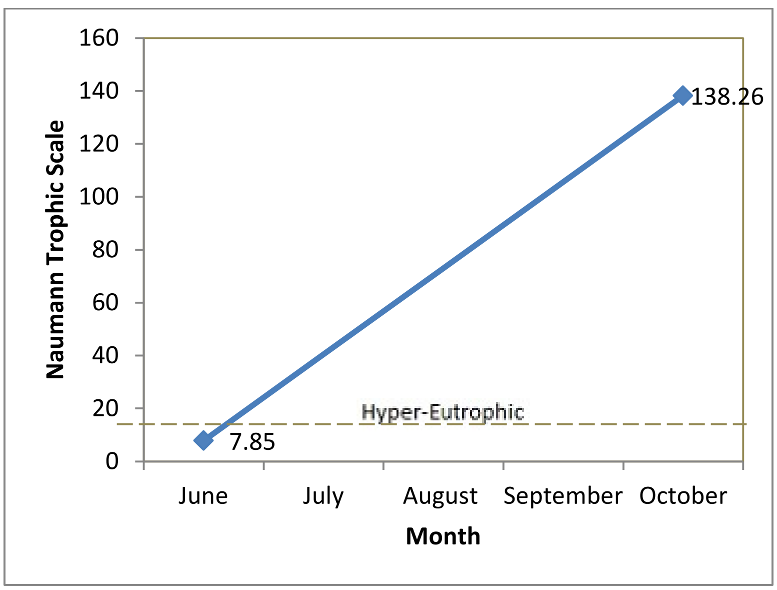

Figure 2.71: 2011 Naumann Trophic Scale results for Lily Pad Lake

Figure 2.71 depicts the Naumann Trophic Scale results for Lily Pad Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 7.85 and 138.26 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 73.06 which falls under the hyper-eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.19: 2011 results for Lily Pad Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Mesotrophic	-	-	Hyper-Eutrophic	Eutrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Strongly Mesotrophic	-	-	Hyper-Eutrophic	Strongly Eutrophic
Naumann	Mesotrophic	-	-	Hyper-Eutrophic	Hyper-Eutrophic
Monthly-Average	Strongly Mesotrophic	-	-	Hyper-Eutrophic	**Slightly-Hyper-Eutrophic**

Table 2.19 summarizes the results for Lily Pad Lake. As each model was used to classify Lily Pad Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Lily Pad Lake as slightly hyper-eutrophic.

2.20 **Lost Lake**

Lost Lake is a relatively small lake located southwest of the Grand Loop Rd/Northeast Entrance Rd intersection and near Roosevelt Lodge. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June, July, and August.

Figure 2.72 shows the results from the Carlson TSI Model for Lost Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 53.1, 46.4, and 41.9 for the months of June, July, and August respectively. The three-month average TSI was calculated to be 47.3 which falls under the mesotrophic classification according to the Carlson TSI Model.

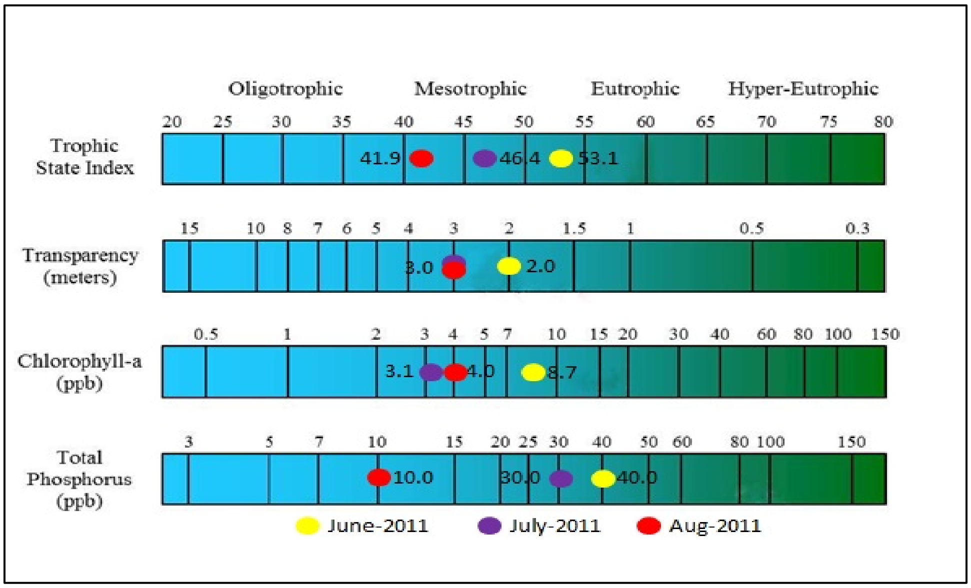

Figure 2.72: 2011 Carlson TSI results for Lost Lake

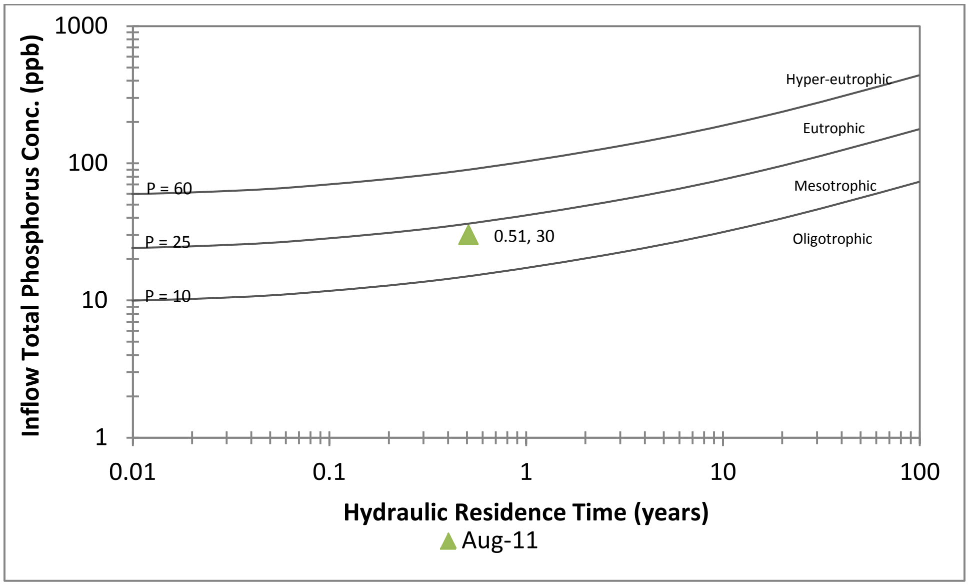

Figure 2.73: 2011 Vollenweider Model results for Lost Lake

Figure 2.73 shows the results from the Vollenweider Model for Lost Lake. The hydraulic residence time was calculated to be 0.51 years for the month of August. The inflow total phosphorus concentration was measured to be 30 ppb for the month of August. As can be seen from the figure, this value represents an overall classification of strongly mesotrophic based on the Vollenweider Model.

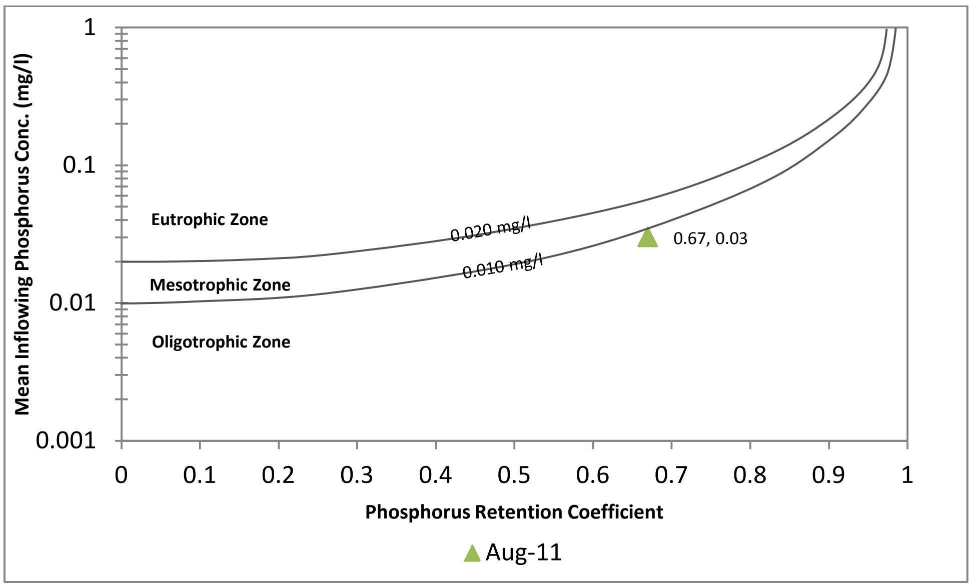

Figure 2.74: 2011 Larsen Mercier Model results for Lost Lake

Figure 2.74 depicts the results from the Larsen Mercier Model for Lost Lake. A PRC value of 0.67 was calculated for the month of August. The inlet phosphorus concentration was measured to be 0.03 mg/L. Table 2.20 depicts that this value represents an overall classification of slightly oligotrophic based on the Larsen Mercier Model.

Figure 2.75 shows the results from the Burns TLI Model for Lost Lake. For the months of June, July, and August the Burns TLI values were calculated to be 4.62, 3.98, and 3.61 respectively. The three-month average TLI was calculated to be 4.09 which falls under the slightly eutrophic classification according to the Burns TLI Model.

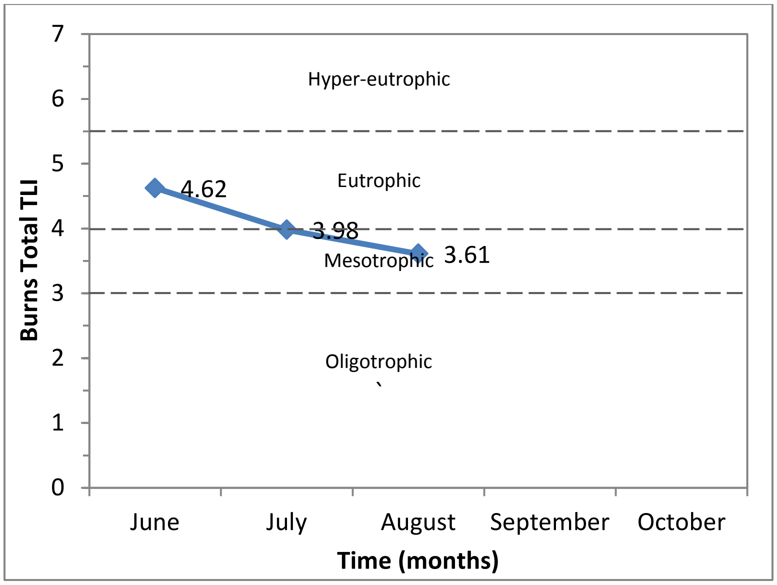

Figure 2.75: 2011 Burns TLI results for Lost Lake

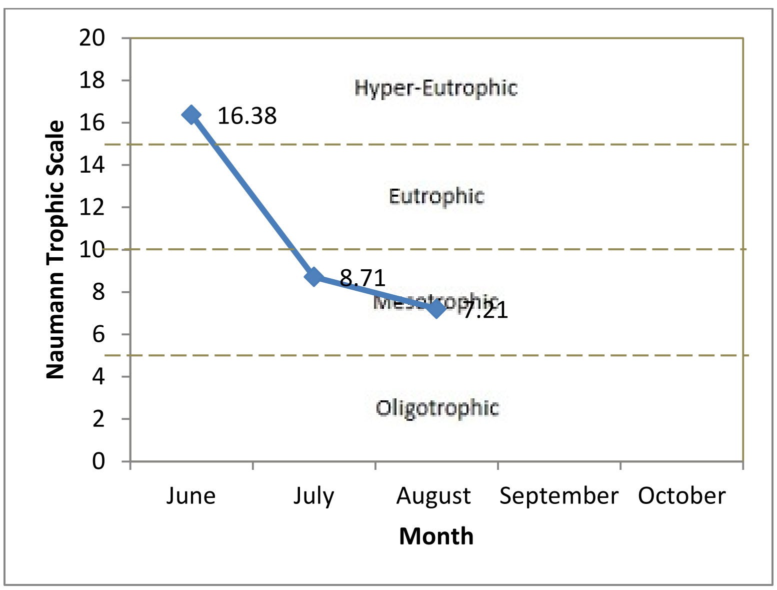

Figure 2.76: 2011 Naumann Trophic Scale results for Lost Lake

Figure 2.76 depicts the Naumann Trophic Scale results for Lost Lake for the months of June, July, and August. The Naumann Trophic Scale was calculated to be 16.38, 8.71, and 7.21 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The three-month average trophic scale was calculated to be 10.77 which falls under the slightly eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.20: 2011 results for Lost Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Strongly Mesotrophic	Mesotrophic	Slightly Mesotrophic	-	Mesotrophic
Vollenweider	-	-	Strongly Mesotrophic	-	Strongly Mesotrophic
Larsen-Mercier	-	-	Slightly Oligotrophic	-	Slightly Oligotrophic
Burns	Eutrophic	Strongly Mesotrophic	Mesotrophic	-	Slightly Eutrophic
Naumann	Slightly Hyper-Eutrophic	Strongly Mesotrophic	Mesotrophic	-	Slightly Eutrophic
Monthly-Average	Strongly Eutrophic	Strongly Mesotrophic	Mesotrophic	-	**Strongly Mesotrophic**

Table 2.20 summarizes the results for Lost Lake. As each model was used to classify Lost Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Lost Lake as strongly mesotrophic.

2.21 **North Twin Lake**

North Twin Lake is a relatively small lake located just west of Grand Loop Rd and east of Obsidian Creek. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June and October.

Figure 2.77 shows the results from the Carlson TSI Model for North Twin Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 40.3 for the month of June and 43.8 for the month of October. The two-month average TSI was calculated to be 42.9 which falls under the mesotrophic classification according to the Carlson TSI Model.

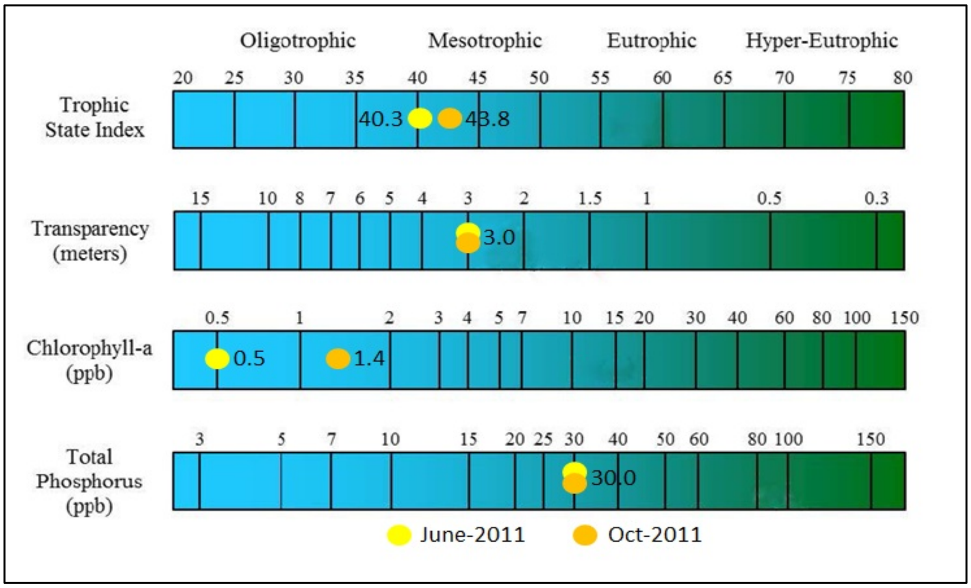

Figure 2.77: 2011 Carlson TSI results for North Twin Lake

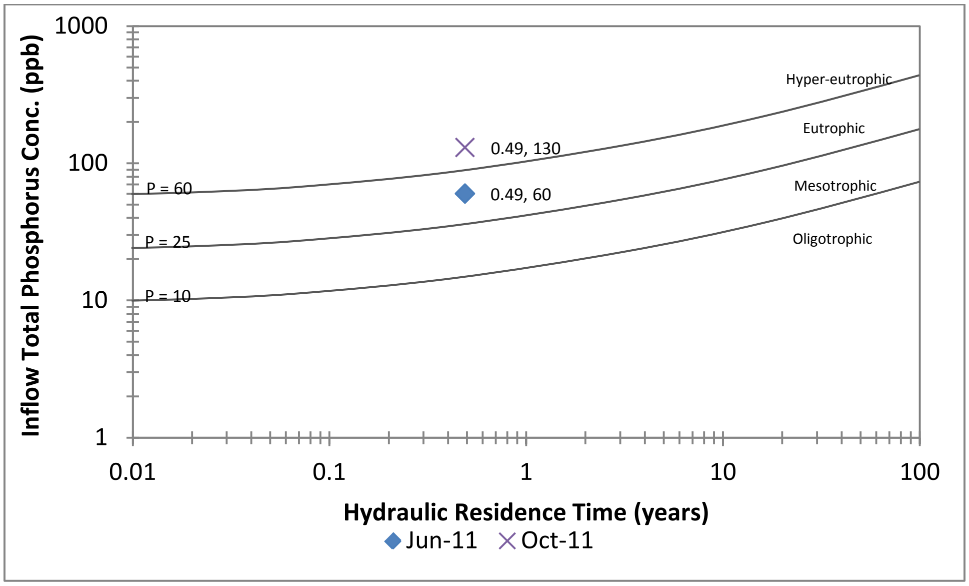

Figure 2.78: 2011 Vollenweider Model results for North Twin Lake

Figure 2.78 shows the results from the Vollenweider Model for North Twin Lake. The hydraulic residence time was calculated to be 0.49 years for the months of June and October. The inflow total phosphorus concentration was measured to be 60 ppb for the month of June and 130 ppb for the month of October. As can be seen from the figure, these values represent an overall classification of strongly eutrophic based on the Vollenweider Model.

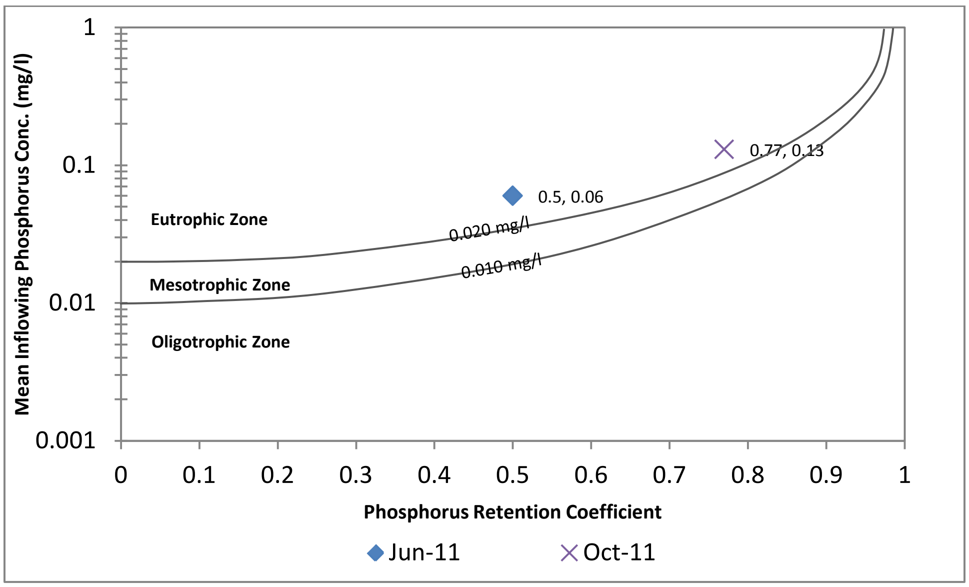

Figure 2.79: 2011 Larsen Mercier Model results for North Twin Lake

Figure 2.79 depicts the results from the Larsen Mercier Model for North Twin Lake. PRC values of 0.5 and 0.77 were calculated for the months of June and October respectively. The inlet phosphorus concentrations were measured to be 0.06 and 0.13 mg/L for the months of June and October respectively. Table 2.21 depicts that these values represent an overall classification of eutrophic based on the Larsen Mercier Model.

Figure 2.80 shows the results from the Burns TLI Model for North Twin Lake. For the months of June and October the Burns TLI values were calculated to be 3.31 and 3.69 respectively. The two-month average TLI was calculated to be 3.56 which falls under the mesotrophic classification according to the Burns TLI Model.

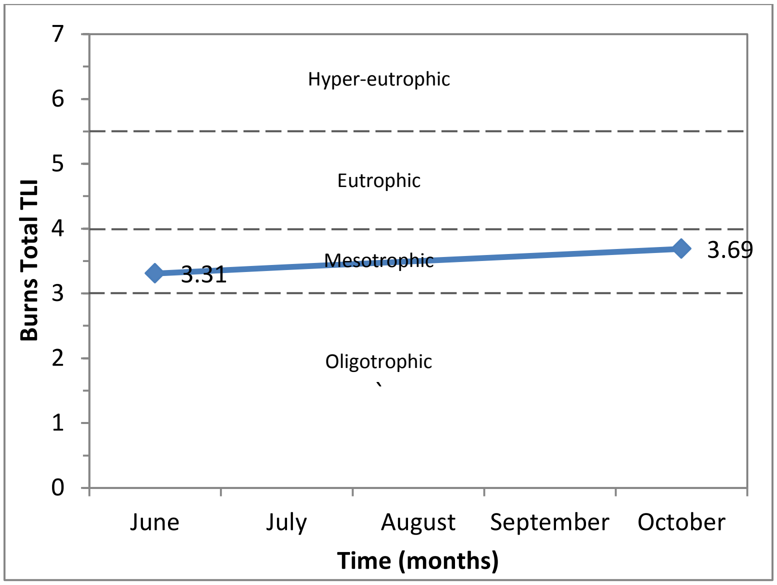

Figure 2.80: 2011 Burns TLI results for North Twin Lake

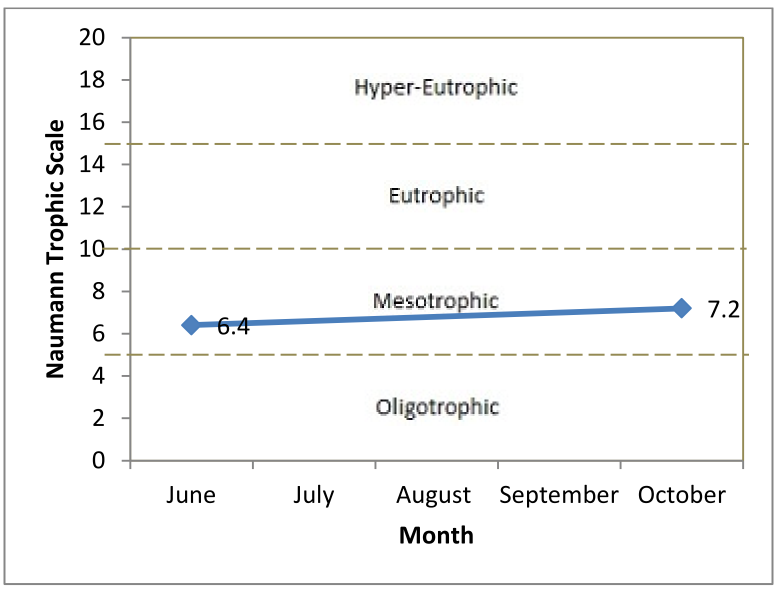

Figure 2.81: 2011 Naumann Trophic Scale results for North Twin Lake

Figure 2.81 depicts the Naumann Trophic Scale results for North Twin Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 6.40 and 7.20 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 6.8 which falls under the mesotrophic classification according to the Naumann Trophic Scale Model.

Table 2.21: 2011 results for North Twin Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Mesotrophic	-	-	Mesotrophic	Mesotrophic
Vollenweider	Eutrophic	-	-	Slightly Hyper-Eutrophic	Strongly Eutrophic
Larsen-Mercier	Eutrophic	-	-	Eutrophic	Eutrophic
Burns	Mesotrophic	-	-	Strongly Mesotrophic	Mesotrophic
Naumann	Slightly Mesotrophic	-	-	Mesotrophic	Mesotrophic
Monthly-Average	Strongly Mesotrophic	-	-	Eutrophic	**Slightly Eutrophic**

Table 2.21 summarizes the results for North Twin Lake. As each model was used to classify North Twin Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify North Twin Lake as slightly eutrophic.

2.22 **Nymph Lake**

Nymph Lake is a very small lake located just west of Grand Loop Rd and south of the Twin Lakes. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of July and August.

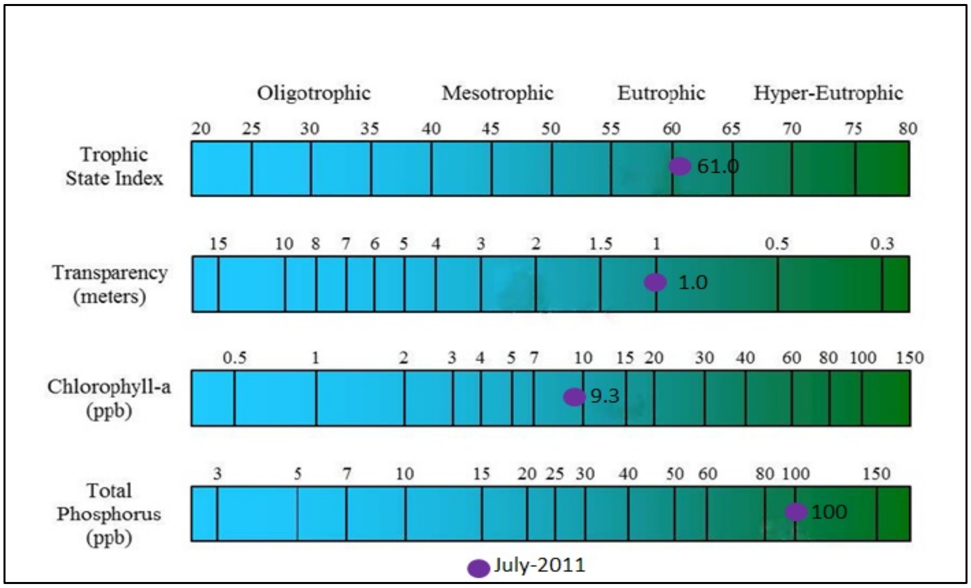

Figure 2.82: 2011 Carlson TSI results for Nymph Lake

Figure 2.82 shows the results from the Carlson TSI Model for Nymph Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 61.0 for the month of July. Table 2.22 shows that the four-month average classification was determined to be eutrophic according to the Carlson TSI Model.

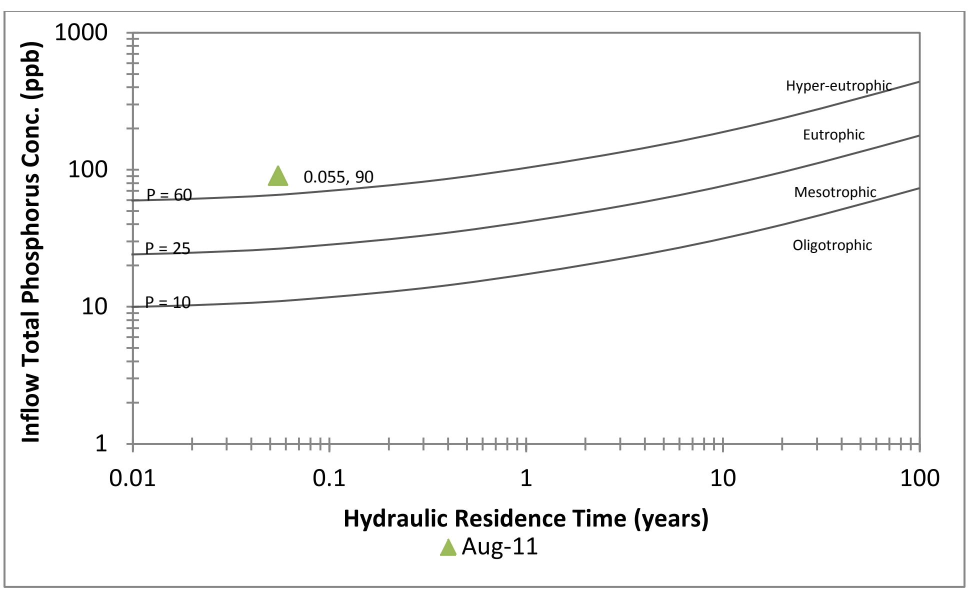

Figure 2.83: 2011 Vollenweider Model results for Nymph Lake

Figure 2.83 shows the results from the Vollenweider Model for Nymph Lake. The hydraulic residence time was calculated to be 0.055 years for the month of July. The inflow total phosphorus concentration was measured to be 90 ppb also for the month of July. As can be seen from the figure, this value represents an overall classification of slightly hyper-eutrophic based on the Vollenweider Model.

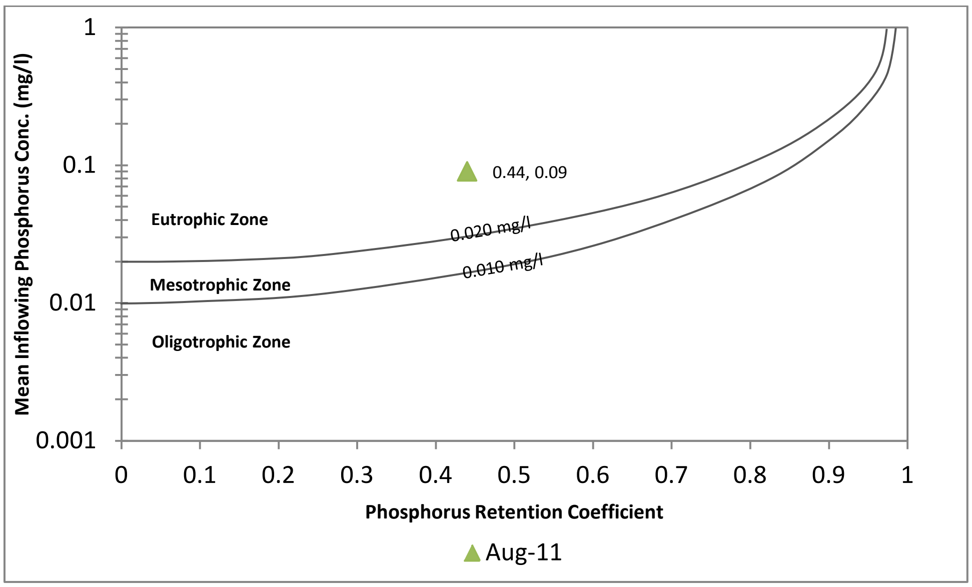

Figure 2.84: 2011 Larsen Mercier Model results for Nymph Lake

Figure 2.84 depicts the results from the Larsen Mercier Model for Nymph Lake. A PRC value of 0.44 was calculated for the month of August. The inlet phosphorus concentration was measured to be 0.09 mg/L. Table 2.22 depicts that this value represents an overall classification of slightly hyper-eutrophic based on the Larsen Mercier Model.

Figure 2.85 shows the results from the Burns TLI Model for Nymph Lake. For the months of July the Burns TLI value was calculated to be 5.27. Table 2.22 shows that this value represents an overall classification of strongly eutrophic according to the Burns TLI Model.

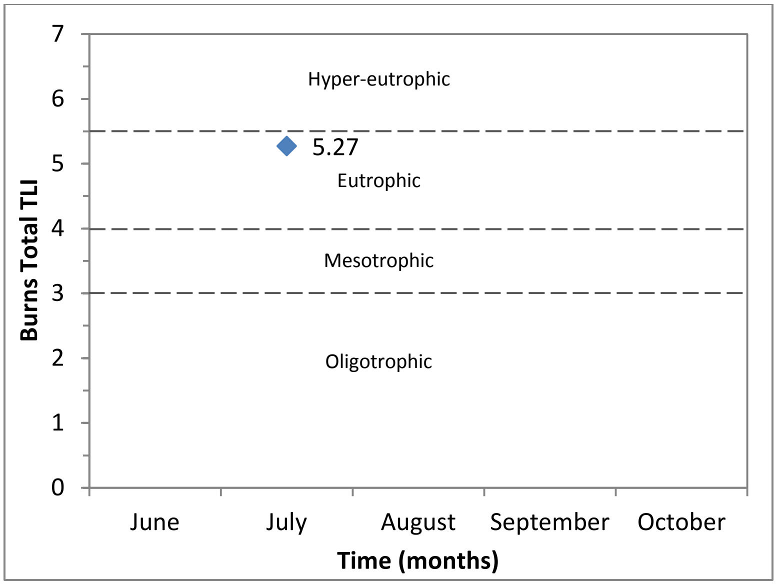

Figure 2.85: 2011 Burns TLI results for Nymph Lake

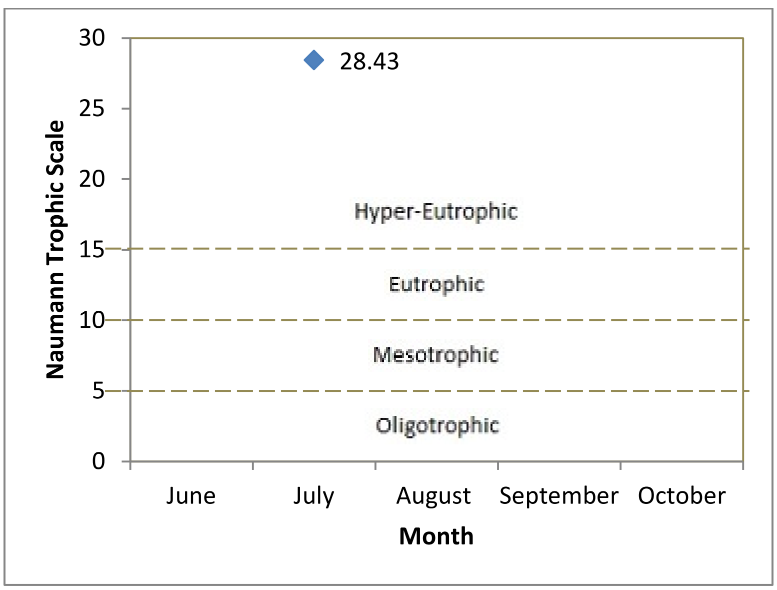

Figure 2.86: 2011 Naumann Trophic Scale results for Nymph Lake

Figure 2.86 depicts the Naumann Trophic Scale results for Nymph Lake for the month of July. The Naumann Trophic Scale was calculated to be 28.43 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Nymph Lake as hyper-eutrophic based on the Naumann Trophic Scale Model.

Table 2.22: 2011 results for Nymph Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Eutrophic	-	-	Eutrophic
Vollenweider	-	-	Hyper-Eutrophic	-	Slightly Hyper-Eutrophic
Larsen-Mercier	-	-	Slightly Hyper-Eutrophic	-	Slightly Hyper-Eutrophic
Burns	-	Strongly Eutrophic	-	-	Strongly Eutrophic
Naumann	-	Hyper-Eutrophic	-	-	Hyper-Eutrophic
Monthly-Average	-	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic	-	**Slightly Hyper-Eutrophic**

Table 2.22 summarizes the results for Nymph Lake. As each model was used to classify Nymph Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Nymph Lake as slightly hyper-eutrophic.

2.23 **Scaup Lake**

Scaup Lake is a very small lake located just north of Grand Loop Rd and Shoshone Lake. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were taken at an inlake location. Measurements were made in the months of October.

Figure 2.87 shows the results from the Carlson TSI Model for Scaup Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 46.6 for the month of October. Table 2.23 shows that the four-month average classification was determined to be mesotrophic according to the Carlson TSI Model.

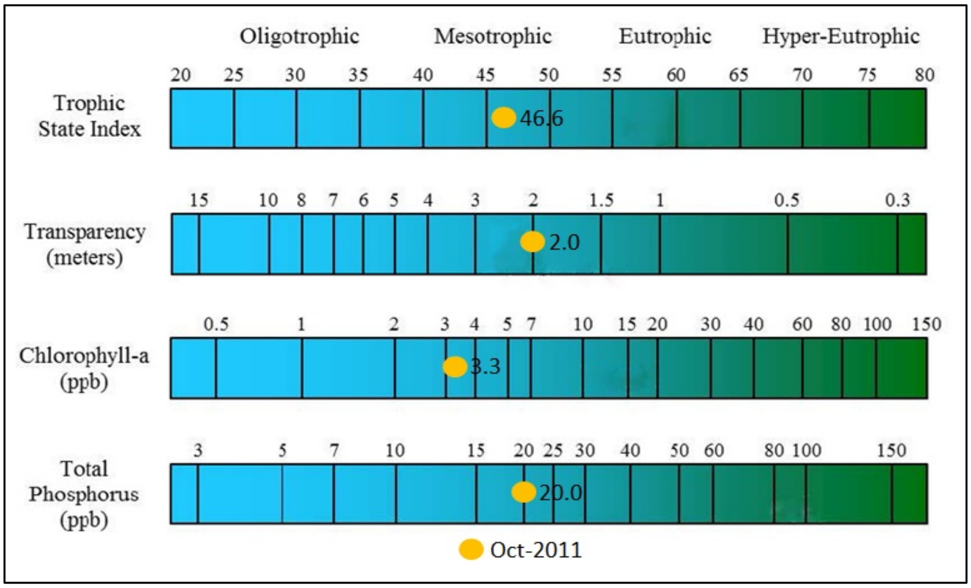

Figure 2.87: 2011 Carlson TSI results for Scaup Lake

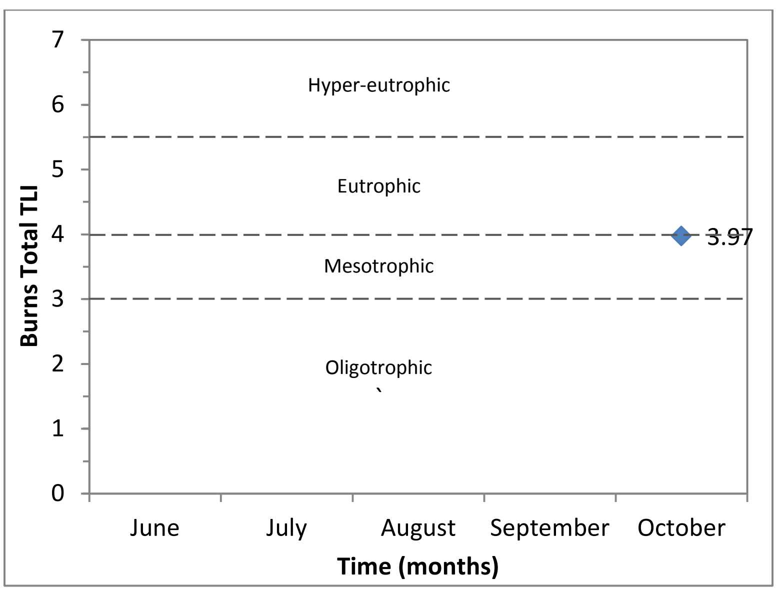

Figure 2.88: 2011 Burns TLI results for Scaup Lake

Figure 2.88 shows the results from the Burns TLI Model for Scaup Lake. For the month of October the Burns TLI value was calculated to be 3.97. Table 2.23 shows that this value represents an overall classification of strongly mesotrophic according to the Burns TLI Model.

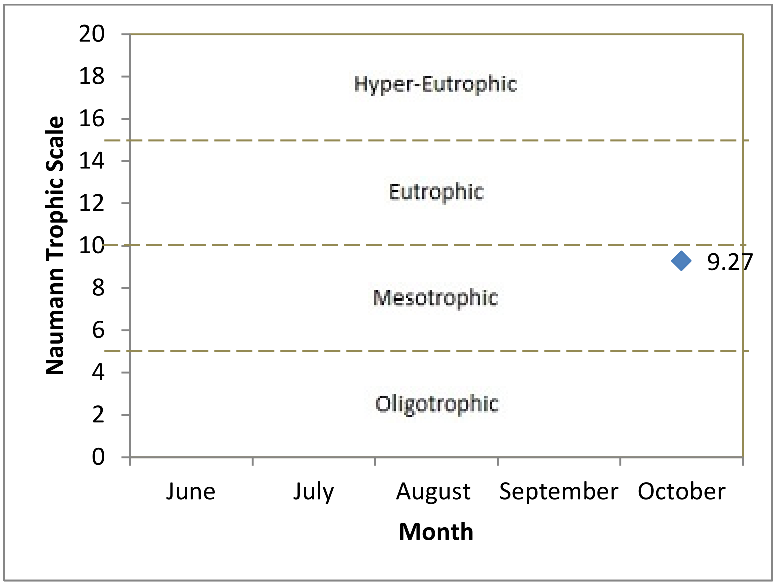

Figure 2.89: 2011 Naumann Trophic Scale results for Scaup Lake

Figure 2.89 depicts the Naumann Trophic Scale results for Scaup Lake for the month of October. The Naumann Trophic Scale was calculated to be 9.27 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Scaup Lake as strongly mesotrophic based on the Naumann Trophic Scale Model.

Table 2.23: 2011 results for Scaup Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	-	Mesotrophic	Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	-	Strongly Mesotrophic	Strongly Mesotrophic

Table 2.23 continued: 2011 results for Scaup Lake

Naumann	-	-	-	Strongly Mesotrophic	Strongly Mesotrophic
Monthly-Average	-	-	-	Strongly Mesotrophic	**Strongly Mesotrophic**

Table 2.23 summarizes the results for Scaup Lake. As each model was used to classify Scaup Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Scaup Lake as strongly mesotrophic.

2.24 **Shrimp Lake**

Shrimp Lake is a very small lake located just west of Buck Lake and north of Trout Lake. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of October.

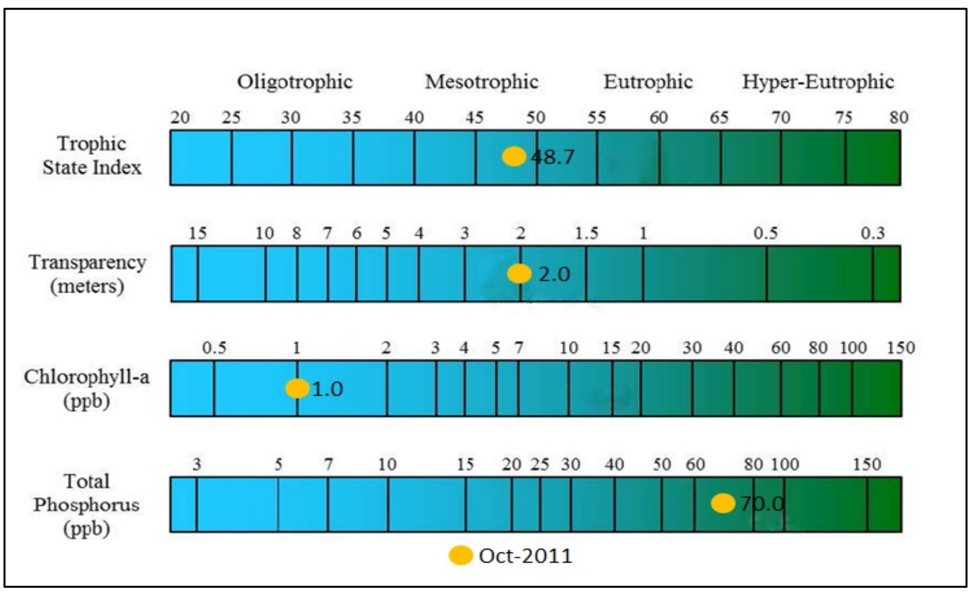

Figure 2.90: 2011 Carlson TSI results for Shrimp Lake

Figure 2.90 shows the results from the Carlson TSI Model for Shrimp Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 48.7 for the month of October. Table 2.24 shows that the four-month average classification was determined to be strongly mesotrophic according to the Carlson TSI Model.

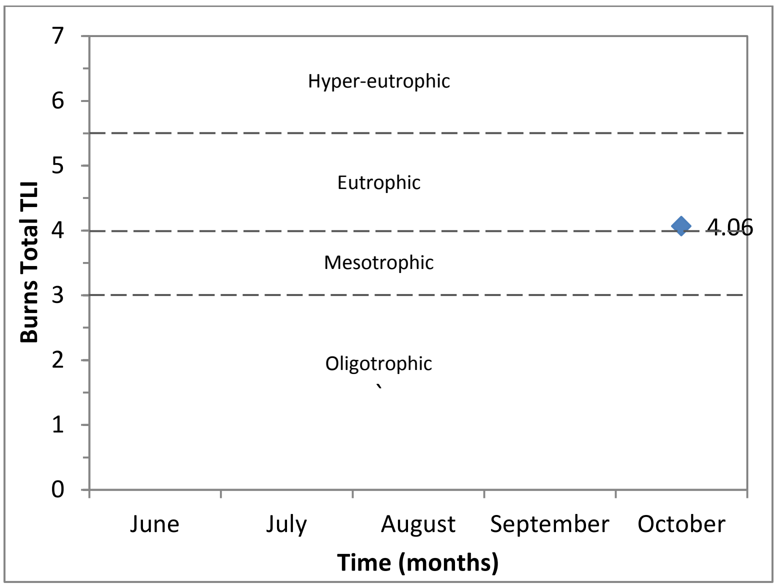

Figure 2.91: 2011 Burns TLI results for Shrimp Lake

Figure 2.91 shows the results from the Burns TLI Model for Shrimp Lake. For the month of October the Burns TLI value was calculated to be 4.06. Table 2.24 shows that this value represents an overall classification of slightly eutrophic according to the Burns TLI Model.

Figure 2.92 depicts the Naumann Trophic Scale results for Shrimp Lake for the month of October. The Naumann Trophic Scale was calculated to be 12.99 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Shrimp Lake as eutrophic based on the Naumann Trophic Scale Model.

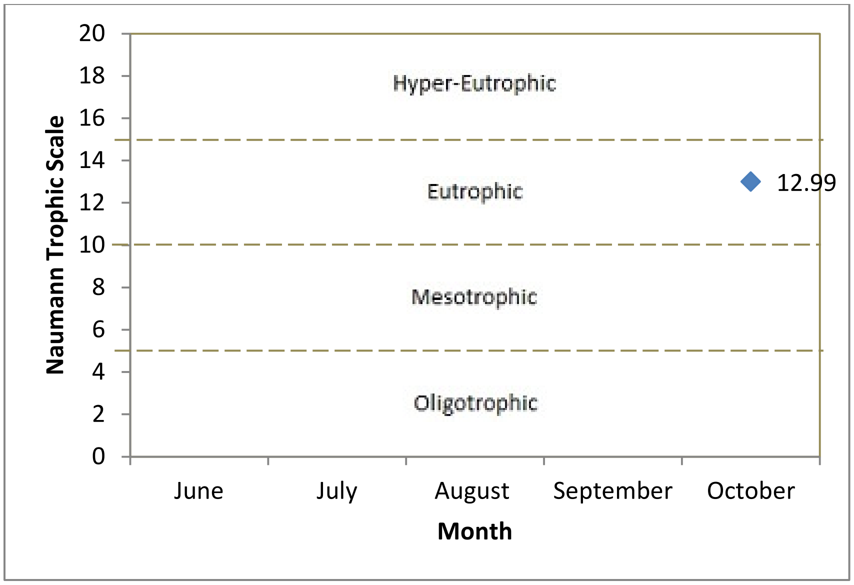

Figure 2.92: 2011 Naumann Trophic Scale results for Shrimp Lake

Table 2.24: 2011 results for Shrimp Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	-	Strongly Mesotrophic	Strongly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	-	Slightly Eutrophic	Slightly Eutrophic
Naumann	-	-	-	Eutrophic	Eutrophic
Monthly-Average	-	-	-	Slightly Eutrophic	**Slightly Eutrophic**

Table 2.24 summarizes the results for Shrimp Lake. As each model was used to classify Shrimp Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Shrimp Lake as slightly eutrophic.

2.25 **South Twin Lake**

South Twin Lake is a relatively small lake located just west of the Grand Loop Rd and north of Nymph Lake. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the months of June and October.

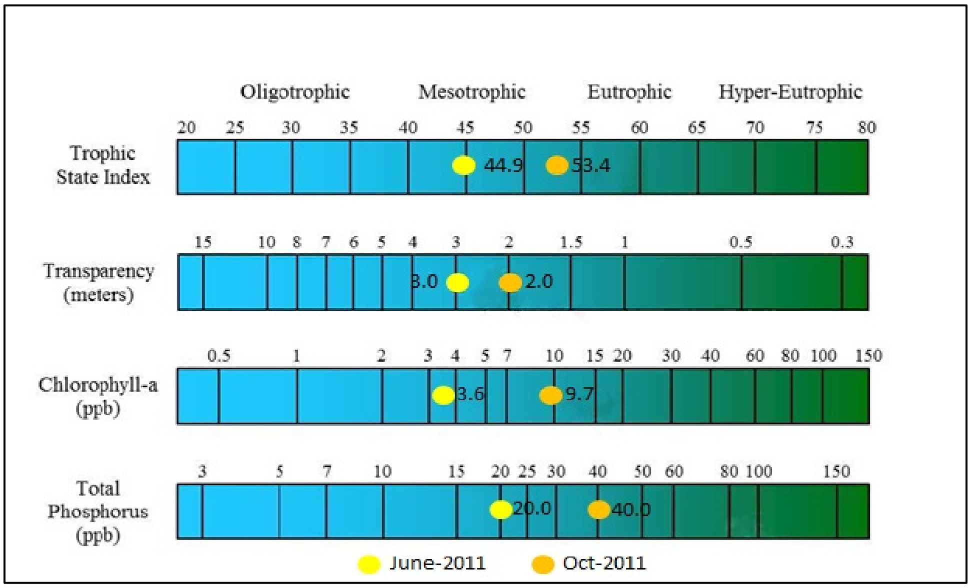

Figure 2.93: 2011 Carlson TSI results for South Twin Lake

Figure 2.93 shows the results from the Carlson TSI Model for South Twin Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 44.9 for the month of June and 53.4 for the month of October. The two-month average TSI was calculated to be 49.6 which falls under the strongly mesotrophic classification according to the Carlson TSI Model.

Figure 2.94 shows the results from the Burns TLI Model for South Twin Lake. For the months of June and October the Burns TLI values were calculated to be 3.86 and 4.66 respectively. The two-month average TLI was calculated to be 4.30 which falls under the slightly eutrophic classification according to the Burns TLI Model.

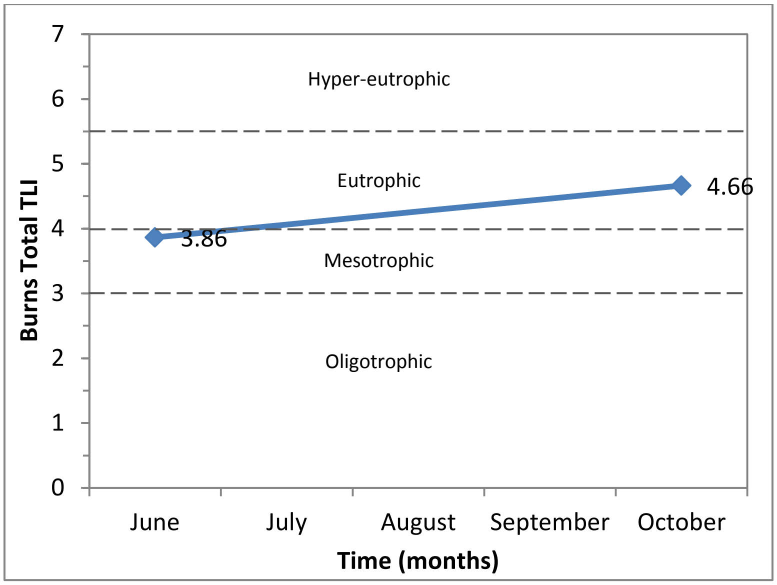

Figure 2.94: 2011 Burns TLI results for South Twin Lake

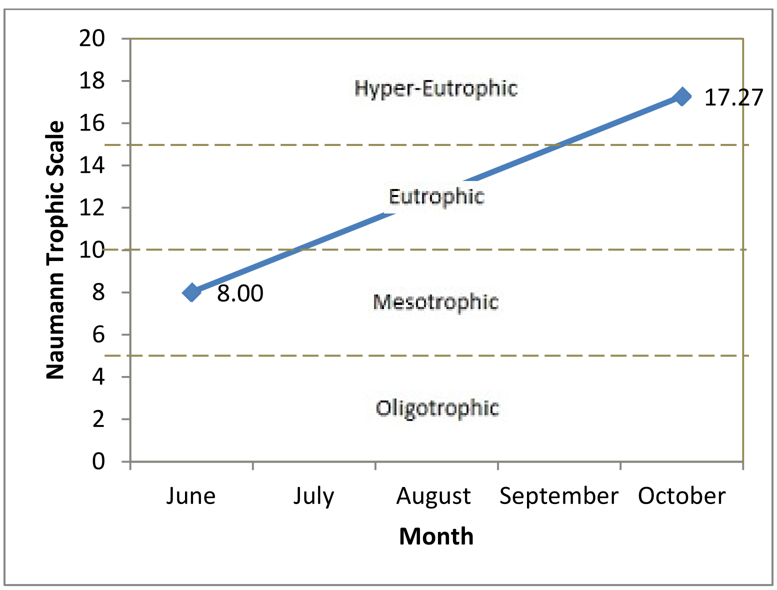

Figure 2.95: 2011 Naumann Trophic Scale results for South Twin Lake

Figure 2.95 depicts the Naumann Trophic Scale results for South Twin Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 8.00 and 17.27 for these months respectively based on primary production, phosphorus, chlorophyll-a, and

Secchi depth values. The two-month average trophic scale was calculated to be 12.64 which falls under the eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.25: 2011 results for South Twin Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Mesotrophic	-	-	Strongly Mesotrophic	Strongly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Strongly Mesotrophic	-	-	Eutrophic	Slightly Eutrophic
Naumann	Mesotrophic	-	-	Hyper-Eutrophic	Eutrophic
Monthly-Average	Mesotrophic	-	-	Eutrophic	**Slightly Eutrophic**

Table 2.25 summarizes the results for South Twin Lake. As each model was used to classify South Twin Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify South Twin Lake as slightly eutrophic.

2.26 **Swan Lake**

Swan Lake is a relatively small lake located just west of Highway 89 (Grand Loop Rd) and south of Mammoth. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the months of June and October.

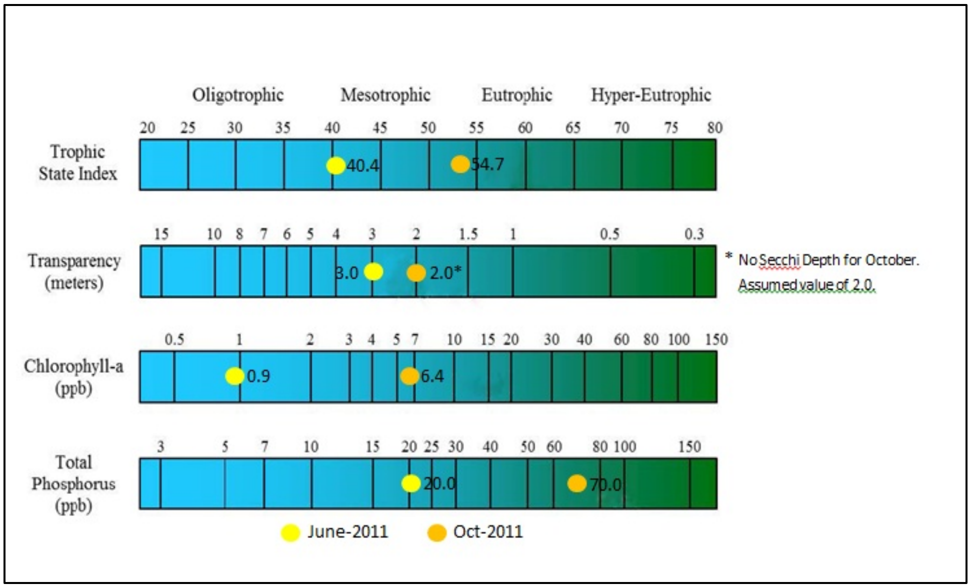

Figure 2.96: 2011 Carlson TSI results for Swan Lake

Figure 2.96 shows the results from the Carlson TSI Model for Swan Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 40.4 for the month of June and 54.7 for the month of October. The two-month average TSI was calculated to be 49.2 which falls under the mesotrophic classification according to the Carlson TSI Model.

Figure 2.97 shows the results from the Burns TLI Model for Swan Lake. For the months of June and October the Burns TLI values were calculated to be 3.35 and 4.75 respectively. The two-month average TLI was calculated to be 4.18 which falls under the strongly mesotrophic classification according to the Burns TLI Model.

Figure 2.98 depicts the Naumann Trophic Scale results for Swan Lake for the months of June and October. The Naumann Trophic Scale was calculated to be 5.60 and 17.79 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 11.7 which falls under the slightly eutrophic classification according to the Naumann Trophic Scale Model.

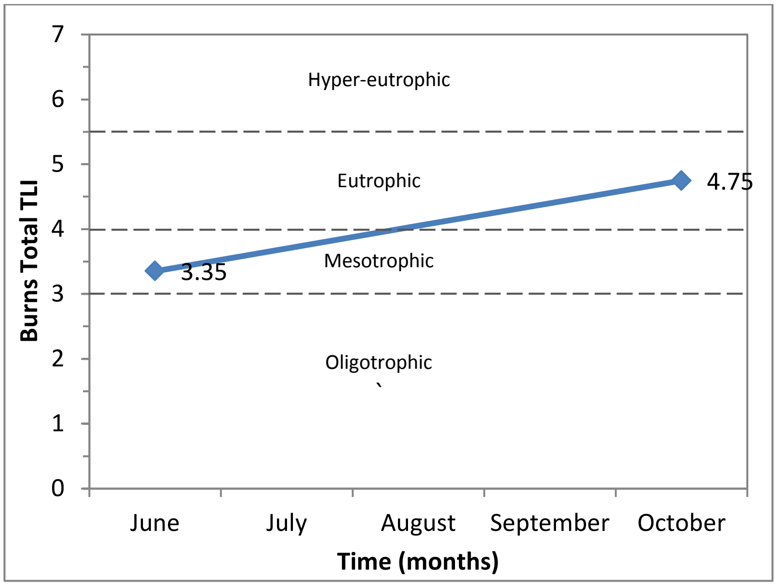

Figure 2.97: 2011 Burns TLI results for Swan Lake

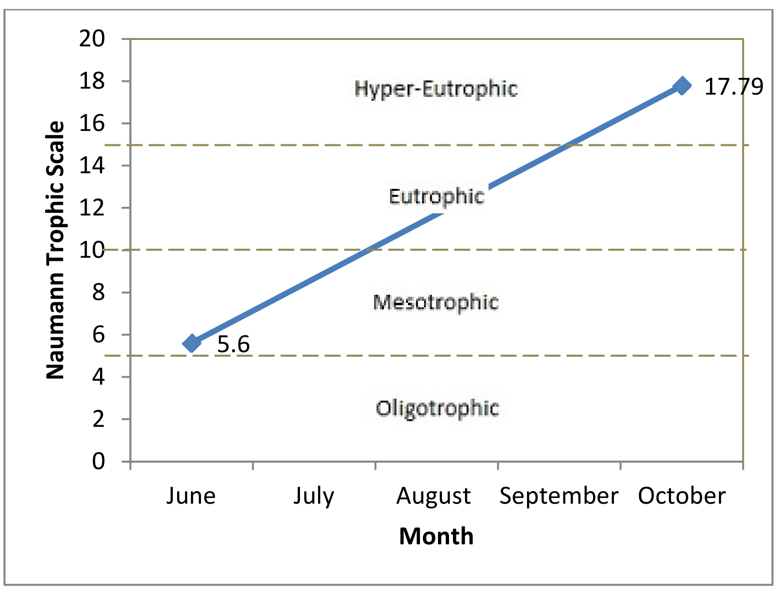

Figure 2.98: 2011 Naumann Trophic Scale results for Swan Lake

Table 2.26: 2011 results for Swan Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Slightly Mesotrophic	-	-	Slightly Eutrophic	Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	Mesotrophic	-	-	Eutrophic	Strongly Mesotrophic
Naumann	Slightly Mesotrophic	-	-	Hyper-Eutrophic	Slightly Eutrophic
Monthly-Average	Slightly Mesotrophic	-	-	Strongly Eutrophic	**Strongly Mesotrophic**

Table 2.26 summarizes the results for Swan Lake. As each model was used to classify Swan Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Swan Lake as strongly mesotrophic.

2.27 **Sylvan Lake**

Sylvan Lake is a relatively small lake located just west of Highway 20 near the East Entrance. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of July and October.

Figure 2.99 shows the results from the Carlson TSI Model for Sylvan Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 35.3 for the month of July and 40.2 for the month of October. The two-month average TSI was calculated to be 37.8 which falls under the slightly mesotrophic classification according to the Carlson TSI Model.

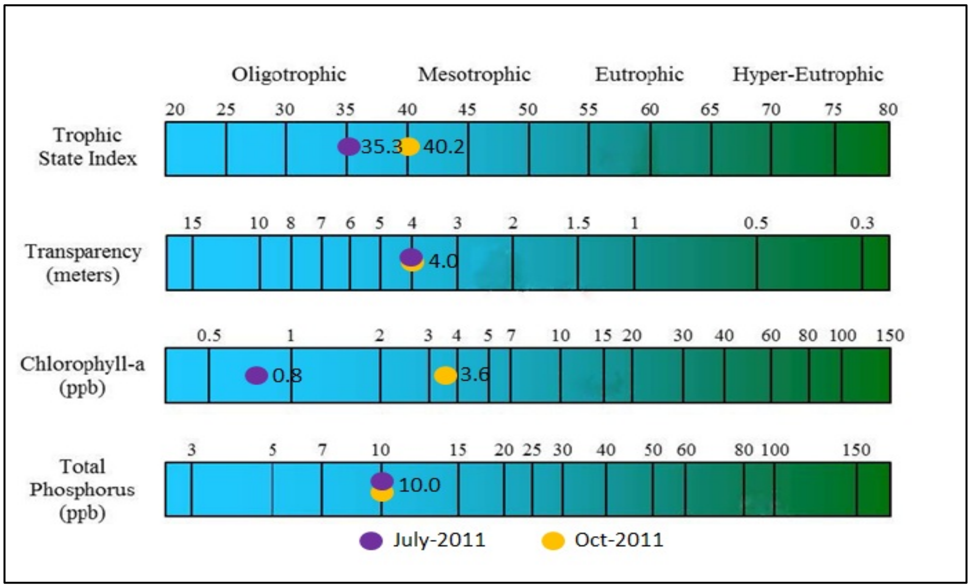

Figure 2.99: 2011 Carlson TSI results for Sylvan Lake

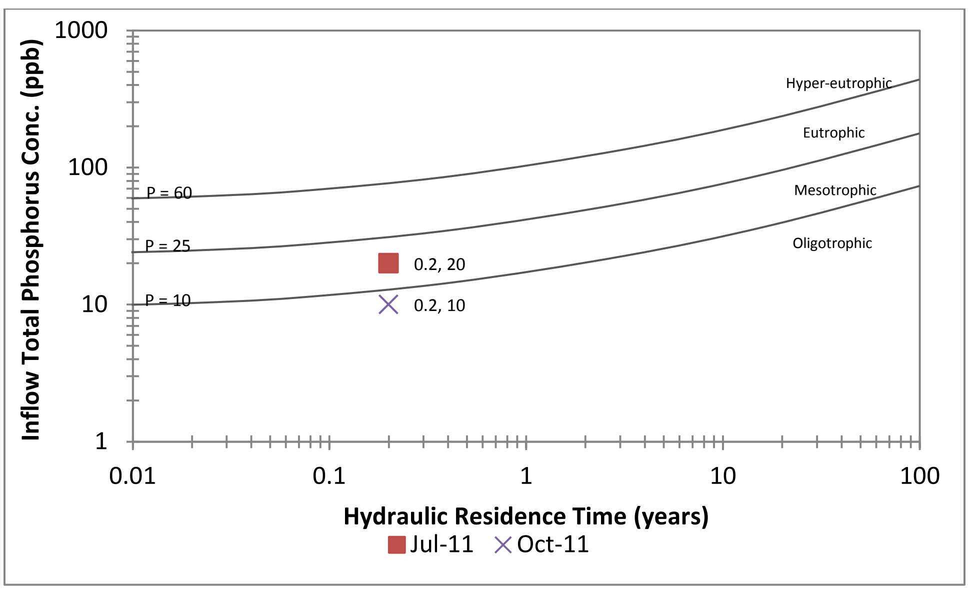

Figure 2.100: 2011 Vollenweider Model results for Sylvan Lake

Figure 2.100 shows the results from the Vollenweider Model for Sylvan Lake. The hydraulic residence time was calculated to be 0.2 years for the months of July and October. The inflow total phosphorus concentration was measured to be 20 ppb for the month of July and 10 ppb for the month of October. As can be seen from the figure, these values represent an overall classification of slightly mesotrophic based on the Vollenweider Model.

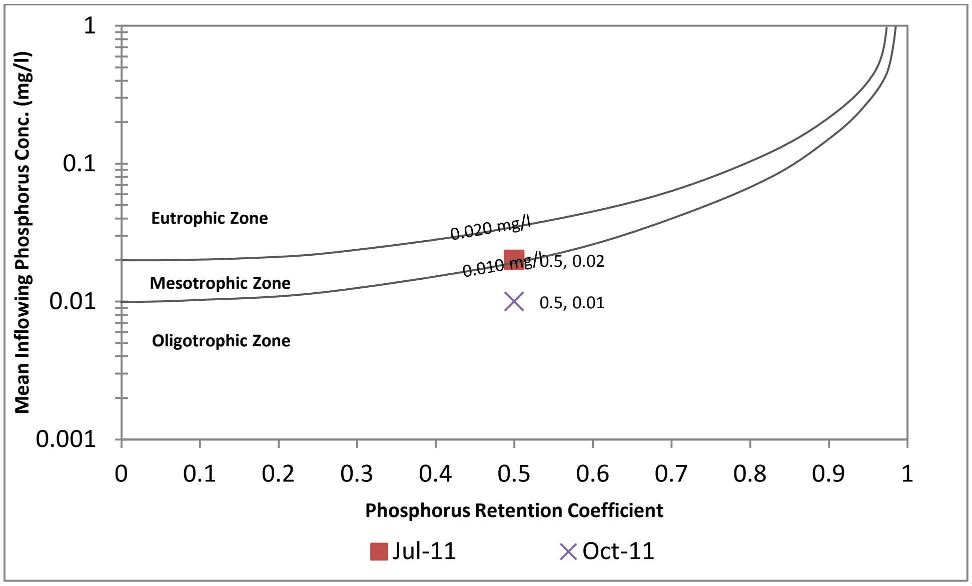

Figure 2.101: 2011 Larsen Mercier Model results for Sylvan Lake

Figure 2.101 depicts the results from the Larsen Mercier Model for Sylvan Lake. A PRC value of 0.5 was calculated for the months of July and October respectively. The inlet phosphorus concentrations were measured to be 0.02 and 0.01 mg/L for the months of July and October respectively. Table 2.27 depicts that these values represent an overall classification of slightly oligotrophic based on the Larsen Mercier Model.

Figure 2.102 shows the results from the Burns TLI Model for Sylvan Lake. For the months of July and October the Burns TLI values were calculated to be 2.91 and 3.47 respectively. The two-month average TLI was calculated to be 3.19 which falls under the slightly mesotrophic classification according to the Burns TLI Model.

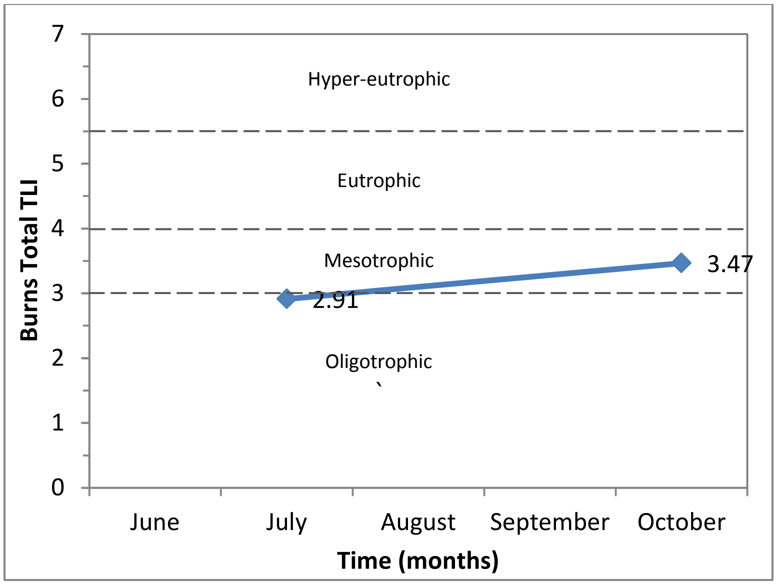

Figure 2.102: 2011 Burns TLI results for Sylvan Lake

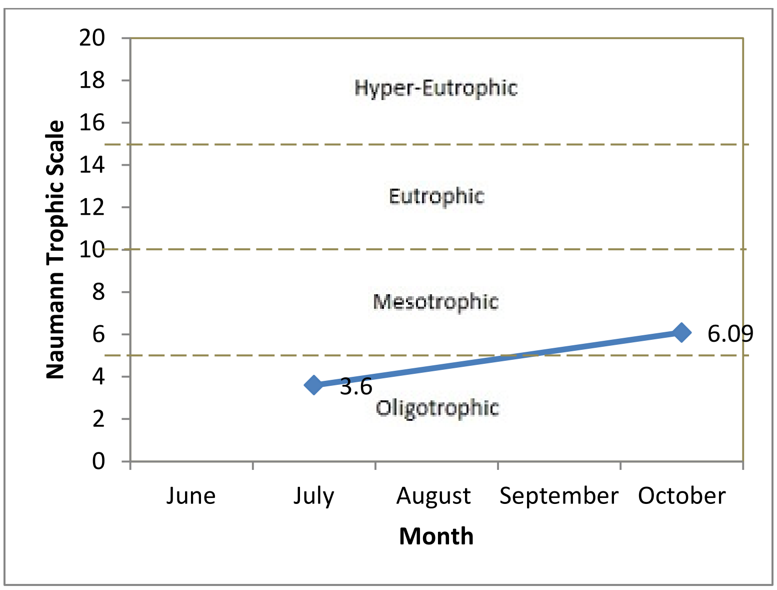

Figure 2.103: 2011 Naumann Trophic Scale results for Sylvan Lake

Figure 2.103 depicts the Naumann Trophic Scale results for Sylvan Lake for the months of July and October. The Naumann Trophic Scale was calculated to be 3.60 and 6.09 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The two-month average trophic scale was calculated to be 5.25 which falls under the slightly mesotrophic classification according to the Naumann Trophic Scale Model.

Table 2.27: 2011 results for Sylvan Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Slightly Oligotrophic	-	Slightly Mesotrophic	Slightly Mesotrophic
Vollenweider	-	Mesotrophic	-	Slightly Oligotrophic	Slightly Mesotrophic
Larsen-Mercier	-	Slightly Mesotrophic	-	Oligotrophic	Slightly Oligotrophic
Burns	-	Slightly Oligotrophic	-	Mesotrophic	Slightly Mesotrophic
Naumann	-	Slightly Oligotrophic	-	Slightly Mesotrophic	Slightly Mesotrophic
Monthly-Average	-	Slightly Oligotrophic	-	Mesotrophic	**Slightly Mesotrophic**

Table 2.27 summarizes the results for Sylvan Lake. As each model was used to classify Sylvan Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Sylvan Lake as slightly mesotrophic.

2.28 Tanager Lake

Tanager Lake is a relatively small lake located west of the Southeast Entrance. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of August.

Figure 2.104 shows the results from the Carlson TSI Model for Tanager Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 37.4 for the month of August. Table 2.28 shows that the four-month average classification was determined to be slightly oligotrophic according to the Carlson TSI Model.

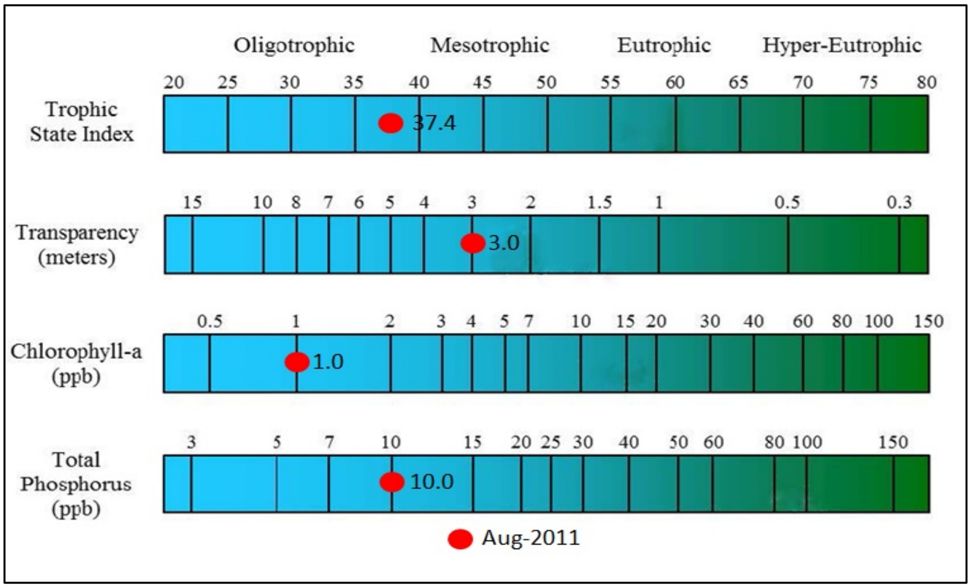

Figure 2.104: 2011 Carlson TSI results for Tanager Lake

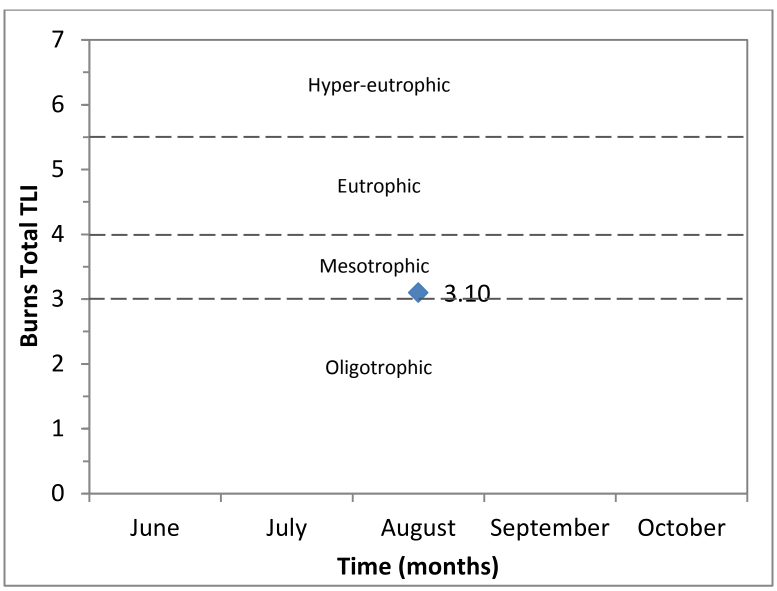

Figure 2.105: 2011 Burns TLI results for Tanager Lake

Figure 2.105 shows the results from the Burns TLI Model for Tanager Lake. For the month of August the Burns TLI value was calculated to be 3.10. Table 2.28 shows that these values represent an overall classification of slightly mesotrophic according to the Burns TLI Model.

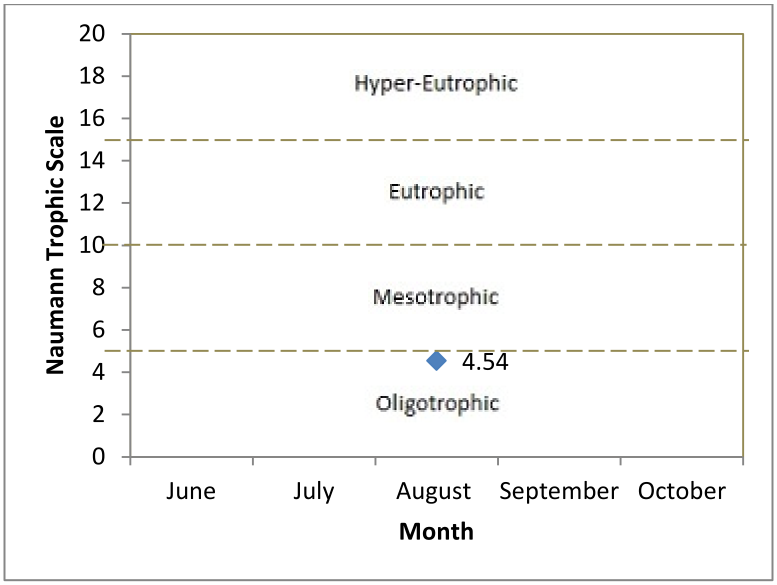

Figure 2.106: 2011 Naumann Trophic Scale results for Tanager Lake

Figure 2.106 depicts the Naumann Trophic Scale results for Tanager Lake for the month of August. The Naumann Trophic Scale was calculated to be 4.54 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Tanager Lake as slightly oligotrophic based on the Naumann Trophic Scale Model.

Table 2.28: 2011 results for Tanager Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	Slightly Oligotrophic	-	Slightly Oligotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	Slightly Mesotrophic	-	Slightly Mesotrophic

Table 2.28 continued: 2011 results for Tanager Lake

Naumann	-	-	Slightly Oligotrophic	-	Slightly Oligotrophic
Monthly-Average	-	-	Slightly Oligotrophic	-	**Slightly Oligotrophic**

Table 2.28 summarizes the results for Tanager Lake. As each model was used to classify Tanager Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Tanager Lake as slightly oligotrophic.

2.29 **Terrace Springs**

Terrace Springs is a very small lake located at Madison Junction and northeast of the Grand Loop Rd/West Entrance Rd intersection. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of July.

Figure 2.107 shows the results from the Carlson TSI Model for Terrace Springs. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 46.4 for the month of July. Table 2.29 shows that the four-month average classification was determined to be mesotrophic according to the Carlson TSI Model.

Figure 2.108 shows the results from the Burns TLI Model for Terrace Springs. For the month of July the Burns TLI value was calculated to be 3.88. Table 2.29 shows that this value represents an overall classification of strongly mesotrophic according to the Burns TLI Model.

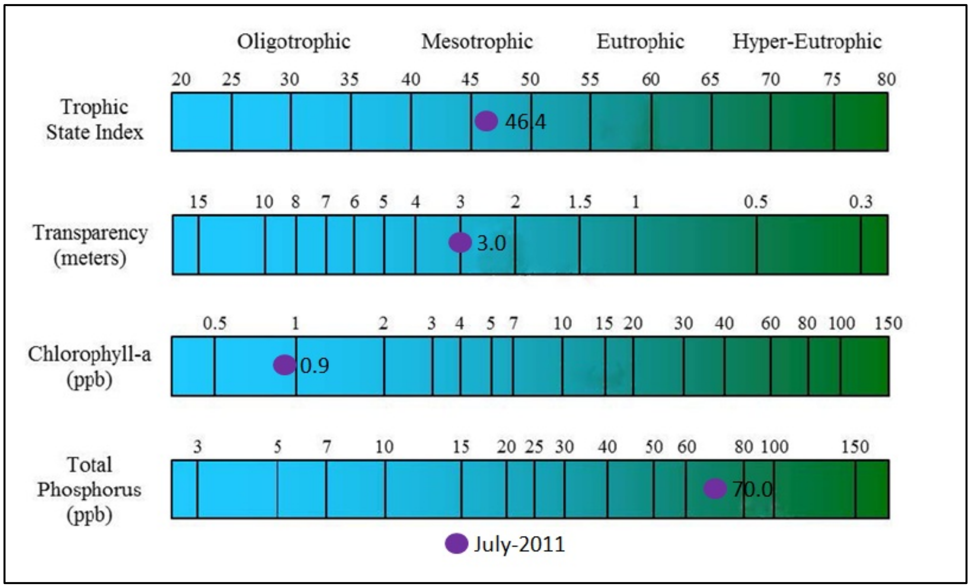

Figure 2.107: 2011 Carlson TSI results for Terrace Springs

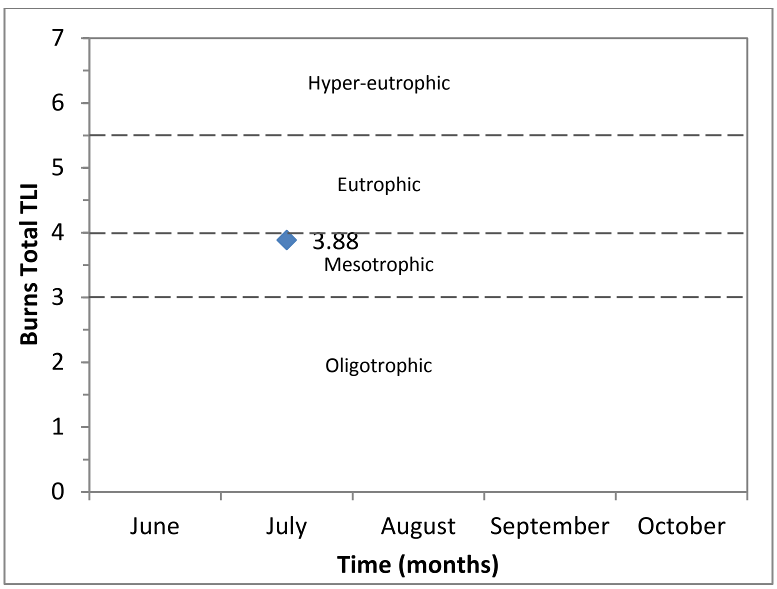

Figure 2.108: 2011 Burns TLI results for Terrace Springs

Figure 2.109 depicts the Naumann Trophic Scale results for Terrace Springs for the month of July. The Naumann Trophic Scale was calculated to be 11.37 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Terrace Springs as slightly eutrophic based on the Naumann Trophic Scale Model.

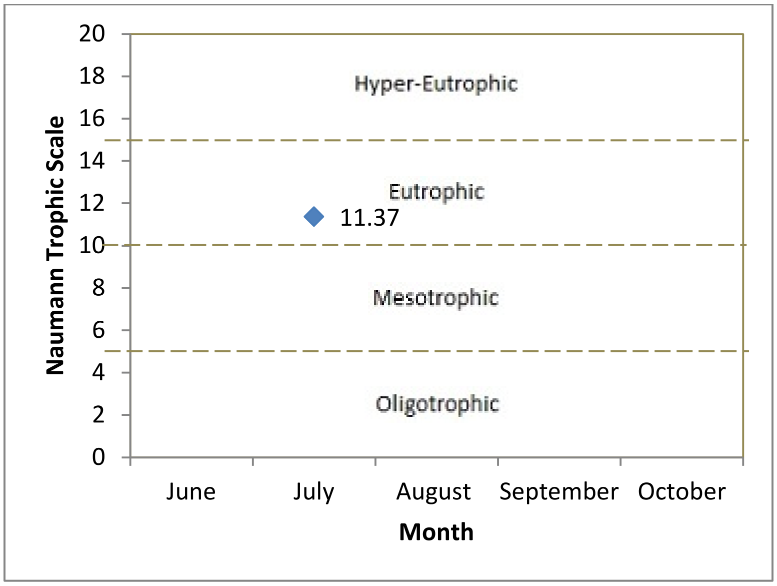

Figure 2.109: 2011 Naumann Trophic Scale results for Terrace Springs

Table 2.29: 2011 results for Terrace Springs

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Mesotrophic	-	-	Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	Strongly Mesotrophic	-	-	Strongly Mesotrophic
Naumann	-	Slightly Eutrophic	-	-	Slightly Eutrophic
Monthly-Average	-	Strongly Mesotrophic	-	-	**Strongly Mesotrophic**

Table 2.29 summarizes the results for Terrace Springs. As each model was used to classify Terrace Springs into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Terrace Springs as strongly mesotrophic.

2.30 **Trout Lake**

Trout Lake is a relatively small lake located just west of Highway 212 near the NE Entrance. In 2011, phosphorus was measured at both inlet and inlake locations. Chlorophyll-a and Secchi depth were also measured inlake. Measurements were made in the months of June, July, August, and October.

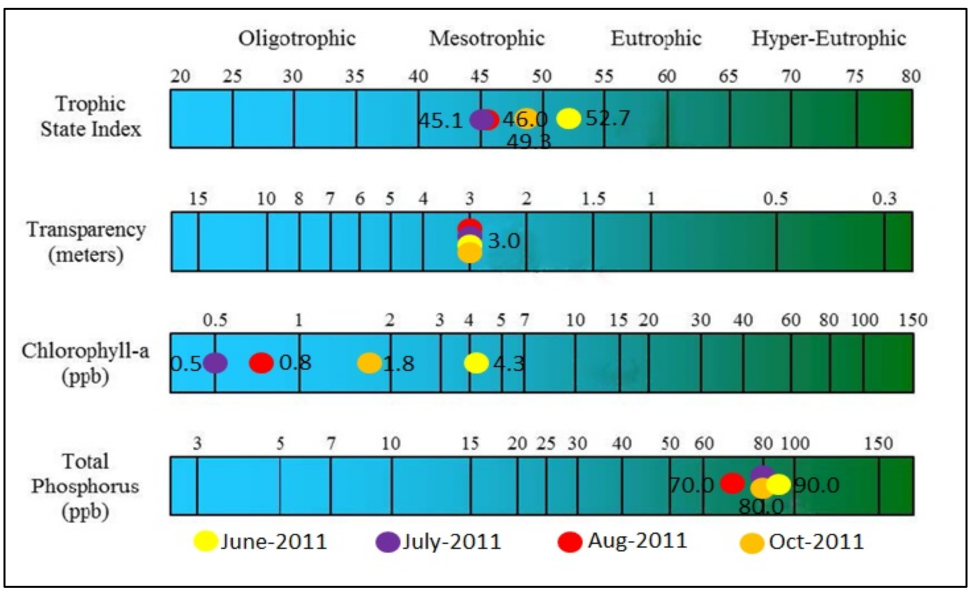

Figure 2.110: 2011 Carlson TSI results for Trout Lake

Figure 2.110 shows the results from the Carlson TSI Model for Trout Lake. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 52.7 for the month of June, 45.1 for the month of July, 46.0 for the month of August, and

49.8 for the month October. The four-month average TSI was calculated to be 48.3 which falls under the mesotrophic classification according to the Carlson TSI Model.

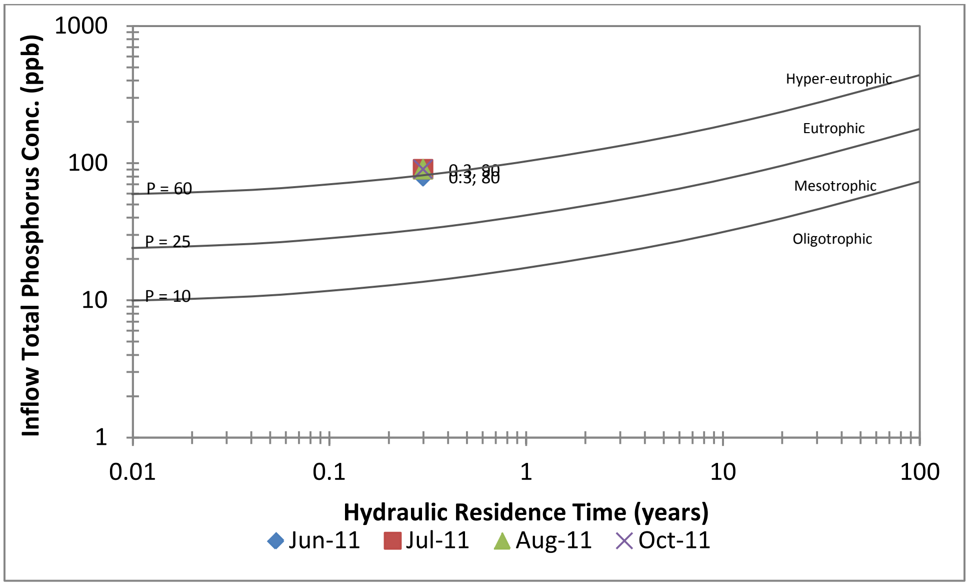

Figure 2.111: 2011 Vollenweider Model results for Trout Lake

Figure 2.111 shows the results from the Vollenweider Model for Trout Lake. The hydraulic residence time was calculated to be 0.3 years for the months of June, July, August, and October. The inflow total phosphorus concentration was measured to be 80 ppb for the month of June and 90 ppb for the months of July, August, and October. As can be seen from the figure, these values represent an overall classification of slightly hyper-eutrophic based on the Vollenweider Model.

Figure 2.112 depicts the results from the Larsen Mercier Model for Trout Lake. PRC values of 0.0, 0.11, 0.22, and 0.11 were calculated for the months of June, July, August, and October respectively. The inlet phosphorus concentrations were measured to be 0.08 mg/L for the month of June and 0.09 mg/L for the months of July, August, and October. Table 2.30

depicts that these values represent an overall classification of hyper-eutrophic based on the Larsen Mercier Model.

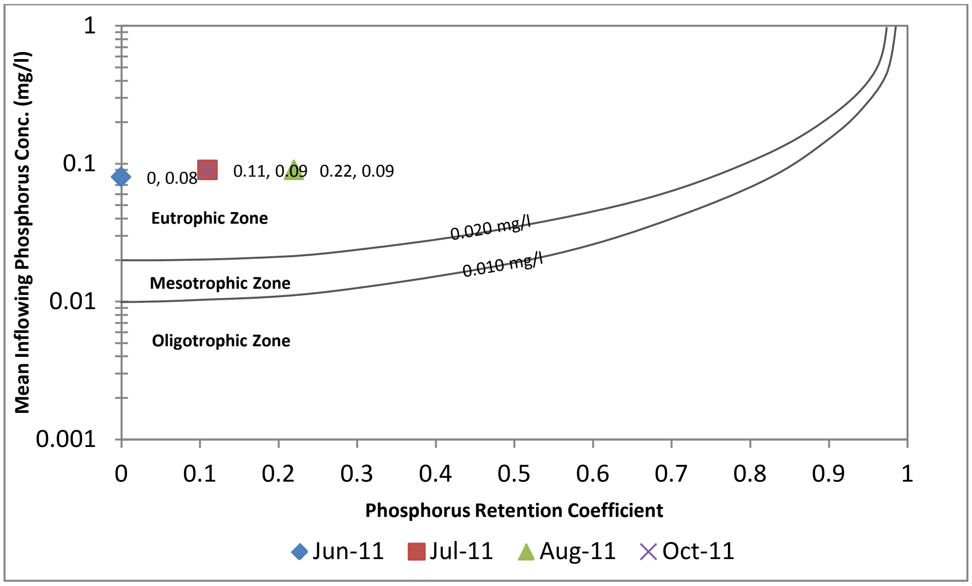

Figure 2.112: 2011 Larsen Mercier Model results for Trout Lake

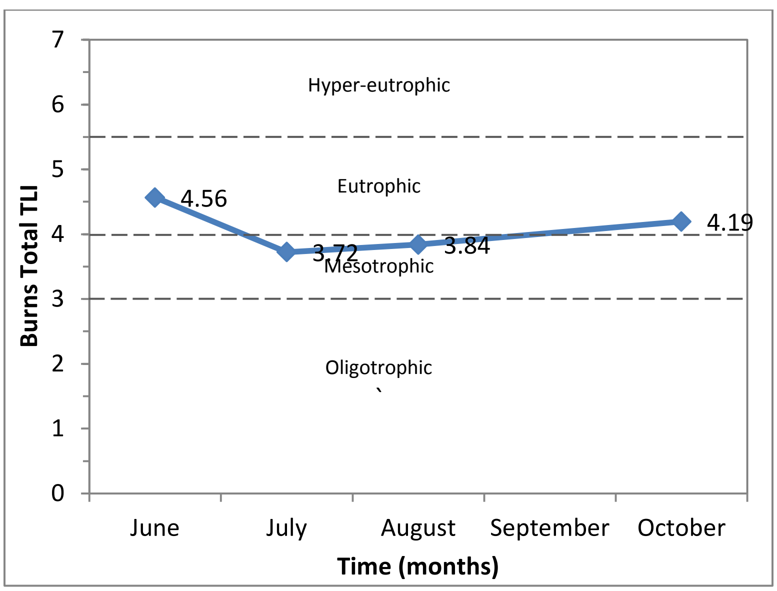

Figure 2.113: 2011 Burns TLI results for Trout Lake

Figure 2.113 shows the results from the Burns TLI Model for Trout Lake. For the months of June, July, August, and October the Burns TLI values were calculated to be 4.56, 3.72, 3.84, and 4.19 respectively. The four-month average TLI was calculated to be 4.08 which falls under the slightly eutrophic classification according to the Burns TLI Model.

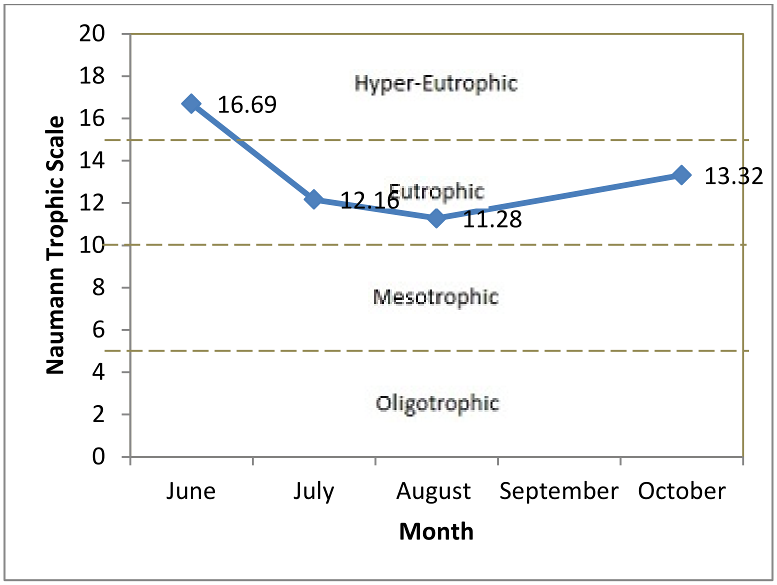

Figure 2.114: 2011 Naumann Trophic Scale results for Trout Lake

Figure 2.114 depicts the Naumann Trophic Scale results for Trout Lake for the months of June, July, August, and October. The Naumann Trophic Scale was calculated to be 16.69, 12.16, 11.28, 13.32 for these months respectively based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. The four-month average trophic scale was calculated to be 13.36 which falls under the eutrophic classification according to the Naumann Trophic Scale Model.

Table 2.30: 2011 results for Trout Lake

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	Strongly Mesotrophic	Mesotrophic	Mesotrophic	Strongly Mesotrophic	Mesotrophic
Vollenweider	Strongly Eutrophic	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic	Slightly Hyper-Eutrophic

Table 2.30 continued: 2011 results for Trout Lake

Larsen-Mercier	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic
Burns	Eutrophic	Strongly Mesotrophic	Strongly Mesotrophic	Slightly Eutrophic	Slightly Eutrophic
Naumann	Hyper-Eutrophic	Eutrophic	Slightly Eutrophic	Eutrophic	Eutrophic
Monthly-Average	Strongly Eutrophic	Strongly Eutrophic	Strongly Eutrophic	Strongly Eutrophic	**Strongly Eutrophic**

Table 2.30 summarizes the results for Trout Lake. As each model was used to classify Trout Lake into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Trout Lake as strongly eutrophic.

2.31 **Yellowstone Lake at Bridge Bay**

Bridge Bay is located at the western side of Yellowstone Lake, the largest lake in Yellowstone National Park. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of August.

Figure 2.115 shows the results from the Carlson TSI Model for Yellowstone Lake at Bridge Bay. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 39.3 for the month of August. Table 2.31 shows that the four-month average classification was determined to be slightly mesotrophic according to the Carlson TSI Model.

Figure 2.116 shows the results from the Burns TLI Model for Yellowstone Lake at Bridge Bay. For the month of August the Burns TLI value was calculated to be 3.29. Table 2.31 shows that this value represents an overall classification of slightly mesotrophic according to the Burns TLI Model.

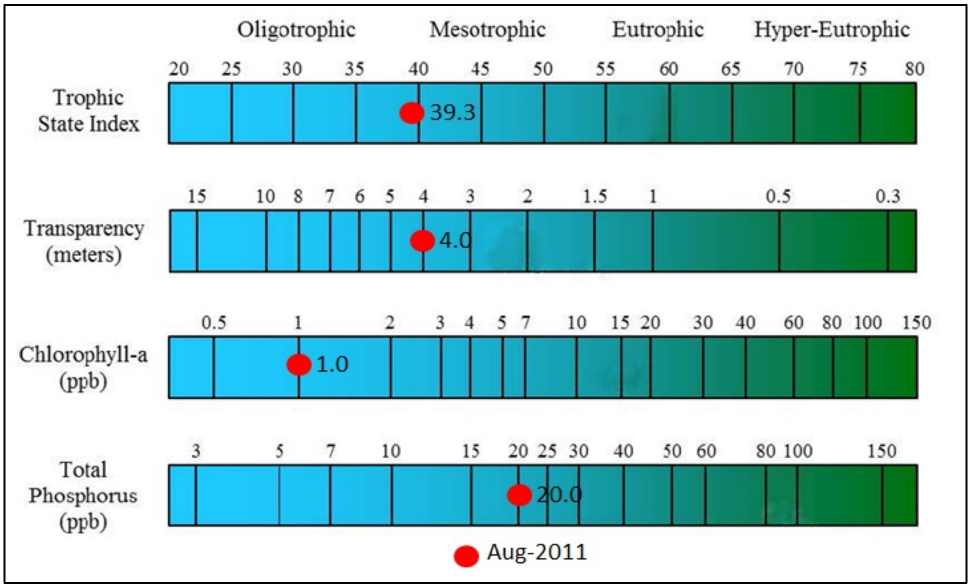

Figure 2.115: 2011 Carlson TSI results for Yellowstone Lake at Bridge Bay

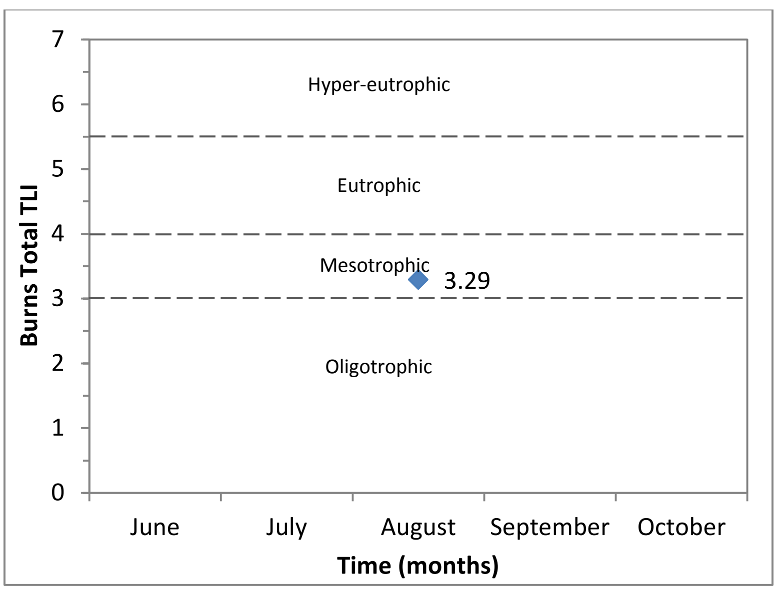

Figure 2.116: 2011 Burns TLI results for Yellowstone Lake at Bridge Bay

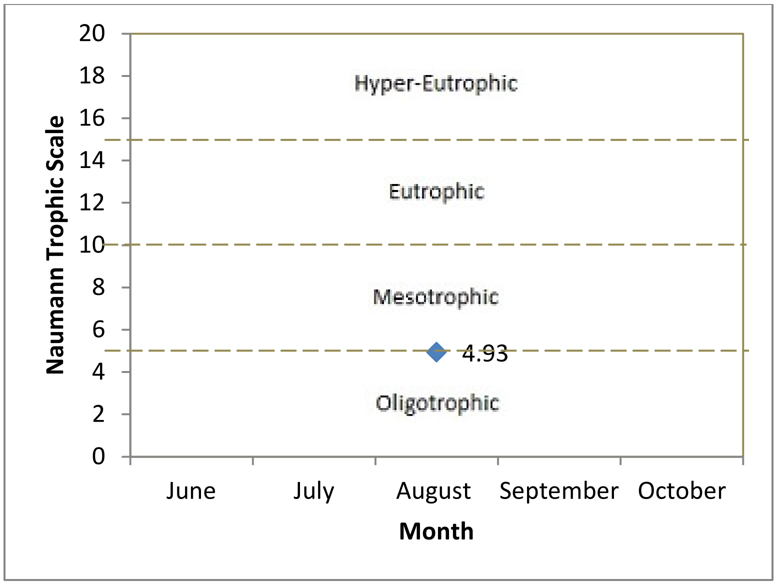

Figure 2.117: 2011 Naumann Trophic Scale results for Yellowstone Lake at Bridge Bay

Figure 2.117 depicts the Naumann Trophic Scale results for Yellowstone Lake at Bridge Bay for the month of August. The Naumann Trophic Scale was calculated to be 4.93 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Yellowstone Lake at Bridge Bay as slightly oligotrophic based on the Naumann Trophic Scale Model.

Table 2.31: 2011 results for Yellowstone Lake at Bridge Bay

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	-	Slightly Mesotrophic	-	Slightly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	-	Slightly Mesotrophic	-	Slightly Mesotrophic
Naumann	-	-	Slightly Oligotrophic	-	Slightly Oligotrophic

Table 2.31 continued: 2011 results for Yellowstone Lake at Bridge Bay

Monthly-Average	-	-	Slightly Mesotrophic	-	**Slightly Mesotrophic**

Table 2.31 summarizes the results for Yellowstone Lake at Bridge Bay. As each model was used to classify Yellowstone Lake at Bridge Bay into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Yellowstone Lake at Bridge Bay as slightly mesotrophic.

2.32 **Yellowstone Lake at West Thumb**

West Thumb is located at the southwestern side of Yellowstone Lake, the largest lake in Yellowstone National Park. In 2011, phosphorus, chlorophyll-a, and Secchi depth measurements were made at an inlake location. Measurements were made in the month of July.

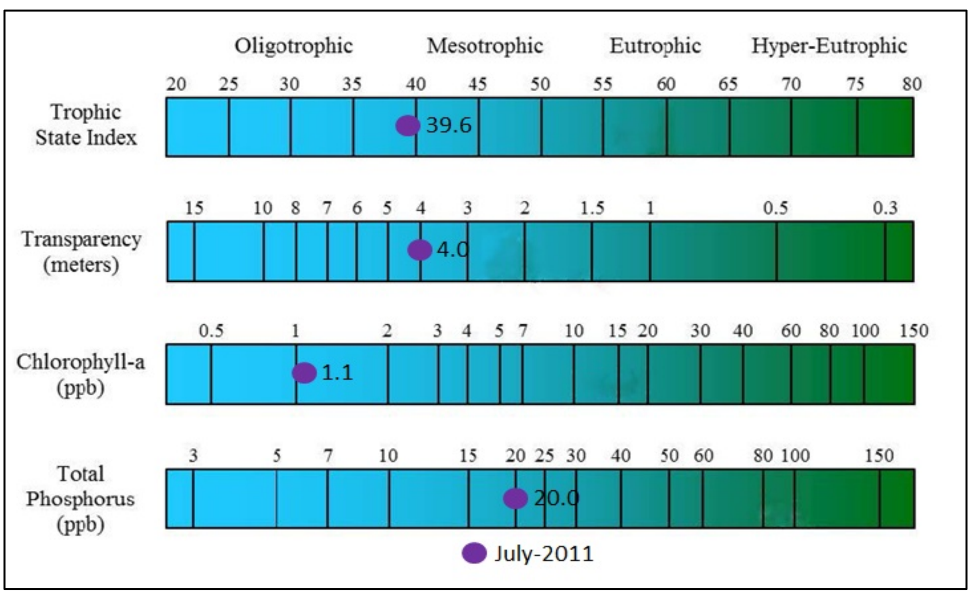

Figure 2.118: 2011 Carlson TSI results for Yellowstone Lake at West Thumb

Figure 2.118 shows the results from the Carlson TSI Model for Yellowstone Lake at West Thumb. The figure depicts the inlake phosphorus concentration (ppb), the chlorophyll-a concentration (ppb), the Secchi depth (meters), and the overall trophic state index. The trophic state index was calculated to be 39.6 for the month of July. Table 2.32 shows that the four-month average classification was determined to be slightly mesotrophic according to the Carlson TSI Model.

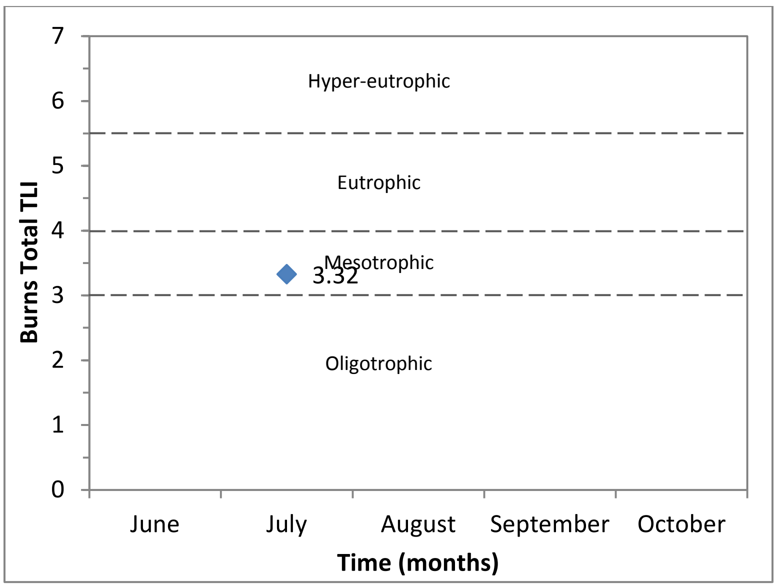

Figure 2.119: 2011 Burns TLI results for Yellowstone Lake at West Thumb

Figure 2.119 shows the results from the Burns TLI Model for Yellowstone Lake at West Thumb. For the month of July the Burns TLI value was calculated to be 3.32. Table 2.32 shows that this value represents an overall classification of mesotrophic according to the Burns TLI Model.

Figure 2.120 depicts the Naumann Trophic Scale results for Yellowstone Lake at West Thumb for the month of July. The Naumann Trophic Scale was calculated to be 5.02 based on primary production, phosphorus, chlorophyll-a, and Secchi depth values. This value denotes an overall classification for Yellowstone Lake at West Thumb as slightly mesotrophic based on the Naumann Trophic Scale Model.

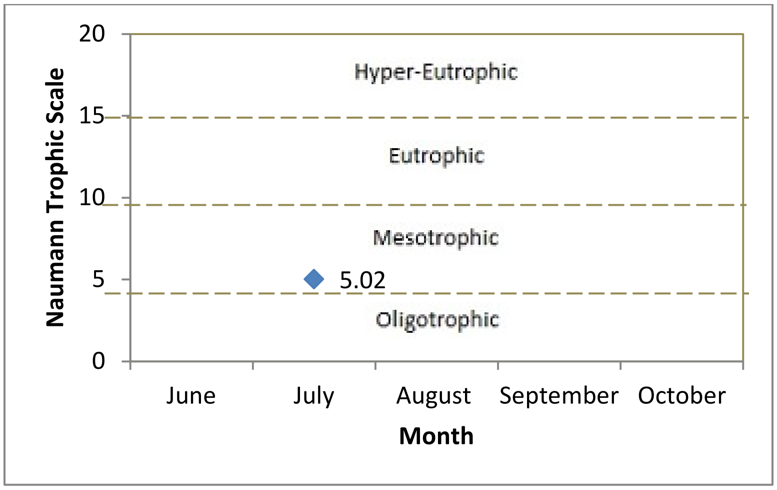

Figure 2.120: 2011 Naumann Trophic Scale results for Yellowstone Lake at West Thumb

Table 2.32: 2011 results for Yellowstone Lake at West Thumb

Model	*June*	*July*	*August*	*October*	*Average*
Carlson	-	Slightly Mesotrophic	-	-	Slightly Mesotrophic
Vollenweider	-	-	-	-	-
Larsen-Mercier	-	-	-	-	-
Burns	-	Mesotrophic	-	-	Mesotrophic
Naumann	-	Slightly Mesotrophic	-	-	Slightly Mesotrophic
Monthly-Average	-	Slightly Mesotrophic	-	-	**Slightly Mesotrophic**

Table 2.32 summarizes the results for Yellowstone Lake at West Thumb. As each model was used to classify Yellowstone Lake at West Thumb into a generic trophic state, a qualitative average was used in order to determine an overall trophic state. The 2011 results classify Yellowstone Lake at West Thumb as slightly mesotrophic.

3 YELLOWSTONE LAKES OVER TIME

3.1 Introduction

A valuable portion of this document included a study of each lake and the changes in trophic state and nutrient loading over time. As was mentioned previously, anthropogenic sources of nutrient loading cause an acceleration of the eutrophication process. This chapter includes a look at the Carlson TSI and its changes over time, as well as the Vollenweider and Larsen Mercier Models (where inlet data are available) over time, total inlake phosphorus concentrations over time, and total inlake chlorophyll-a concentrations over time.

The Vollenweider and Larsen Mercier plots look similar to those for the 2011 data, with similar trophic state classifications on the plots themselves. The Carlson TSI plots are a TSI vs. time plot. A linear trendline, the equation for the trendline, the correlation coefficient, and the tropic state classification are also depicted on the graphs. In the case of the Carlson TSI graphs, an average TSI for each year is plotted. The phosphorus and chlorophyll-a graphs are also temporal graphs (vs. time). These graphs also show a linear trendline, an equation for the trendline, the correlation coefficient, and the trophic state classification. The trophic state classifications based on total phosphorus concentrations and chlorophyll-a concentrations come from Smith et. al and their article entitled “Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems.”

3.2 **Beaver Lake**

Samples for Beaver Lake were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

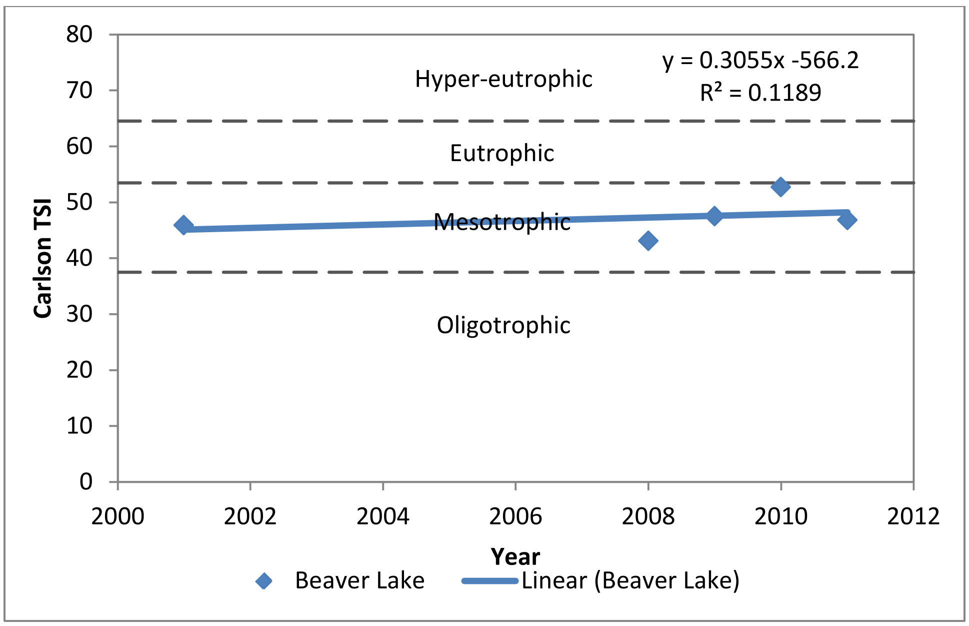

Figure 3.1: Carlson TSI over time for Beaver Lake

Figure 3.1 depicts the Carlson TSI values over time for Beaver Lake. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.1189. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

Figure 3.2 depicts the results of the Vollenweider Model over time for Beaver Lake. The total phosphorus vs. hydraulic residence time data points range from slightly oligotrophic in August 2001 to hyper-eutrophic in August 2009.

Figure 3.3 shows the results of the Larsen Mercier Model over time for Beaver Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in August 2001 to strongly eutrophic in June 2001. The majority of the data points are in the range of slightly eutrophic to strongly eutrophic.

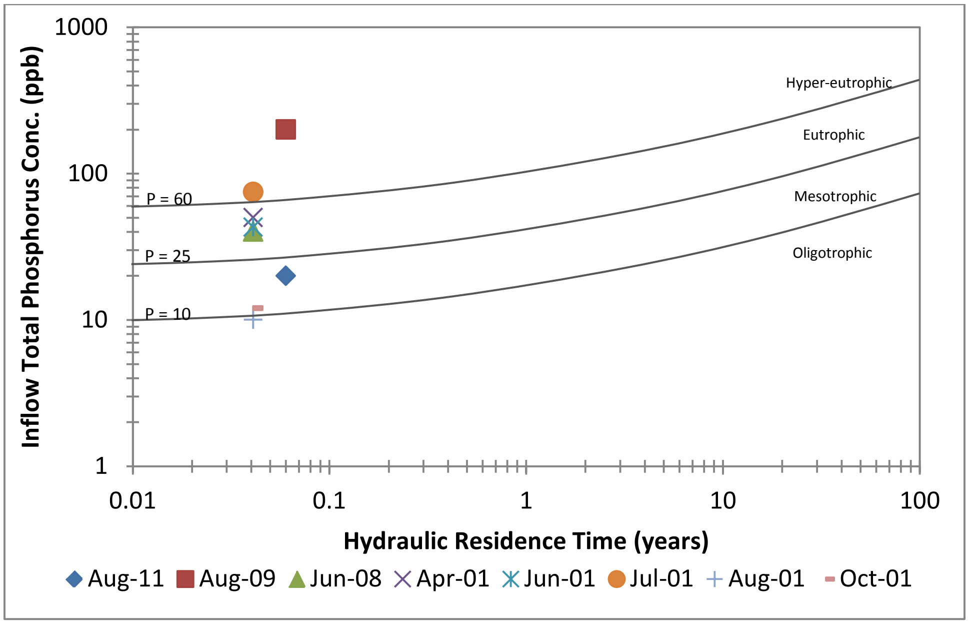

Figure 3.2: Vollenweider Model over time for Beaver Lake

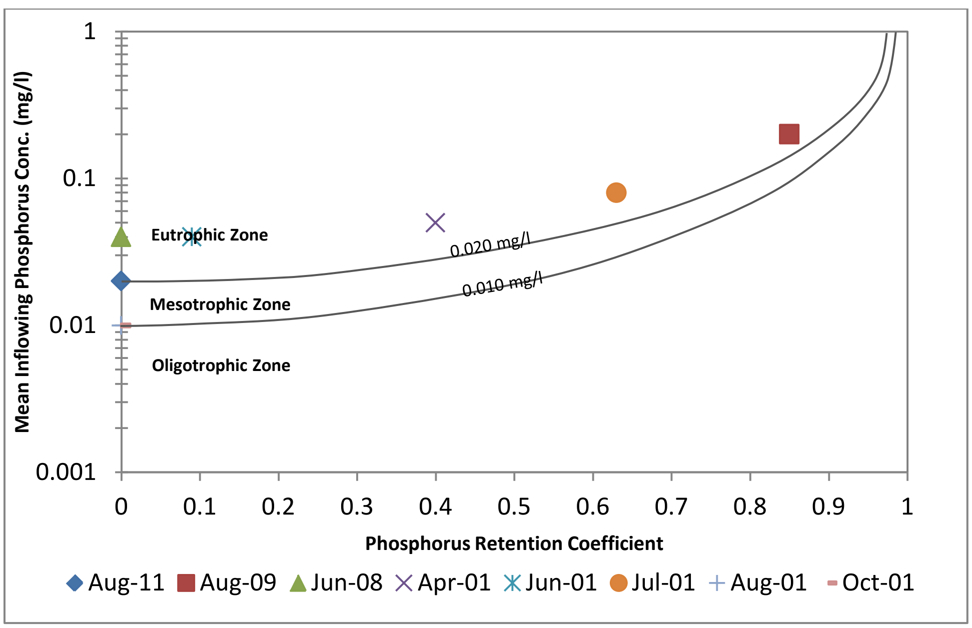

Figure 3.3: Larsen Mercier Model over time for Beaver Lake

Figure 3.4 shows the average total inlake phosphorus concentrations over time for Beaver Lake. These values depict a slight increase in inlake phosphorus with a weak correlation coefficient of 0.0661. The phosphorus concentrations vary in the range of slightly mesotrophic to eutrophic.

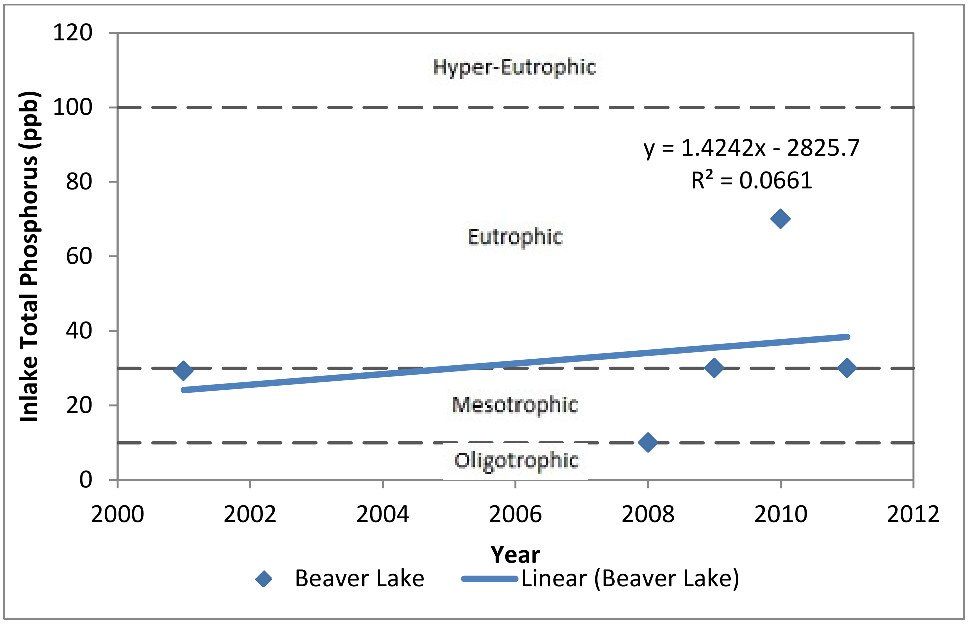

Figure 3.4: Inlake total phosphorus over time for Beaver Lake

Figure 3.5 shows the average total inlake chlorophyll-a concentrations over time for Beaver Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.2175. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly eutrophic.

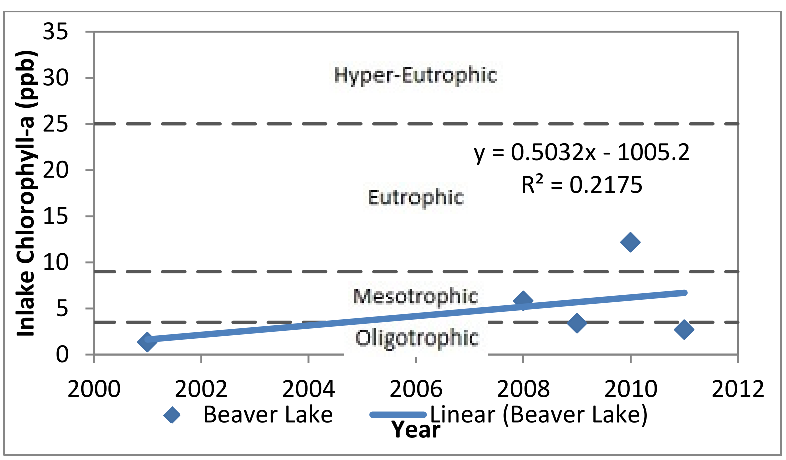

Figure 3.5: Inlake chlorophyll-a over time for Beaver lake

3.3 **Blacktail Pond**

Samples for Blacktail Pond were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

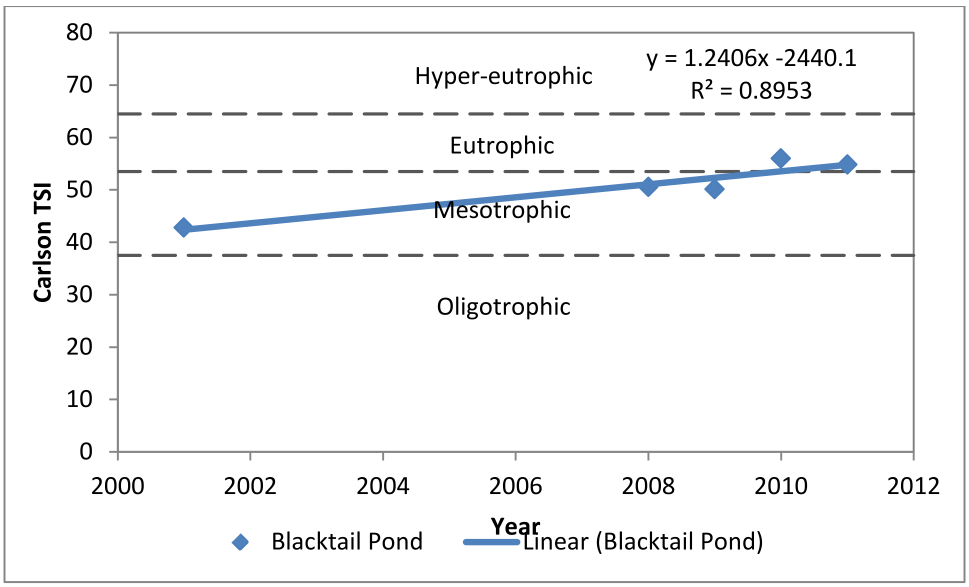

Figure 3.6: Carlson TSI over time for Blacktail Pond

Figure 3.6 depicts the Carlson TSI values over time for Blacktail Pond. The figure depicts a slight increase in TSI values over time with a relatively strong correlation coefficient of 0.8953. The TSI values vary in the range of slightly mesotrophic and slightly eutrophic classification.

Figure 3.7 depicts the results of the Vollenweider Model over time for Blacktail Pond. Only one total inlet phosphorus data point was collected in July 2001. According to the Vollenweider Model, Blacktail Pond was classified as strongly mesotrophic at that time.

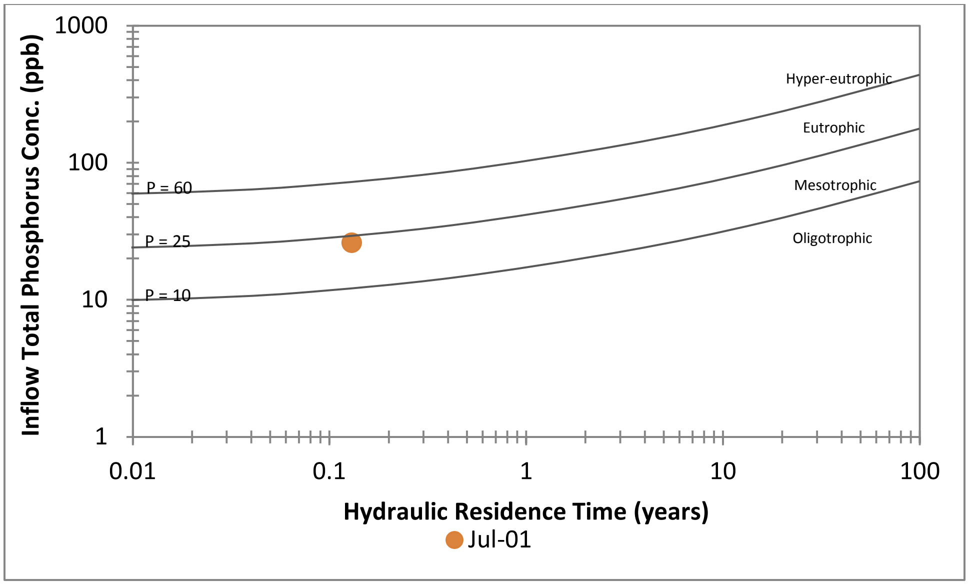

Figure 3.7: Vollenweider Model over time for Blacktail Pond

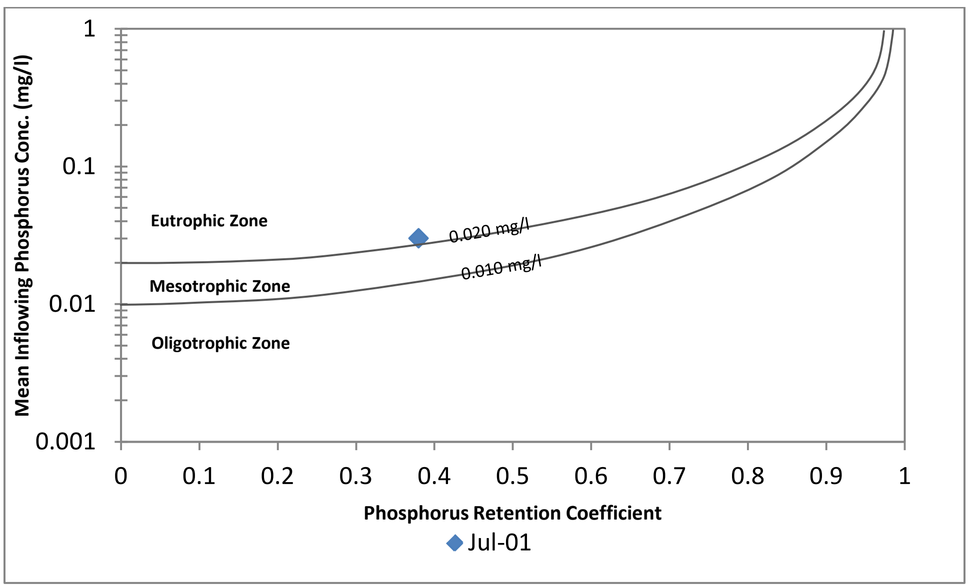

Figure 3.8: Larsen Mercier Model over time for Blacktail Pond

Figure 3.8 shows the results of the Larsen Mercier Model over time for Blacktail Pond. Only one total inlet phosphorus data point was collected in July 2001. According to the Larsen Mercier Model, Blacktail Pond was classified as slightly eutrophic at that time.

Figure 3.9 shows the average total inlake phosphorus concentrations over time for Blacktail Pond. These values depict an increase in inlake phosphorus with an average in strength correlation coefficient of 0.5362. The phosphorus concentrations vary in the range of slightly mesotrophic to eutrophic.

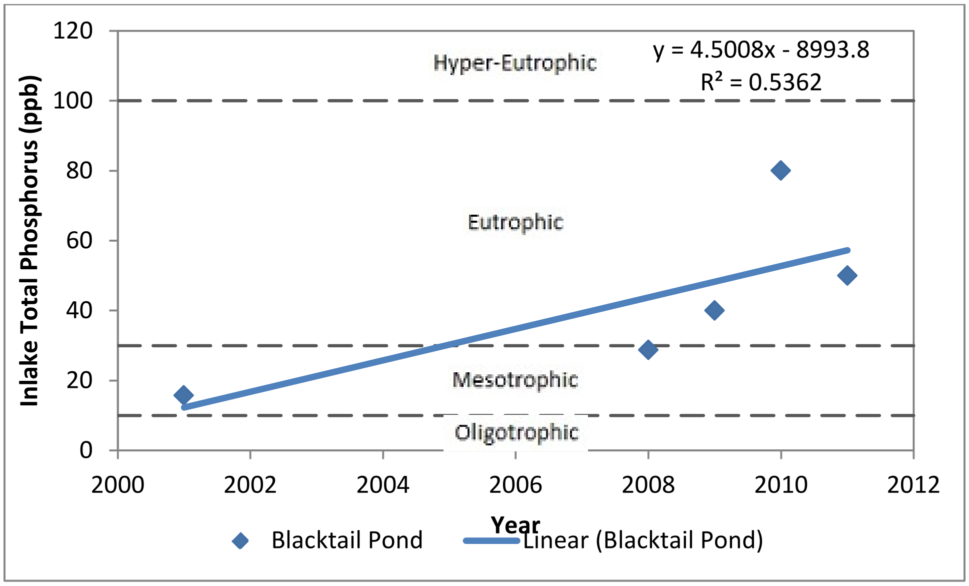

Figure 3.9: Inlake total phosphorus over time for Blacktail Pond

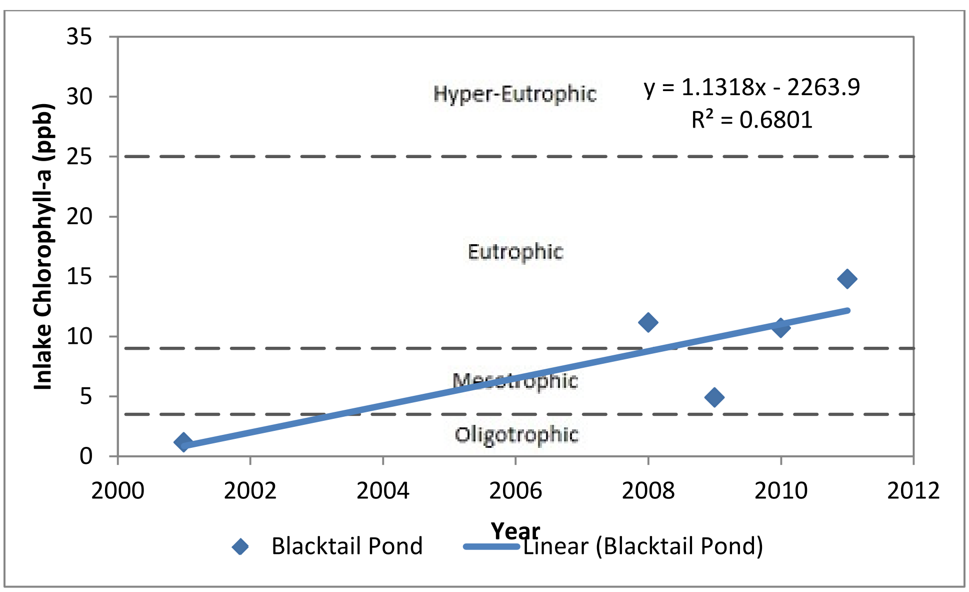

Figure 3.10: Inlake chlorophyll-a over time for Blacktail Pond

Figure 3.10 shows the average total inlake chlorophyll-a concentrations over time for Blacktail Pond. These values depict an increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.6801. The chlorophyll-a concentrations vary in the range of oligotrophic to eutrophic.

3.4 **Buck Lake**

Samples for Buck Lake were collected from 2004 to 2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

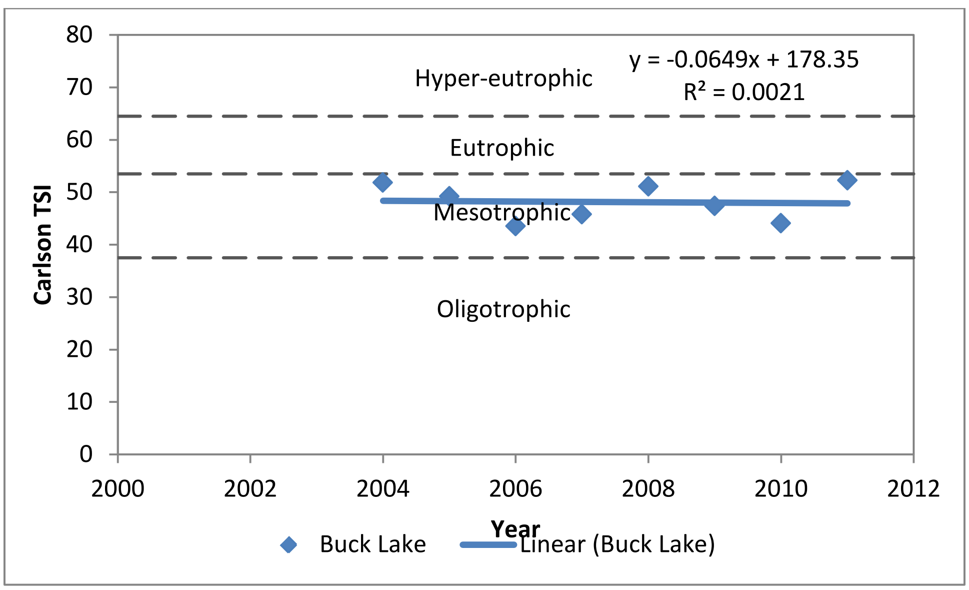

Figure 3.11: Carlson TSI over time for Buck Lake

Figure 3.11 depicts the Carlson TSI values over time for Buck Lake. The figure depicts a slight decrease in TSI values over time with a weak correlation coefficient of 0.0021. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

Figure 3.12 depicts the results of the Vollenweider Model over time for Buck Lake. The total phosphorus vs. hydraulic residence time data points range from eutrophic to hyper-eutrophic from 2004 to 2011.

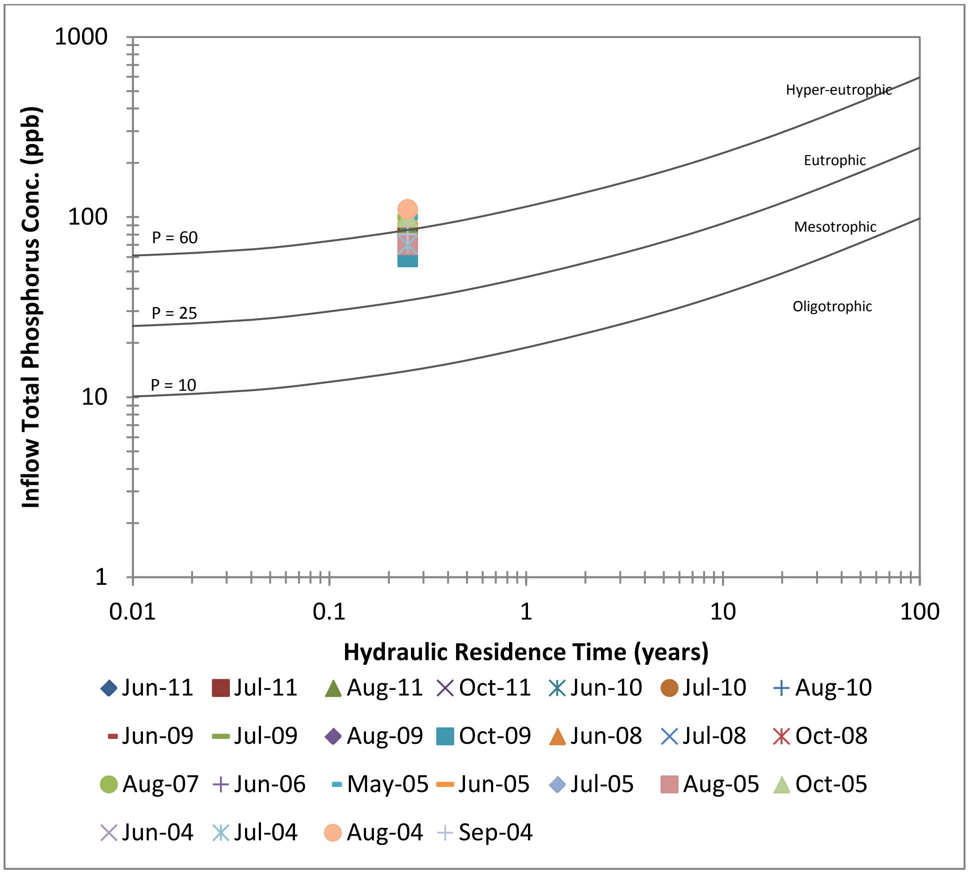

Figure 3.12: Vollenweider Model over time for Buck Lake

Figure 3.13 shows the results of the Larsen Mercier Model over time for Buck Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from oligotrophic in August 2009 to strongly eutrophic in October 2009. The majority of the data points are in the range of slightly eutrophic to strongly eutrophic.

Figure 3.14 shows the average total inlake phosphorus concentrations over time for Buck Lake. These values depict a slight decrease in inlake phosphorus with a weak correlation coefficient of 0.0005. The phosphorus concentrations vary in the range of strongly mesotrophic to slightly eutrophic.

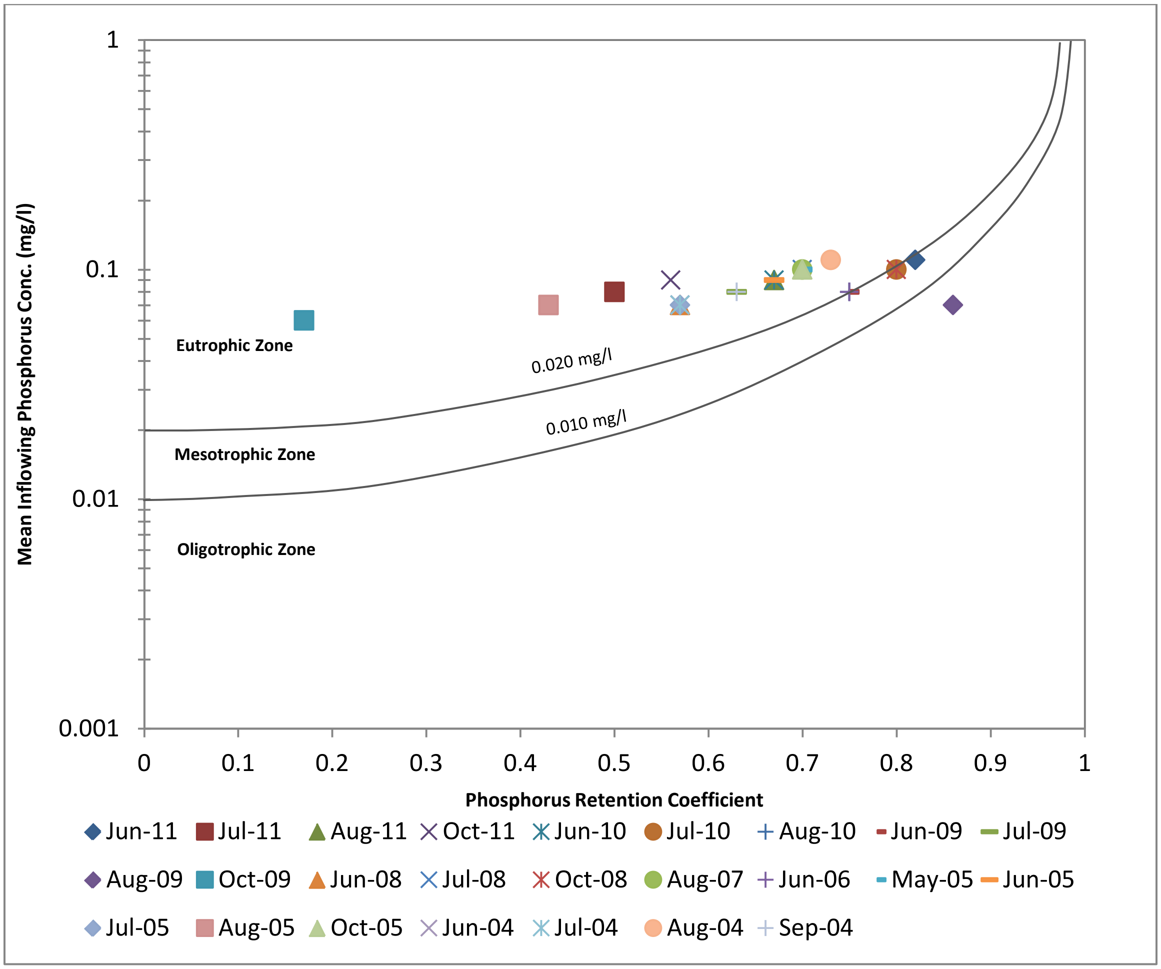

Figure 3.13: Larsen Mercier Model over time for Buck Lake

Figure 3.15 shows the average total inlake chlorophyll-a concentrations over time for Buck Lake. These values depict a slight increase in inlake chlorophyll-a with a weak correlation coefficient of 0.00005. The chlorophyll-a concentrations vary in the range of oligotrophic to eutrophic.

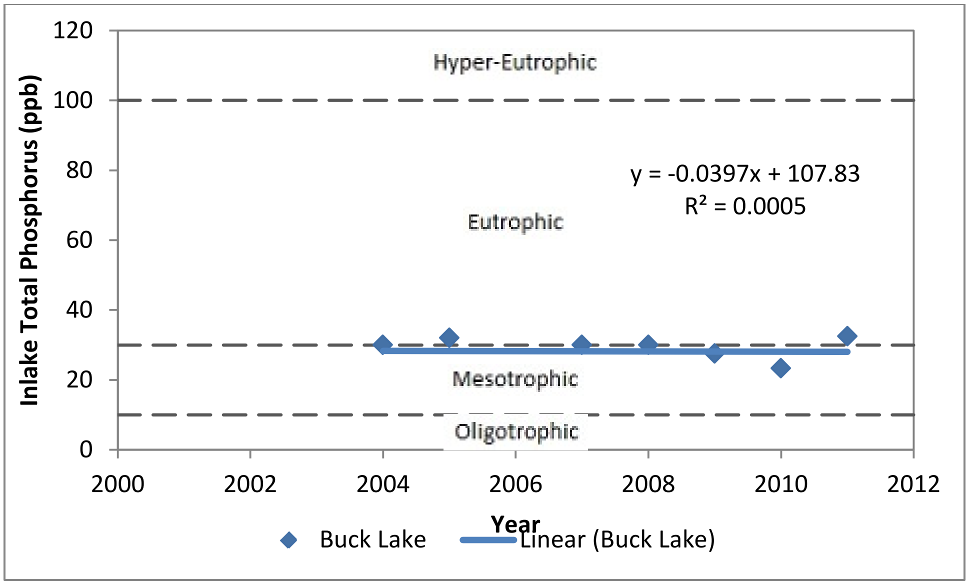

Figure 3.14: Inlake total phosphorus over time for Buck Lake

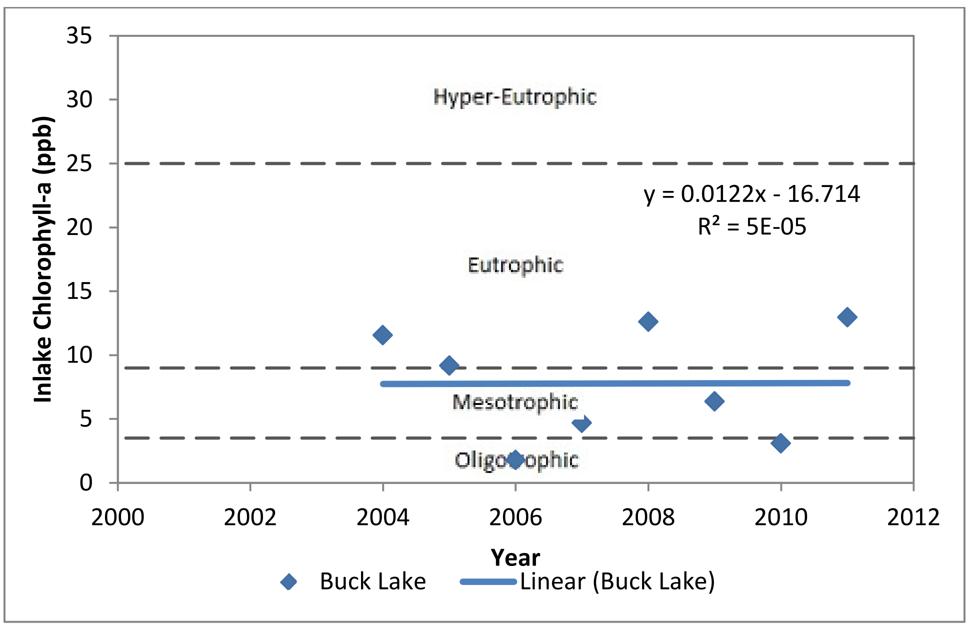

Figure 3.15: Inlake chlorophyll-a over time for Buck Lake

3.5 **Cascade Lake**

Samples for Cascade Lake were collected in 2000, and 2010-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

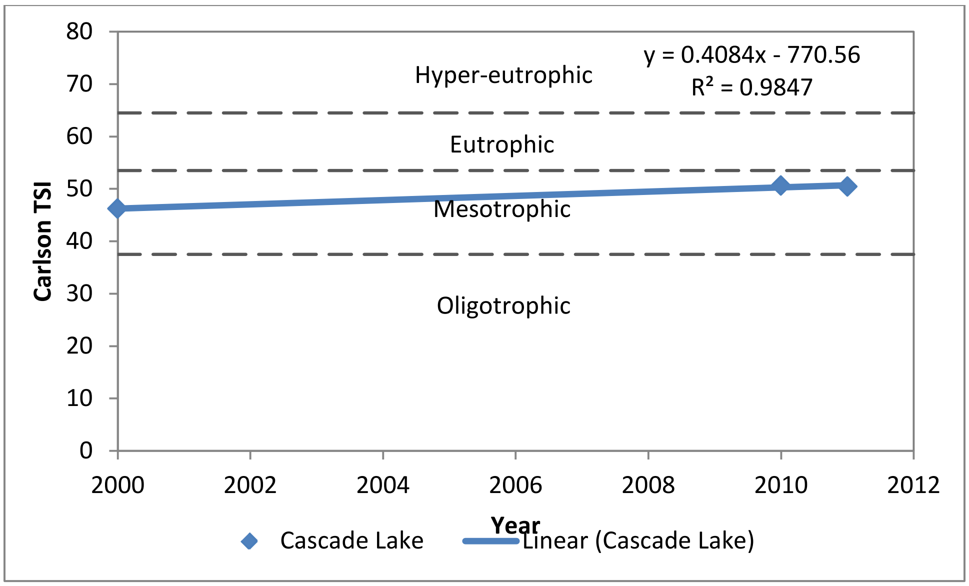

Figure 3.16: Carlson TSI over time for Cascade Lake

Figure 3.16 depicts the Carlson TSI values over time for Cascade Lake. The figure depicts a slight increase in TSI values over time with a strong correlation coefficient of 0.9847. The strong correlation can obviously be accredited to the limited number of data points (three). The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

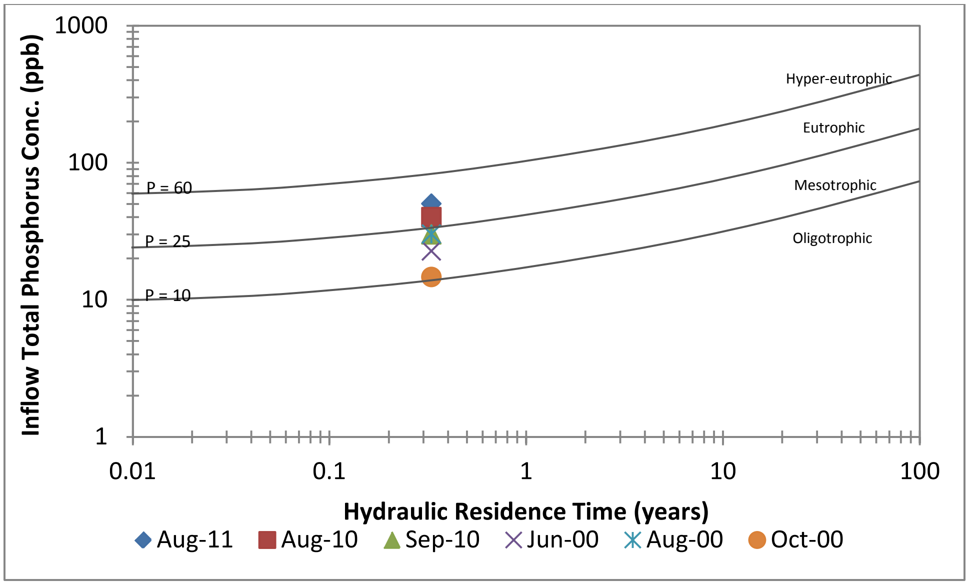

Figure 3.17: Vollenweider Model over time for Cascade Lake

Figure 3.17 depicts the results of the Vollenweider Model over time for Cascade Lake. The total phosphorus vs. hydraulic residence time data points range from slightly mesotrophic in October 2000 to eutrophic in August 2011.

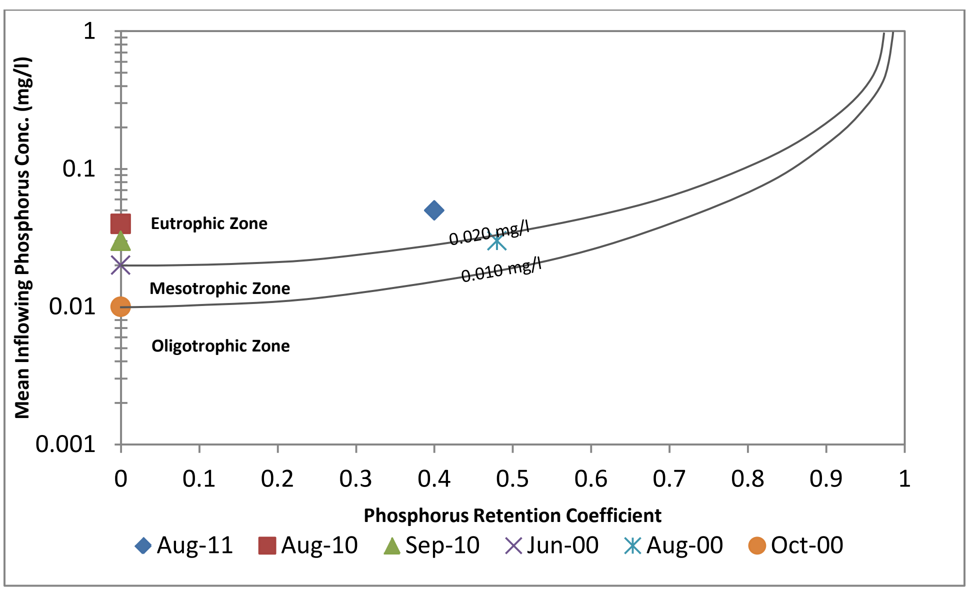

Figure 3.18: Larsen Mercier Model over time for Cascade Lake

Figure 3.18 shows the results of the Larsen Mercier Model over time for Beaver Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly mesotrophic in October 2000 to strongly eutrophic in August 2010. The majority of the data points are in the range of slightly eutrophic to strongly eutrophic.

Figure 3.19 shows the average total inlake phosphorus concentrations over time for Cascade Lake. These values depict a slight increase in inlake phosphorus with a relatively strong correlation coefficient of 0.7961. The phosphorus concentrations vary in the range of mesotrophic to slightly eutrophic.

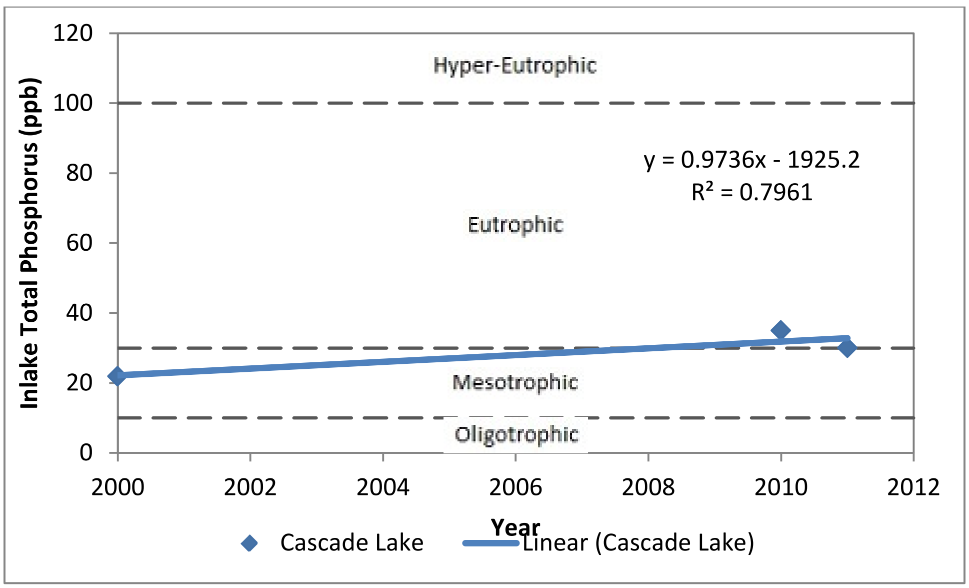

Figure 3.19: Inlake total phosphorus over time for Cascade Lake

Figure 3.20 shows the average total inlake chlorophyll-a concentrations over time for Cascade Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.7409. The chlorophyll-a concentrations vary in the range of slightly mesotrophic to slightly eutrophic.

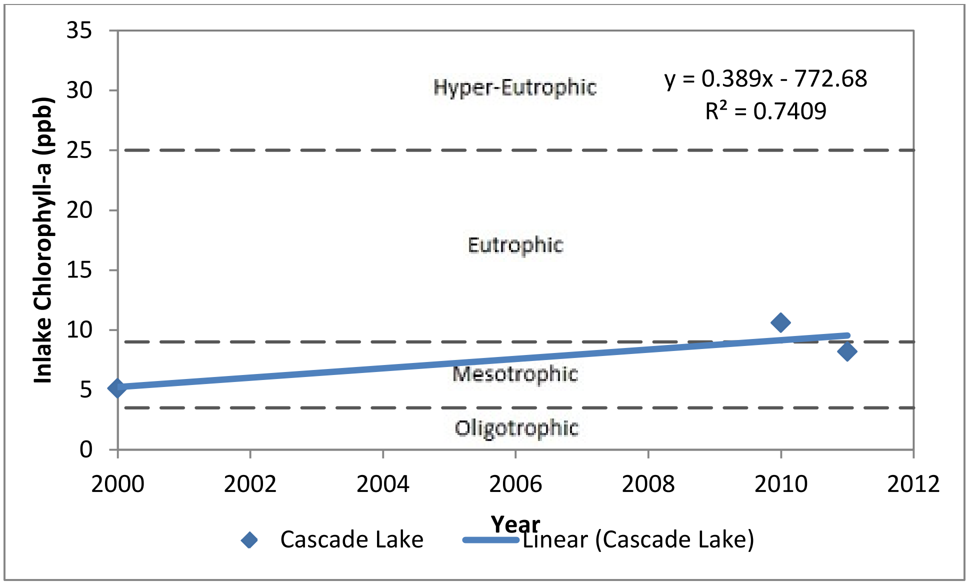

Figure 3.20: Inlake chlorophyll-a over time for Cascade Lake

3.6 **Clear Lake**

Samples for Clear Lake were collected in 2004, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.21 depicts the Carlson TSI values over time for Clear Lake. The figure depicts a decrease in TSI values over time with a relatively strong correlation coefficient of 0.6949. The TSI values vary in the range of mesotrophic and slightly eutrophic classification.

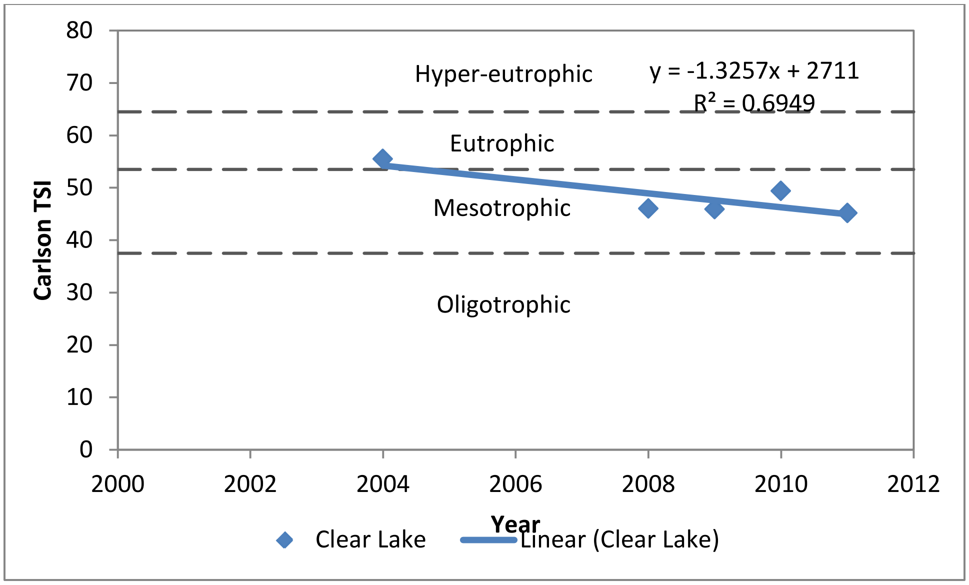

Figure 3.21: Carlson TSI over time for Clear Lake

Figure 3.22 depicts the results of the Vollenweider Model over time for Clear Lake. The total phosphorus vs. hydraulic residence time data points range from slightly hyper-eutrophic in June 2004 to hyper-eutrophic in June 2011.

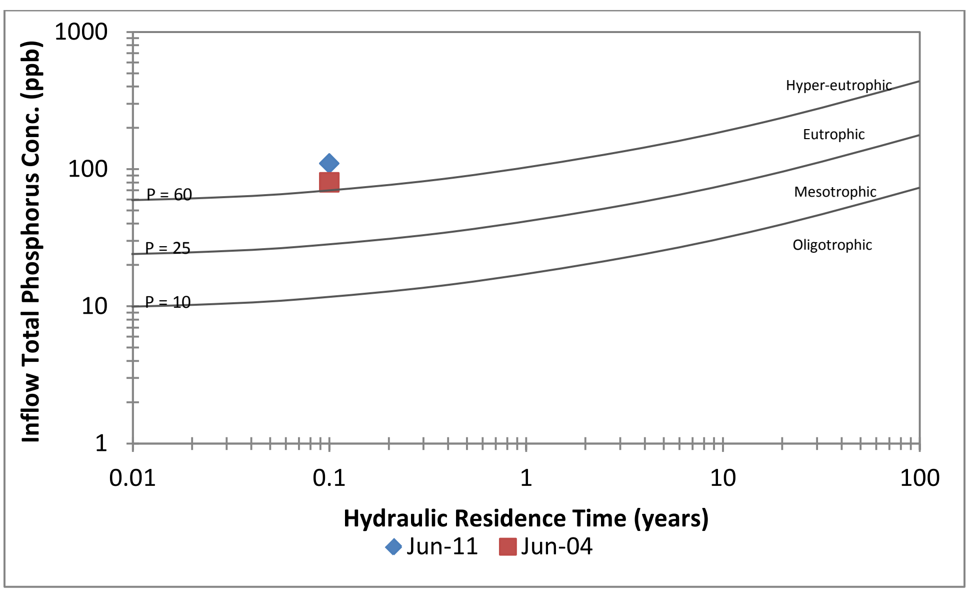

Figure 3.22: Vollenweider Model over time for Clear Lake

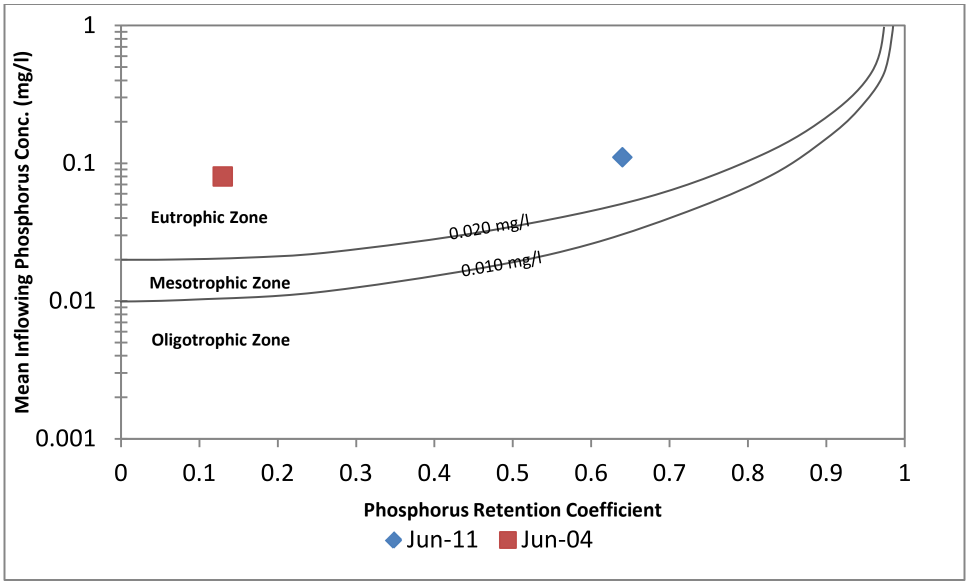

Figure 3.23: Larsen Mercier Model over time for Clear Lake

Figure 3.23 shows the results of the Larsen Mercier Model over time for Clear Lake. Two total inlet phosphorus vs. phosphorus retention coefficient data points exist with a strongly eutrophic classification in both June 2004 and June 2011.

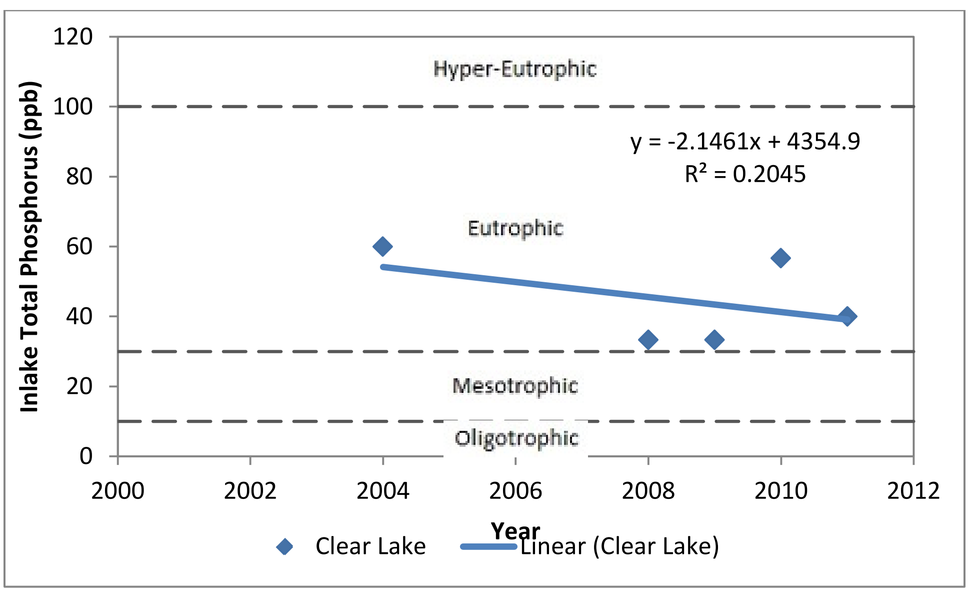

Figure 3.24: Inlake total phosphorus over time for Clear Lake

Figure 3.24 shows the average total inlake phosphorus concentrations over time for Clear Lake. These values depict a decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.2045. The phosphorus concentrations vary in the range of slightly eutrophic to eutrophic.

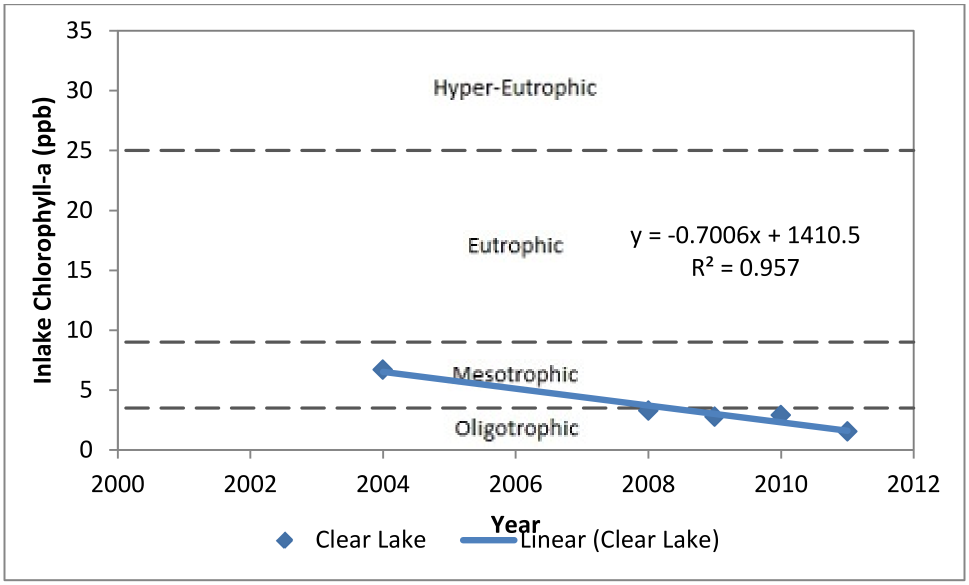

Figure 3.25: Inlake chlorophyll-a over time for Clear Lake

Figure 3.25 shows the average total inlake chlorophyll-a concentrations over time for Clear Lake. These values depict a decrease in inlake chlorophyll-a with a strong correlation coefficient of 0.957. The chlorophyll-a concentrations vary in the range of oligotrophic to mesotrophic.

3.7 Crevice Lake

Samples for Crevice Lake were collected in 2005. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

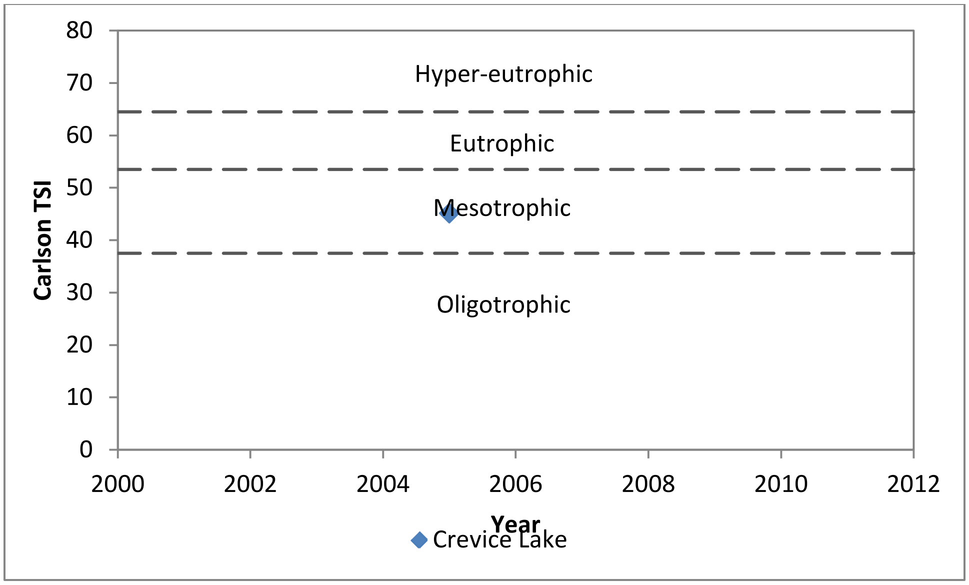

Figure 3.26: Carlson TSI over time for Crevice Lake

Figure 3.26 depicts the Carlson TSI value over time for Crevice Lake. Only one data point exists for the year 2005. This data point represents a mesotrophic classification based on the Carlson TSI Model.

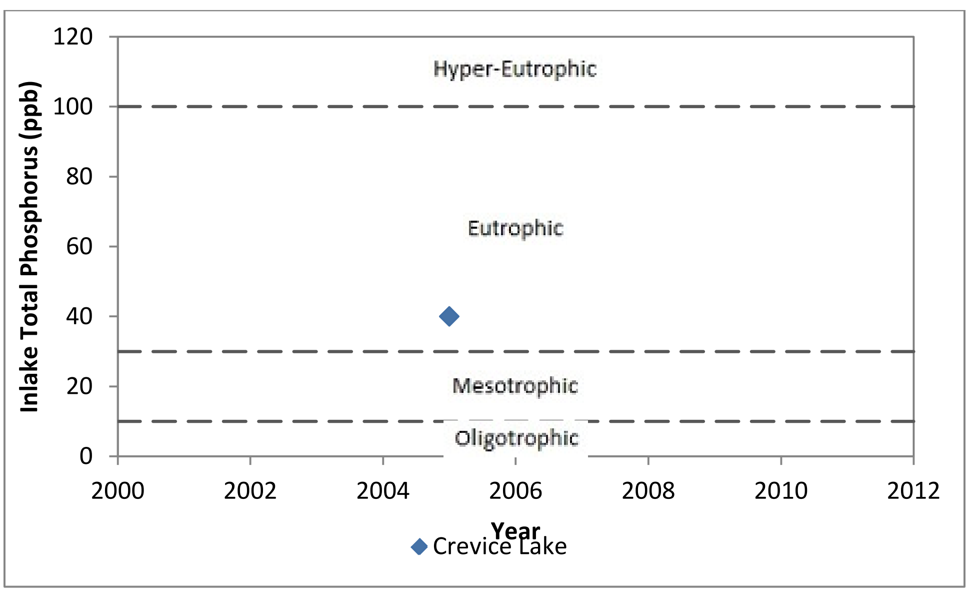

Figure 3.27: Inlake total phosphorus over time for Crevice Lake

Figure 3.27 shows the average total inlake phosphorus concentrations over time for Crevice Lake. Only one data point exists for the year 2005. This data point represents a slightly eutrophic classification based on total inlake phosphorus concentration.

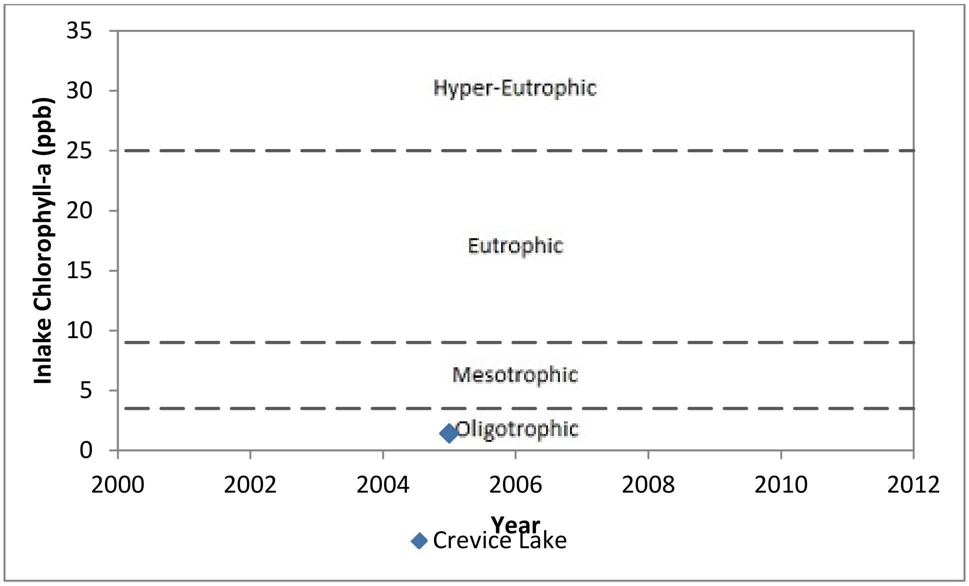

Figure 3.28: Inlake chlorophyll-a over time for Crevice Lake

Figure 3.28 shows the average total inlake chlorophyll-a concentrations over time for Crevice Lake. Only one data point exists for the year 2005. This data point represents an oligotrophic classification based on total inlake chlorophyll-a concentration.

3.8 Druid Lake

Samples for Druid Lake were collected in 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

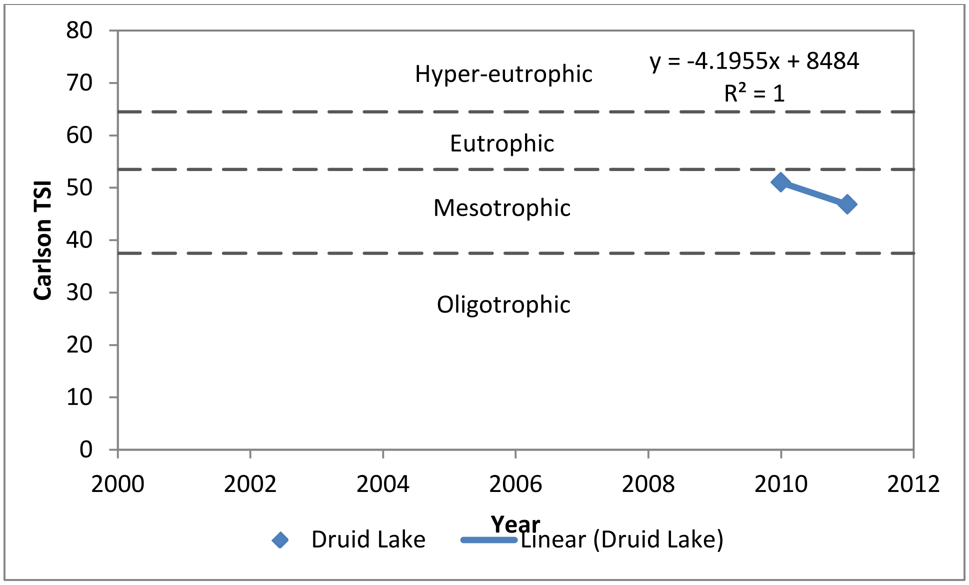

Figure 3.29: Carlson TSI over time for Druid Lake

Figure 3.29 depicts the Carlson TSI values over time for Druid Lake. The figure depicts a decrease in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as mesotrophic and strongly mesotrophic.

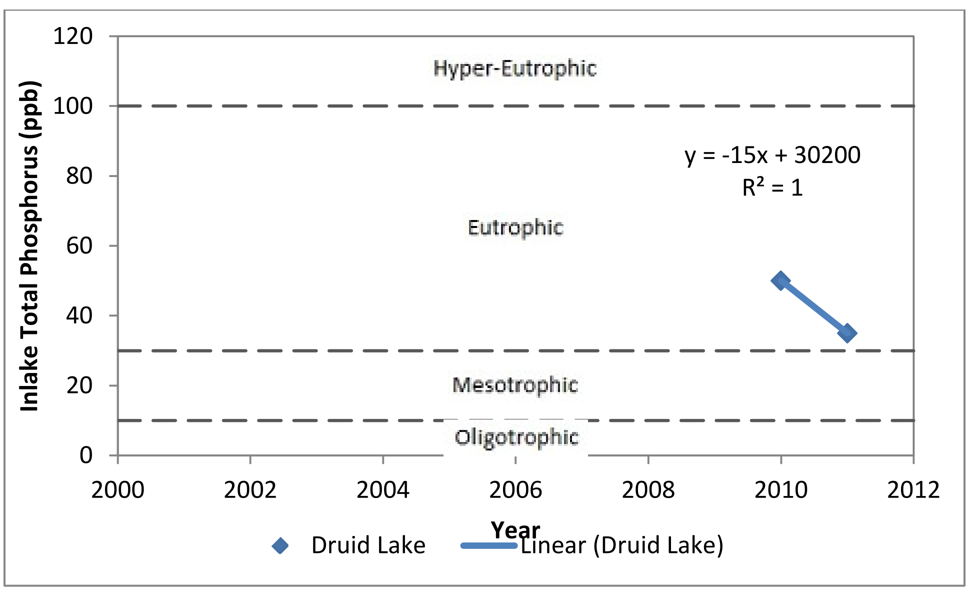

Figure 3.30: Inlake total phosphorus over time for Druid Lake

Figure 3.30 shows the average total inlake phosphorus concentrations over time for Druid Lake. These values depict a decrease in inlake phosphorus. As only two data points were collected, a correlation is difficult to determine. The total inlake phosphorus values were classified as slightly eutrophic and eutrophic.

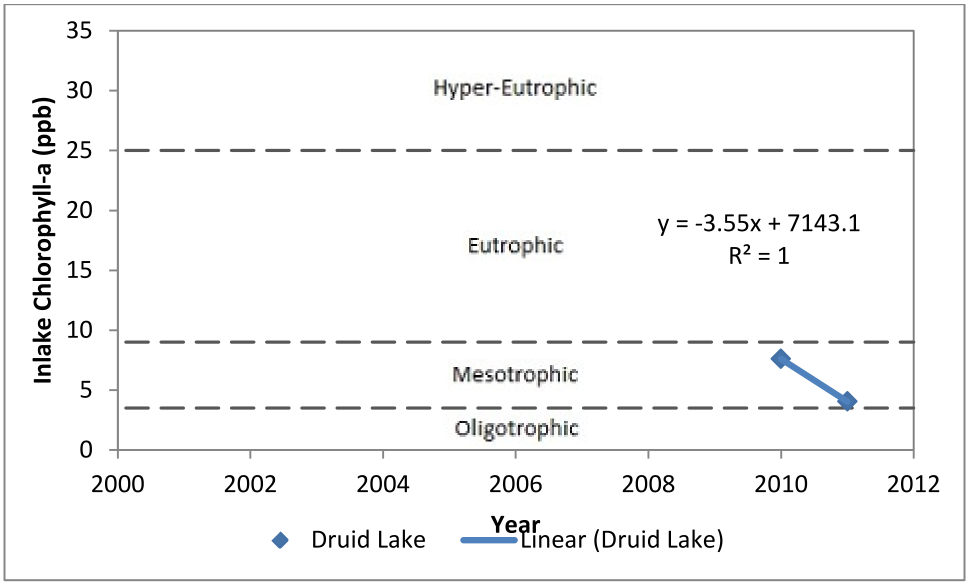

Figure 3.31: Inlake chlorophyll-a over time for Druid Lake

Figure 3.31 shows the average total inlake chlorophyll-a concentrations over time for Druid Lake. These values depict a decrease in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The total inlake chlorophyll-a values were classified as slightly mesotrophic and strongly mesotrophic.

3.9 **Duck Lake**

Samples for Duck Lake were collected in 1999, 2003, and 2008-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

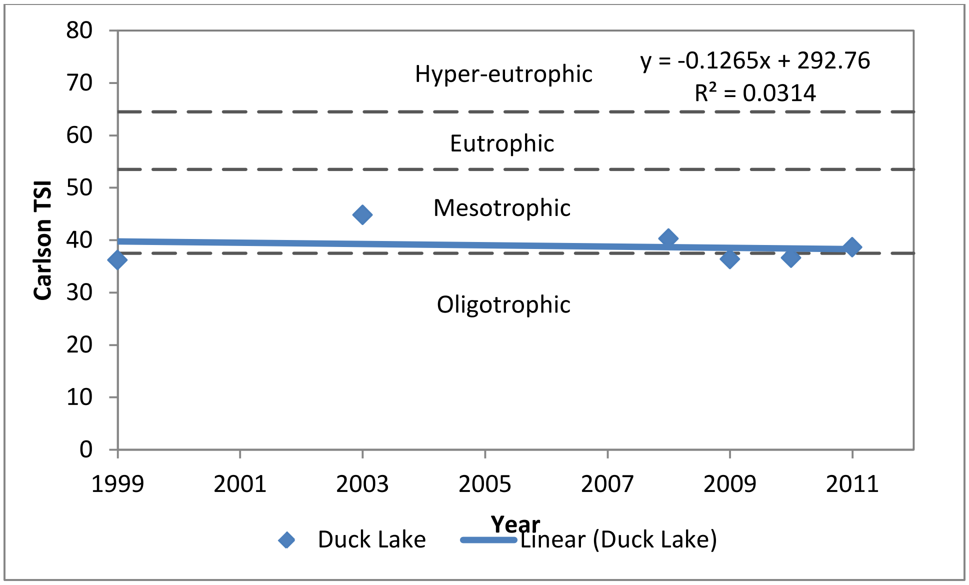

Figure 3.32: Carlson TSI over time for Duck Lake

Figure 3.32 depicts the Carlson TSI values over time for Duck Lake. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.0314. The TSI values vary in the range of slightly oligotrophic to mesotrophic.

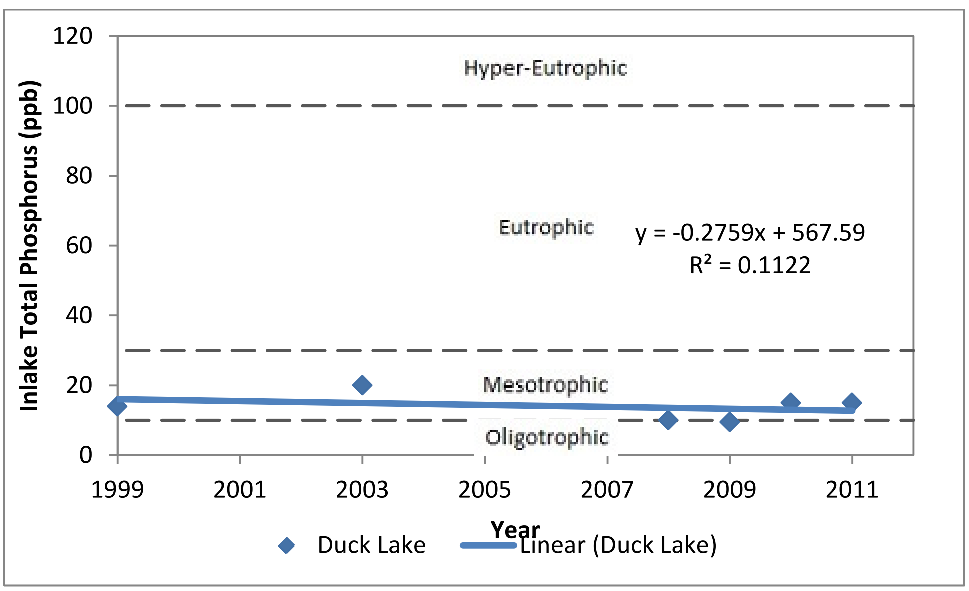

Figure 3.33: Inlake total phosphorus over time for Duck Lake

Figure 3.33 shows the average total inlake phosphorus concentrations over time for Duck Lake. These values depict a slight decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.1122. The phosphorus concentrations vary in the range of slightly mesotrophic to mesotrophic.

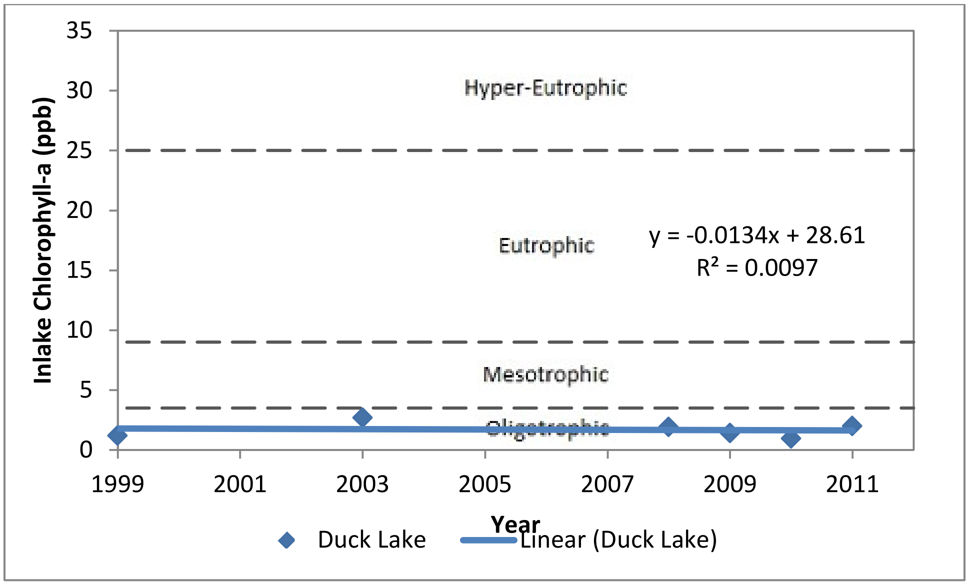

Figure 3.34: Inlake chlorophyll-a over time for Duck lake

Figure 3.34 shows the average total inlake chlorophyll-a concentrations over time for Duck Lake. These values depict a slight decrease in inlake chlorophyll-a with a weak correlation coefficient of 0.0097. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly oligotrophic.

3.10 **Eleanor Lake**

Samples for Eleanor Lake were collected in 2004, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

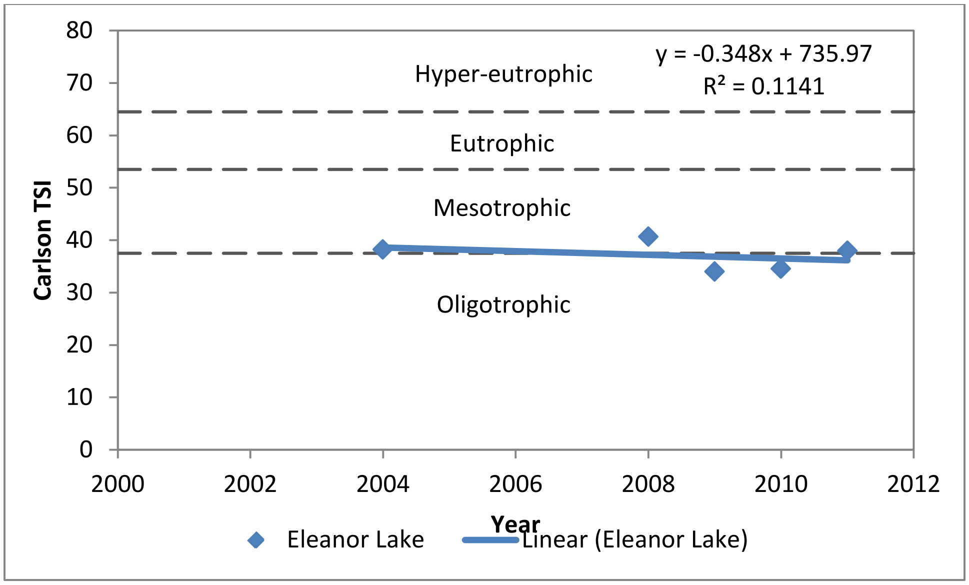

Figure 3.35: Carlson TSI over time for Eleanor Lake

Figure 3.35 depicts the Carlson TSI values over time for Eleanor Lake. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.1141. The TSI values vary in the range of slightly oligotrophic to slightly mesotrophic classification.

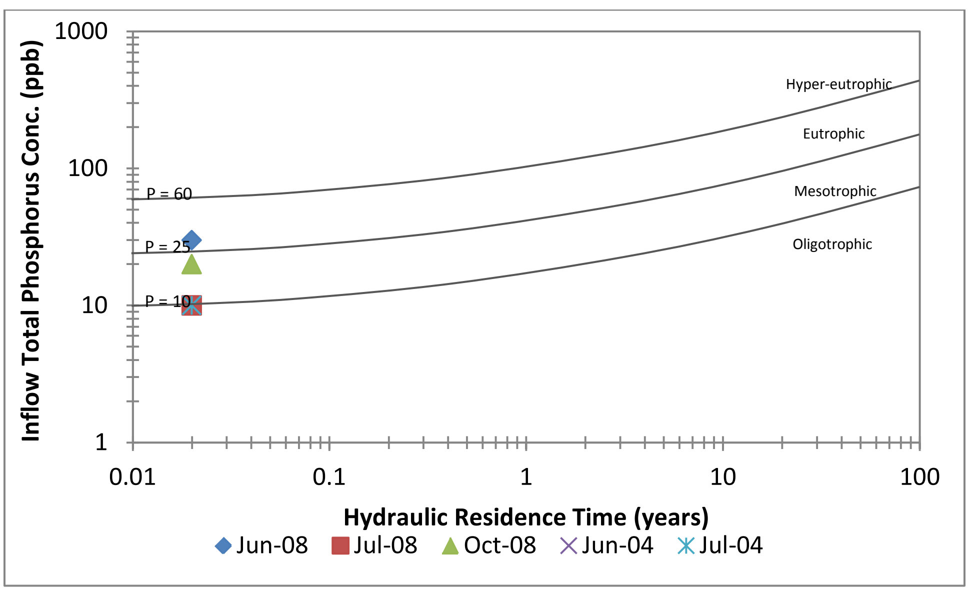

Figure 3.36: Vollenweider Model over time for Eleanor Lake

Figure 3.36 depicts the results of the Vollenweider Model over time for Eleanor Lake. The total phosphorus vs. hydraulic residence time data points range from slightly mesotrophic in July 2004 to slightly eutrophic in June 2008.

Figure 3.37 shows the results of the Larsen Mercier Model over time for Eleanor Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly mesotrophic to slightly eutrophic.

Figure 3.38 shows the average total inlake phosphorus concentrations over time for Eleanor Lake. These values depict a slight decrease in inlake phosphorus with a relatively strong correlation coefficient of 0.6357. The phosphorus concentrations vary in the range of slightly mesotrophic to mesotrophic.

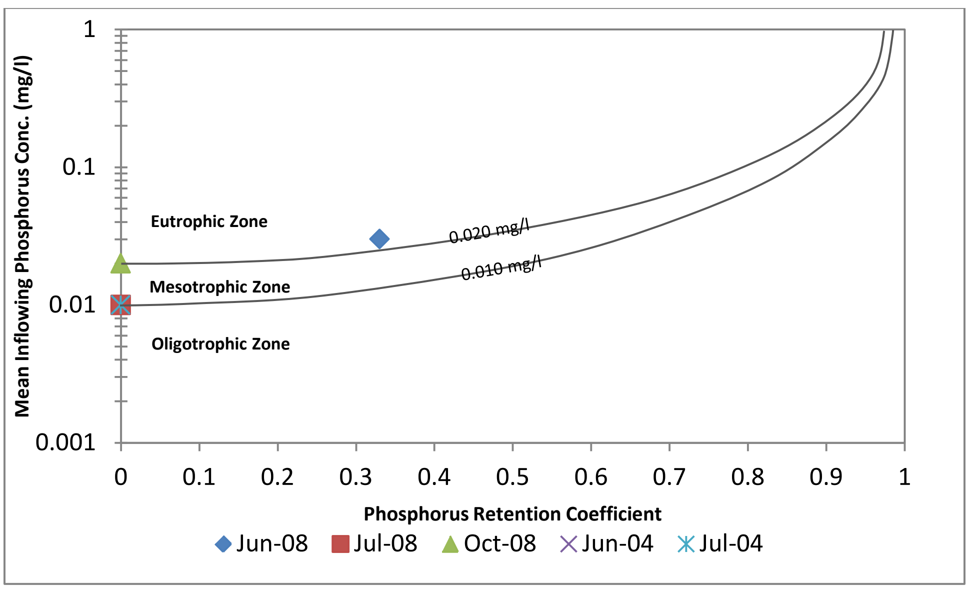

Figure 3.37: Larsen Mercier Model over time for Eleanor Lake

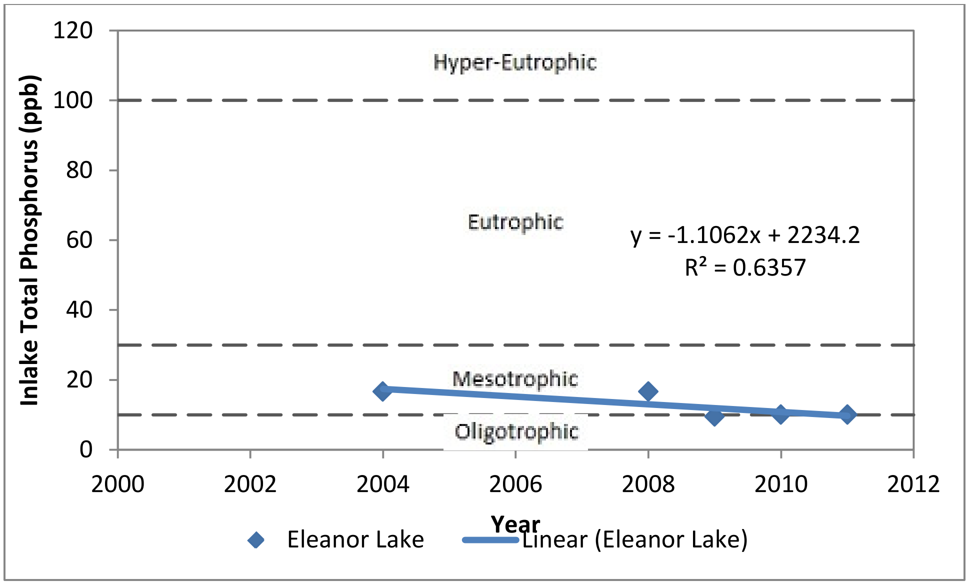

Figure 3.38: Inlake total phosphorus over time for Eleanor Lake

Figure 3.39 shows the average total inlake chlorophyll-a concentrations over time for Eleanor Lake. These values depict a slight decrease in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.057. All chlorophyll-a concentrations fall in the oligotrophic range.

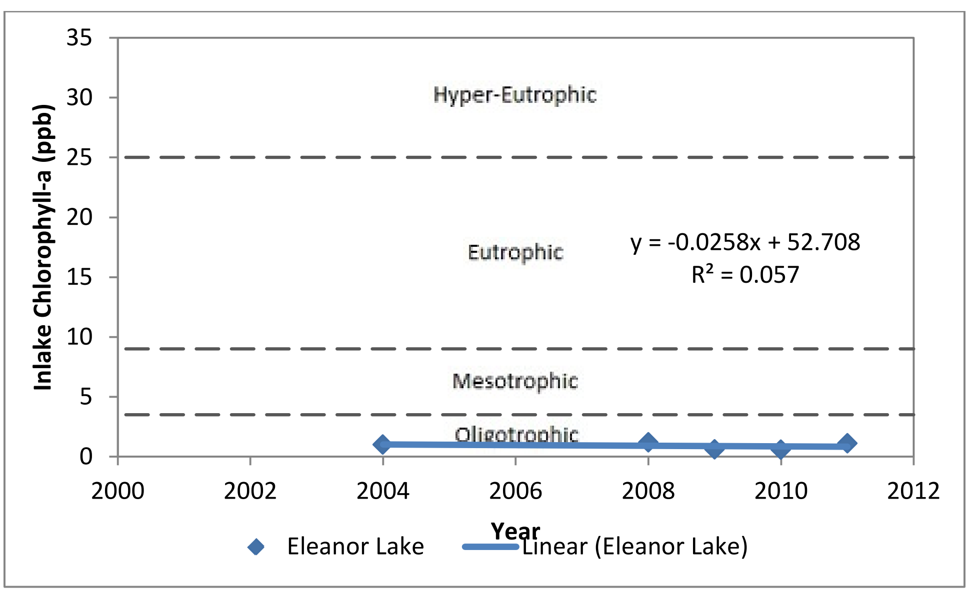

Figure 3.39: Inlake chlorophyll-a over time for Eleanor Lake

3.11 **Feather Lake**

Samples for Feather Lake were collected in 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.40 depicts the Carlson TSI values over time for Feather Lake. The figure depicts a slight increase in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as both strongly eutrophic.

Figure 3.41 shows the average total inlake phosphorus concentrations over time for Feather Lake. These values depict no change in inlake phosphorus. As only two data points were calculated, a correlation is difficult to determine. The total inlake phosphorus values were both classified as hyper-eutrophic.

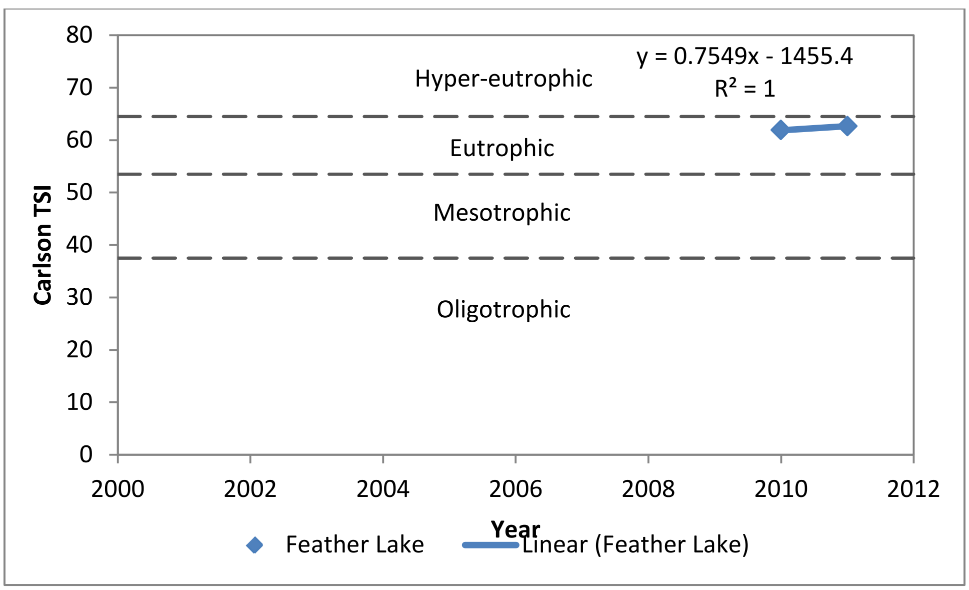

Figure 3.40: Carlson TSI over time for Feather Lake

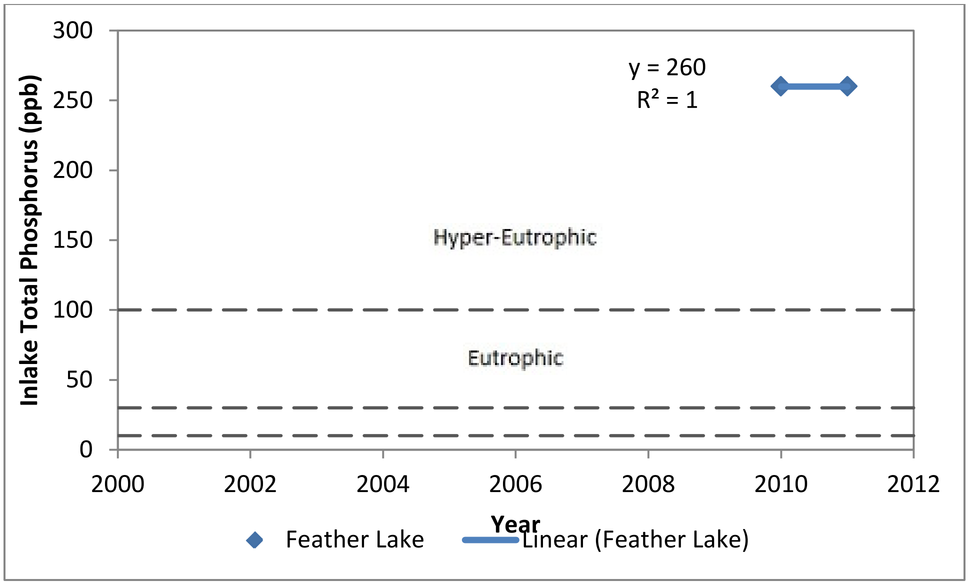

Figure 3.41: Inlake total phosphorus over time for Feather Lake

Figure 3.42 shows the average total inlake chlorophyll-a concentrations over time for Feather Lake. These values depict an increase in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The total inlake chlorophyll-a values were classified as slightly eutrophic and eutrophic.

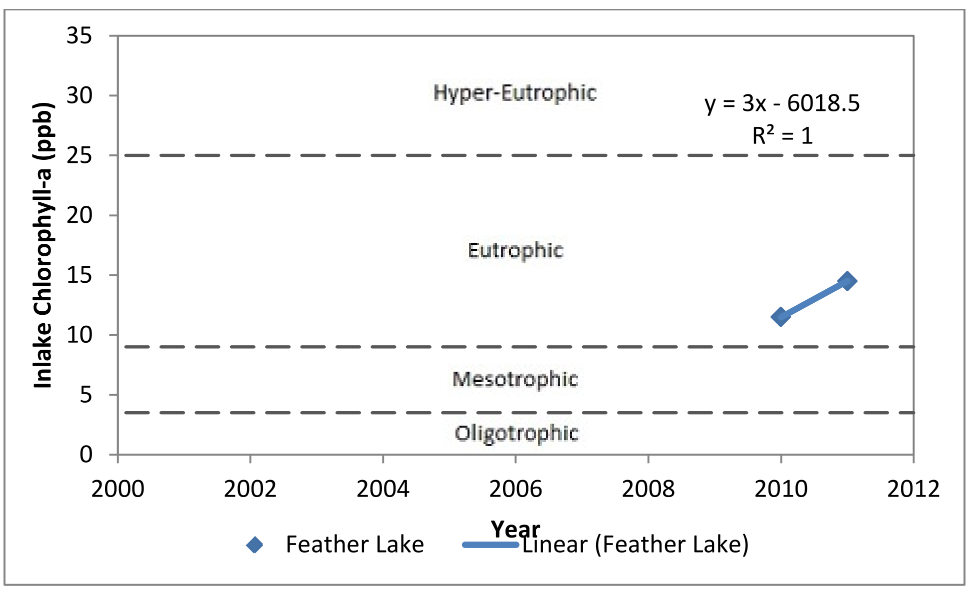

Figure 3.42: Inlake chlorophyll-a over time for Feather Lake

3.12 **Floating Island Lake**

Samples for Floating Island Lake were collected in 2004, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

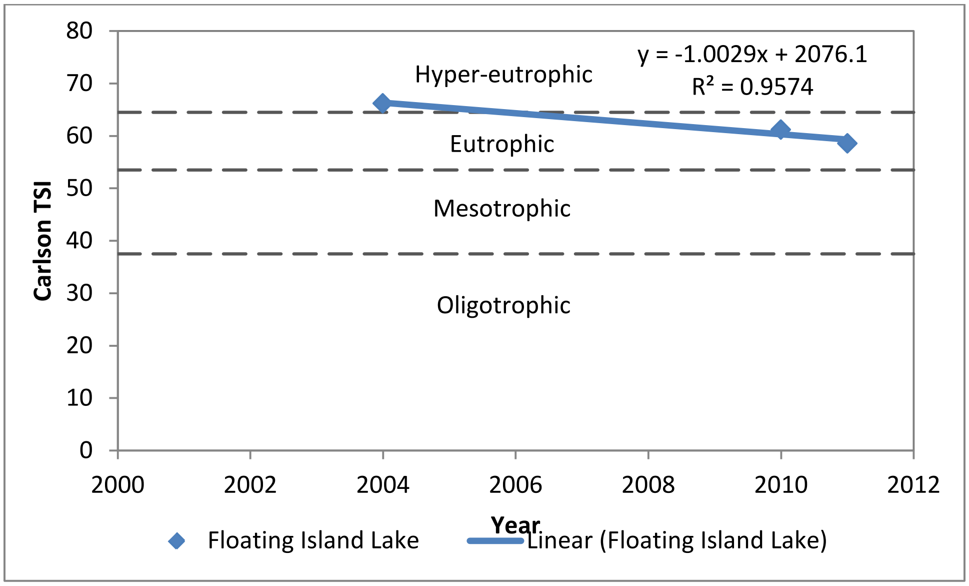

Figure 3.43: Carlson TSI over time for Floating Island Lake

Figure 3.43 depicts the Carlson TSI values over time for Floating Island Lake. The figure depicts a decrease in TSI values over time with a strong correlation coefficient of 0.9574. The strong correlation could be due to the limited number of data points (three). The TSI values vary in the range of eutrophic to slightly hyper-eutrophic classification.

Figure 3.44 shows the average total inlake phosphorus concentrations over time for Floating Island Lake. These values depict a decrease in inlake phosphorus with a strong correlation coefficient of 0.9997. As with the TSI values, the strong correlation could be due to the limited number of data points. The phosphorus concentrations vary in the range of eutrophic and hyper-eutrophic.

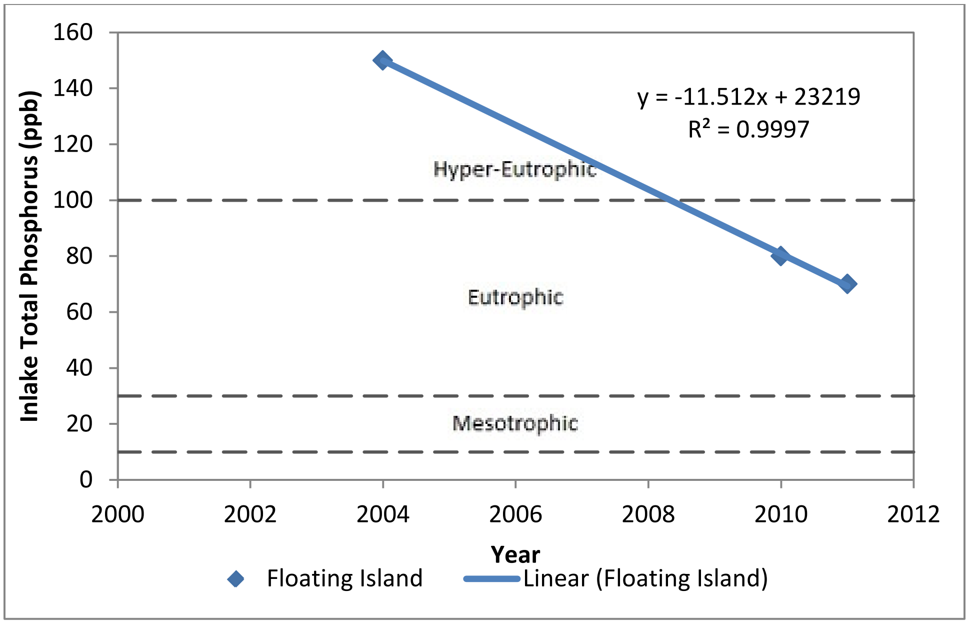

Figure 3.44: Inlake total phosphorus over time for Floating Island Lake

Figure 3.45 shows the average total inlake chlorophyll-a concentrations over time for Floating Island Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.2679. The chlorophyll-a concentrations vary in the range of strongly eutrophic and hyper-eutrophic.

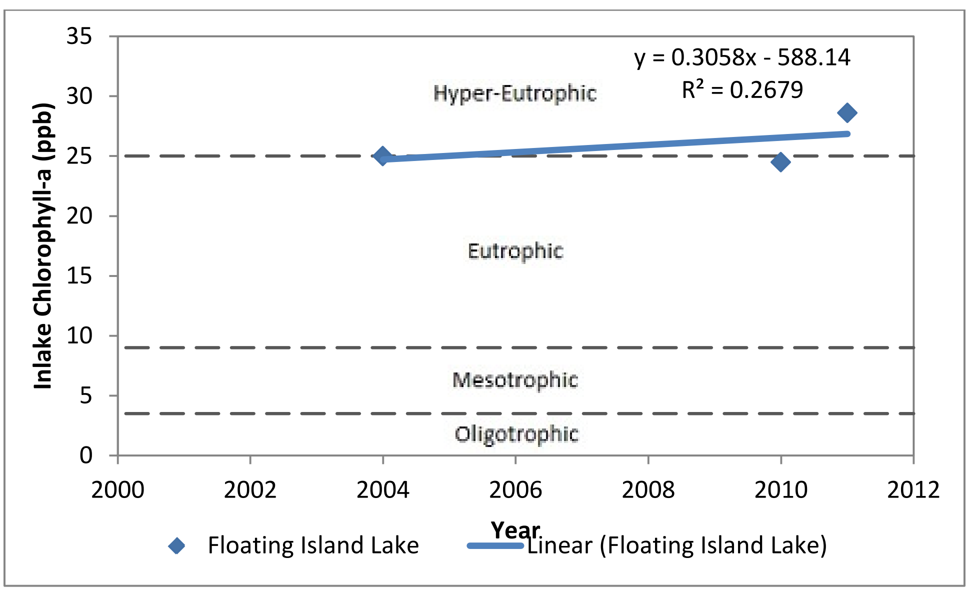

Figure 3.45: Inlake chlorophyll-a over time for Floating Island Lake

3.13 **Goose Lake**

Samples for Goose Lake were collected in 2001, and 2009-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.46 depicts the Carlson TSI values over time for Goose Lake. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.0306. The TSI values vary in the range of slightly mesotrophic and strongly mesotrophic classification.

Figure 3.47 depicts the results of the Vollenweider Model over time for Goose Lake. The total phosphorus vs. hydraulic residence time data points range from slightly oligotrophic in October 2011 and June 2009 to eutrophic in July 2009.

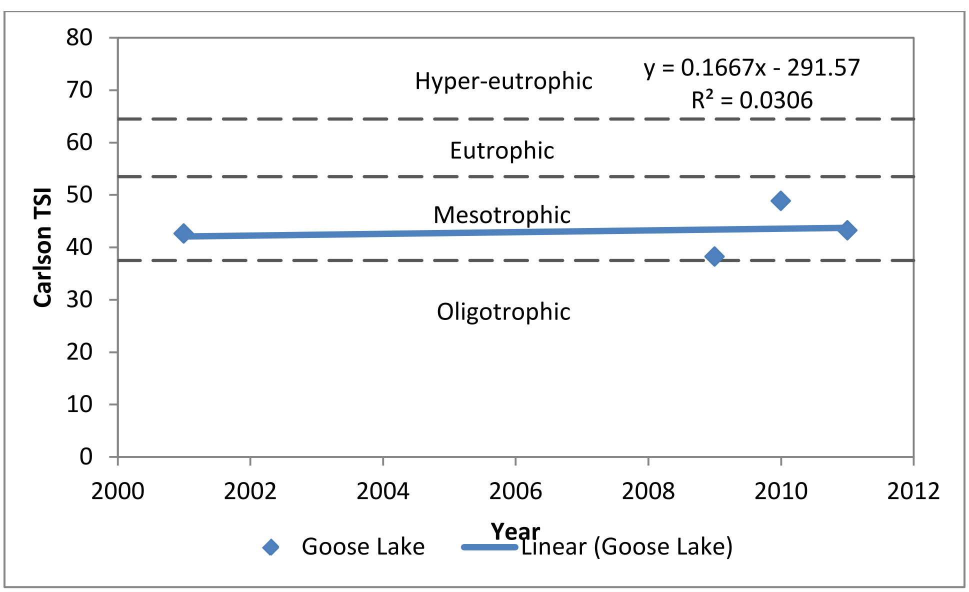

Figure 3.46: Carlson TSI over time for Goose Lake

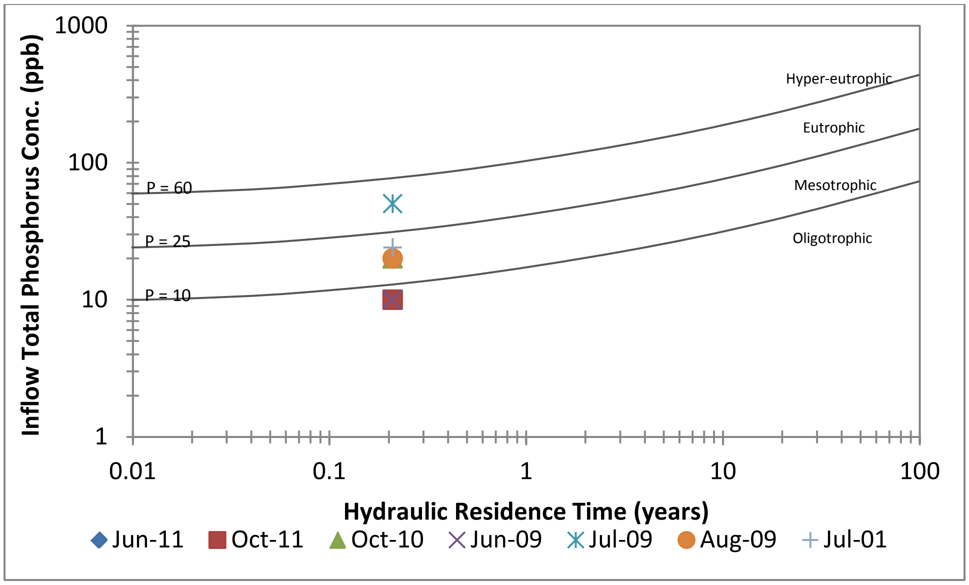

Figure 3.47: Vollenweider Model over time for Goose Lake

Figure 3.48 shows the results of the Larsen Mercier Model over time for Goose Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly mesotrophic in October 2011 and June 2009 to slightly eutrophic in July 2009. The majority of the data points are in the range of slightly mesotrophic to slightly eutrophic.

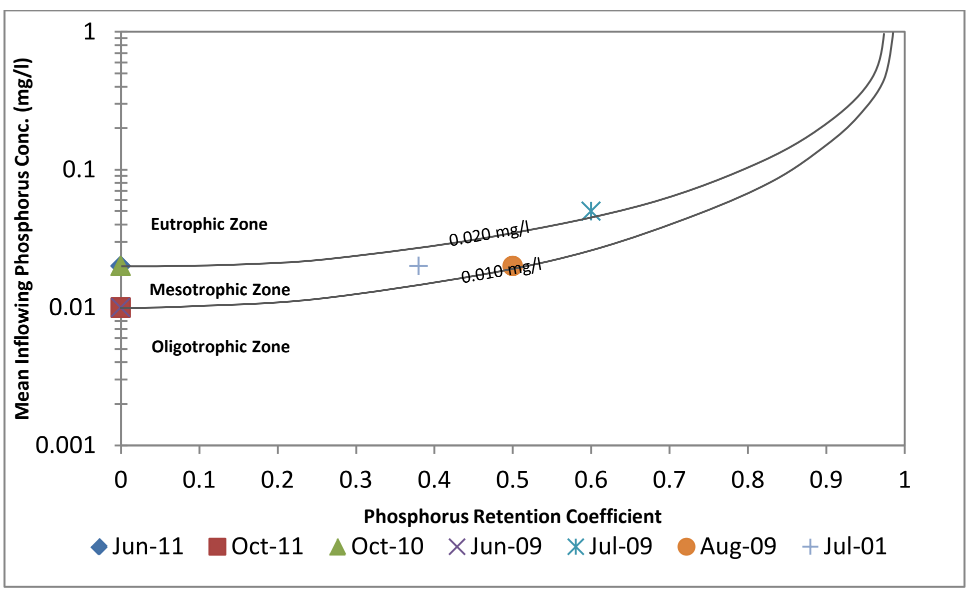

Figure 3.48: Larsen Mercier Model over time for Goose Lake

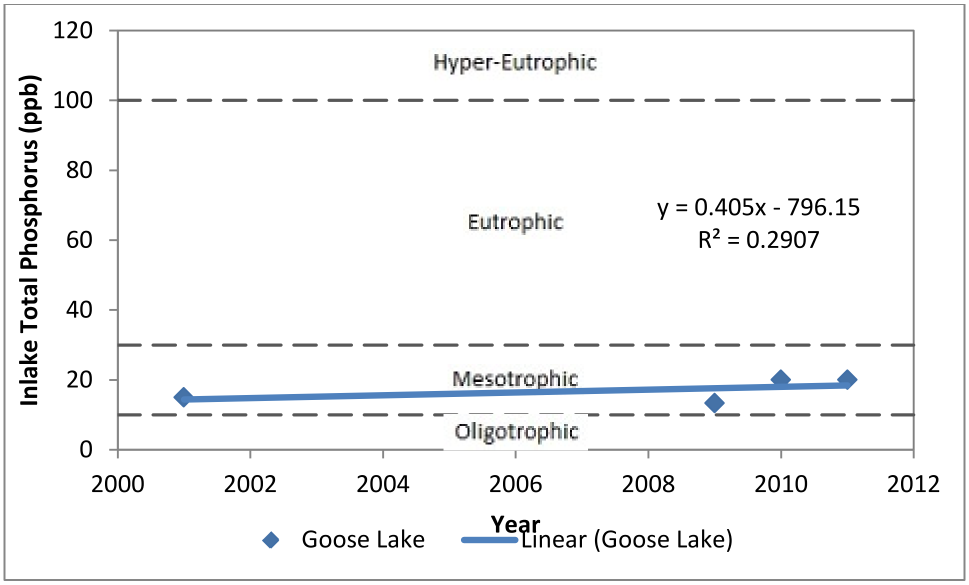

Figure 3.49: Inlake total phosphorus over time for Goose Lake

Figure 3.49 shows the average total inlake phosphorus concentrations over time for Goose Lake. These values depict a slight increase in inlake phosphorus with a relatively weak correlation coefficient of 0.2907. The phosphorus concentrations vary in the range of slightly mesotrophic to mesotrophic.

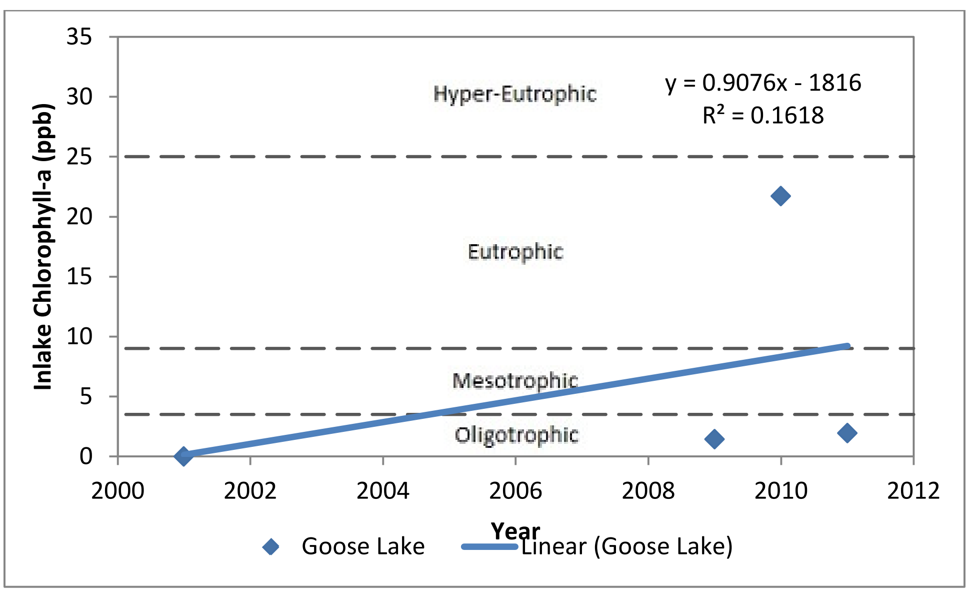

Figure 3.50: Inlake chlorophyll-a over time for Goose Lake

Figure 3.50 shows the average total inlake chlorophyll-a concentrations over time for Goose Lake. These values depict an increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.1618. The chlorophyll-a concentrations vary in the range of oligotrophic to strongly eutrophic.

3.14 Grebe Lake

Samples for Grebe Lake were collected in the year 2000. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.51 depicts the Carlson TSI value in over time for Grebe Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the mesotrophic classification based on the Carlson Model.

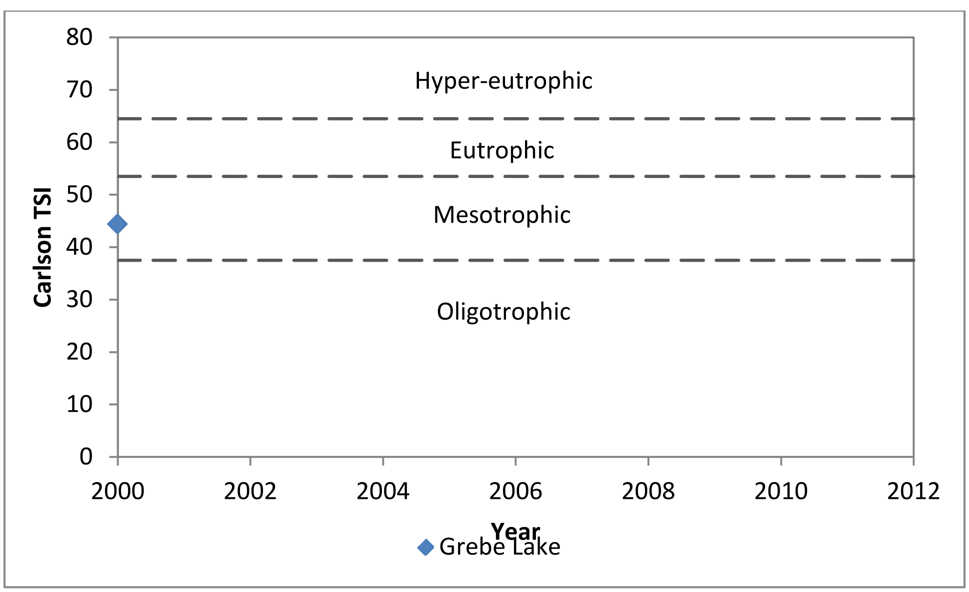

Figure 3.51: Carlson TSI over time for Grebe Lake

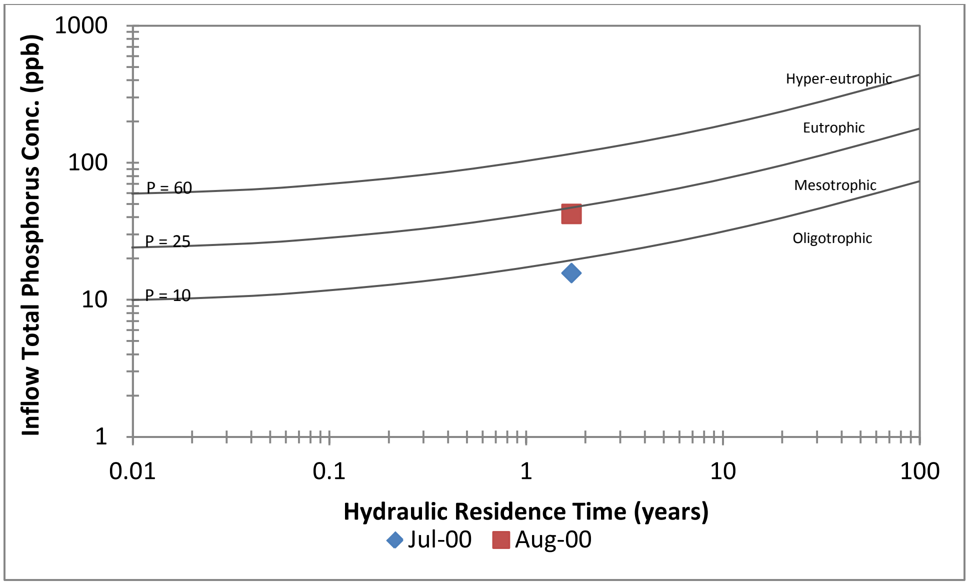

Figure 3.52: Vollenweider Model over time for Grebe Lake

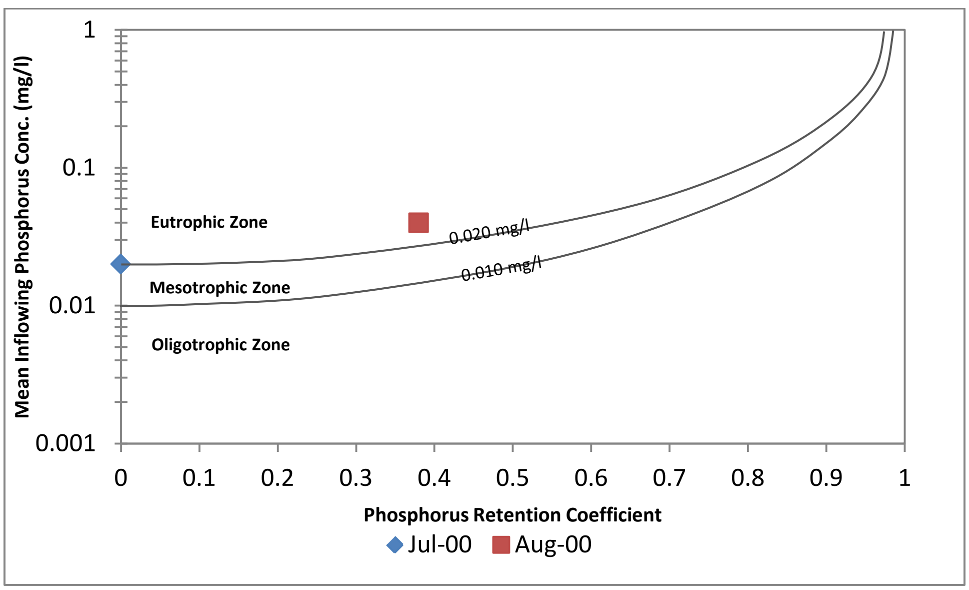

Figure 3.53: Larsen Mercier Model over time for Grebe Lake

Figure 3.53 shows the results of the Larsen Mercier Model over time for Grebe Lake. The two data points for total phosphorus vs. phosphorus retention coefficient fall in the slightly eutrophic classification in July 2000 and eutrophic in August 2000.

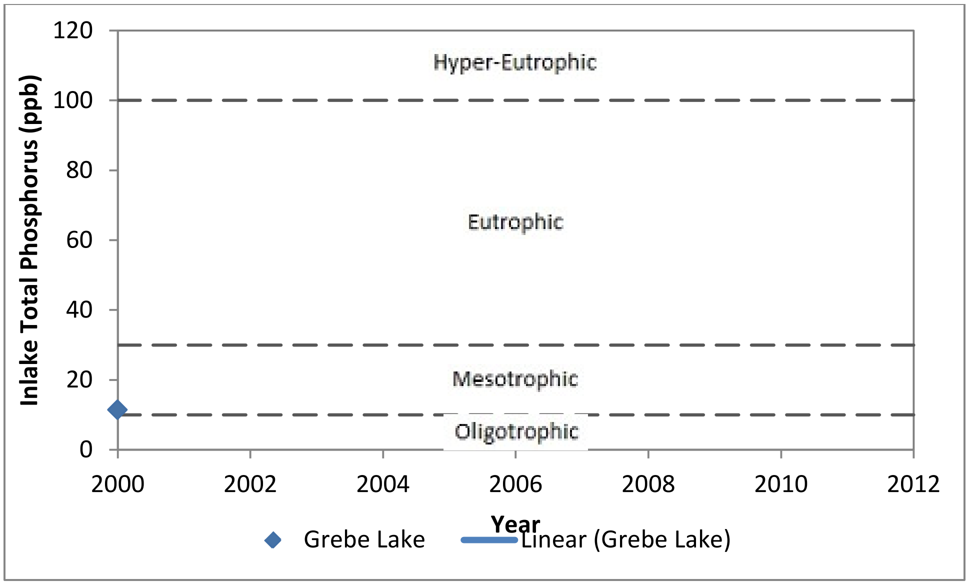

Figure 3.54: Inlake total phosphorus over time for Grebe Lake

Figure 3.54 shows the average total inlake phosphorus concentrations over time for Grebe Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake phosphorus concentrations. The one TP value falls under the slightly mesotrophic classification based on the TP Model.

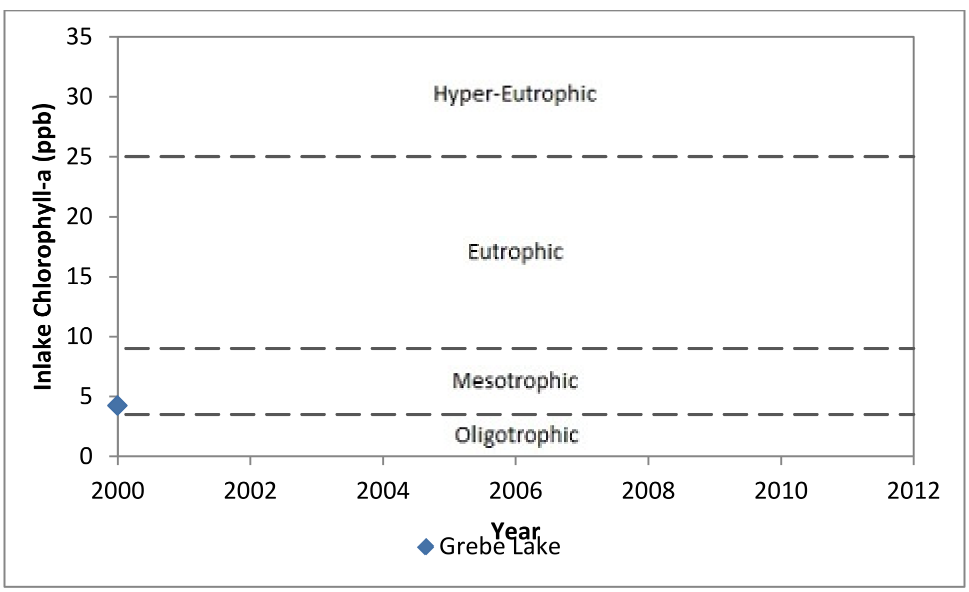

Figure 3.55: Inlake chlorophyll-a over time for Grebe Lake

Figure 3.55 shows the average total inlake chlorophyll-a concentrations over time for Grebe Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake chlorophyll-a concentrations. The one value falls under the slightly mesotrophic classification based on the chlorophyll-a model.

3.15 **Grizzly Lake**

Samples for Grizzly Lake were collected in the year 2010. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

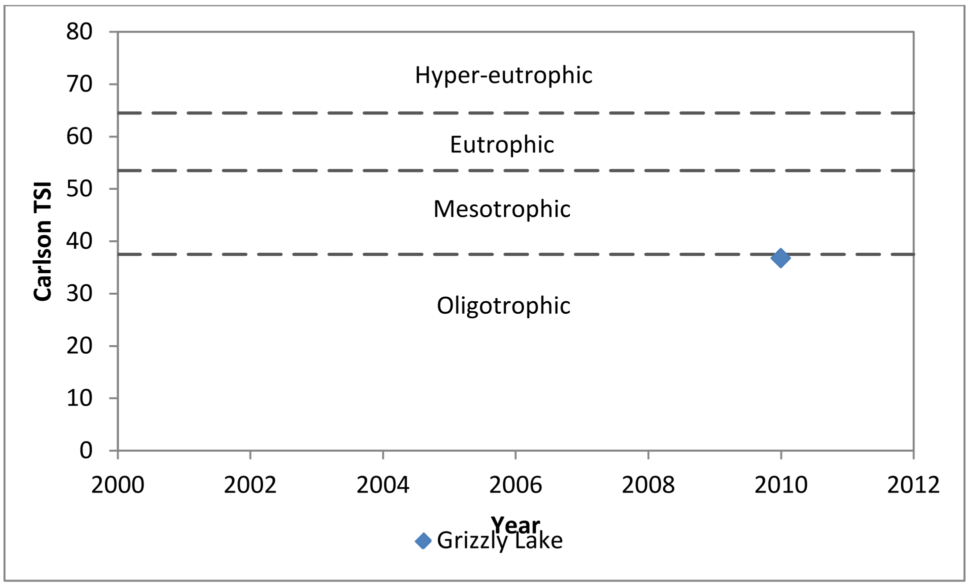

Figure 3.56: Carlson TSI over time for Grizzly Lake

Figure 3.56 depicts the Carlson TSI values over time for Grizzly Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the slightly oligotrophic classification based on the Carlson Model.

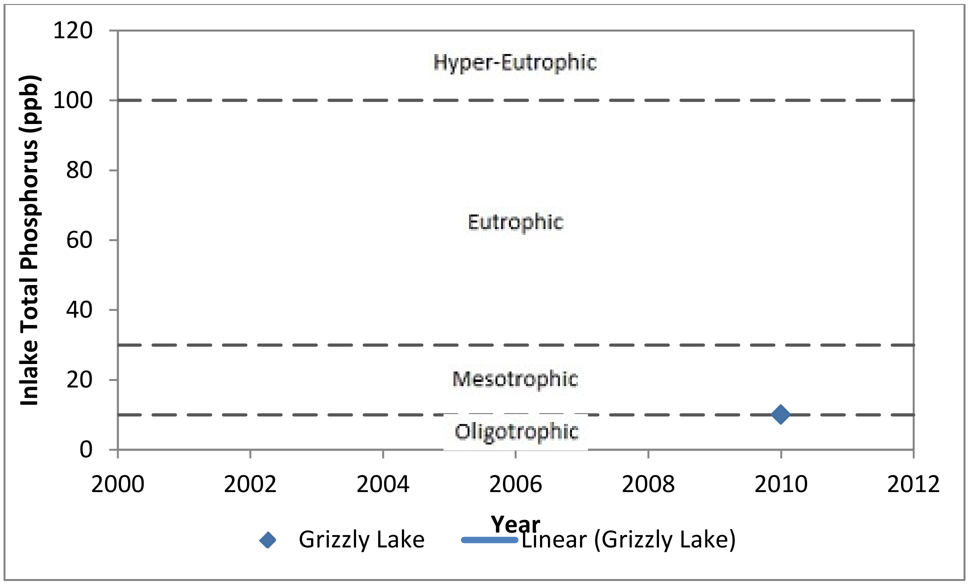

Figure 3.57: Inlake total phosphorus over time for Grizzly Lake

Figure 3.57 shows the average total inlake phosphorus concentrations over time for Grizzly Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake phosphorus concentrations. The one TP value falls under the slightly mesotrophic classification based on the TP Model.

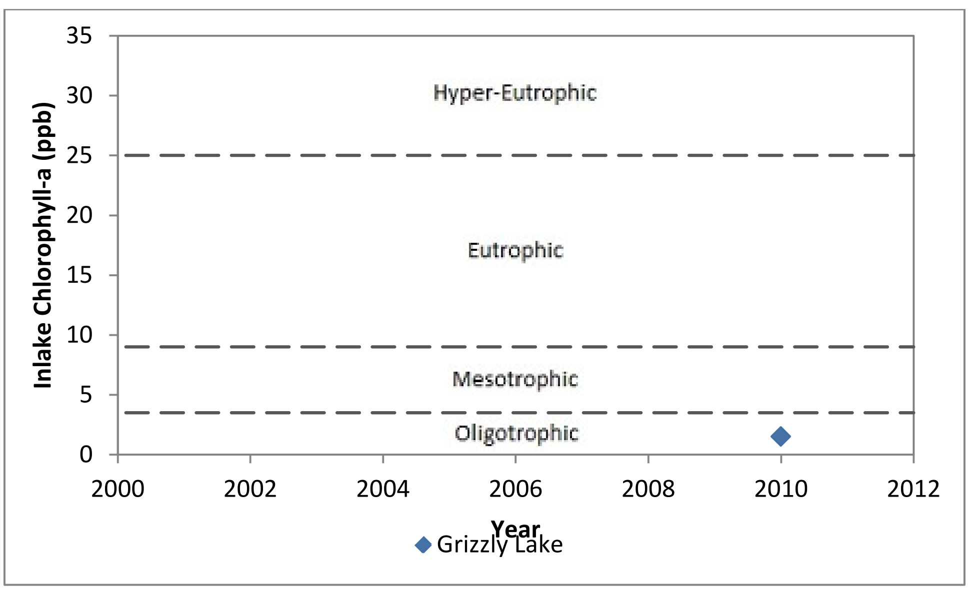

Figure 3.58: Inlake chlorophyll-a over time for Grizzly Lake

Figure 3.58 shows the average total inlake chlorophyll-a concentrations over time for Grizzly Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake chlorophyll-a concentrations. The one value falls under the oligotrophic classification based on the chlorophyll-a model.

3.16 **Harlequin Lake**

Samples for Harlequin Lake were collected in 2001-2003, and 2007-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

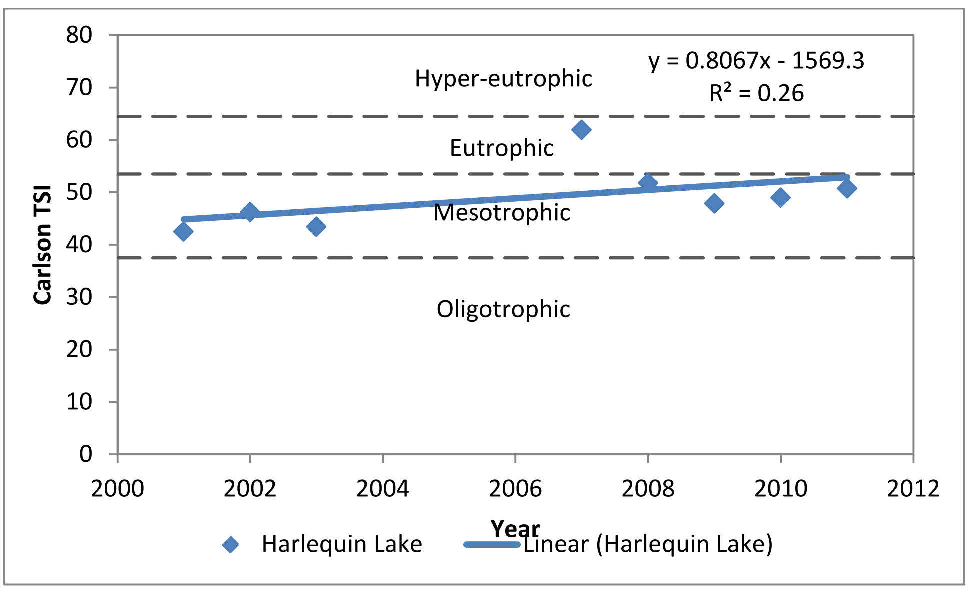

Figure 3.59: Carlson TSI over time for Harlequin Lake

Figure 3.59 depicts the Carlson TSI values over time for Harlequin Lake. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.26. The TSI values vary in the range of slightly mesotrophic and strongly eutrophic classification.

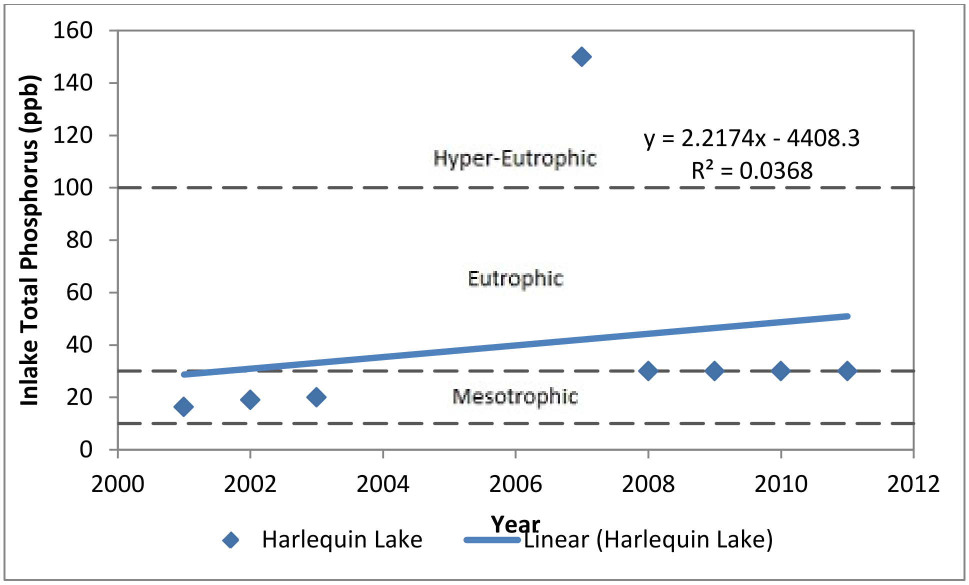

Figure 3.60: Inlake total phosphorus over time for Harlequin Lake

Figure 3.60 shows the average total inlake phosphorus concentrations over time for Harlequin Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.0368. The phosphorus concentrations vary in the range of slightly mesotrophic to hyper-eutrophic.

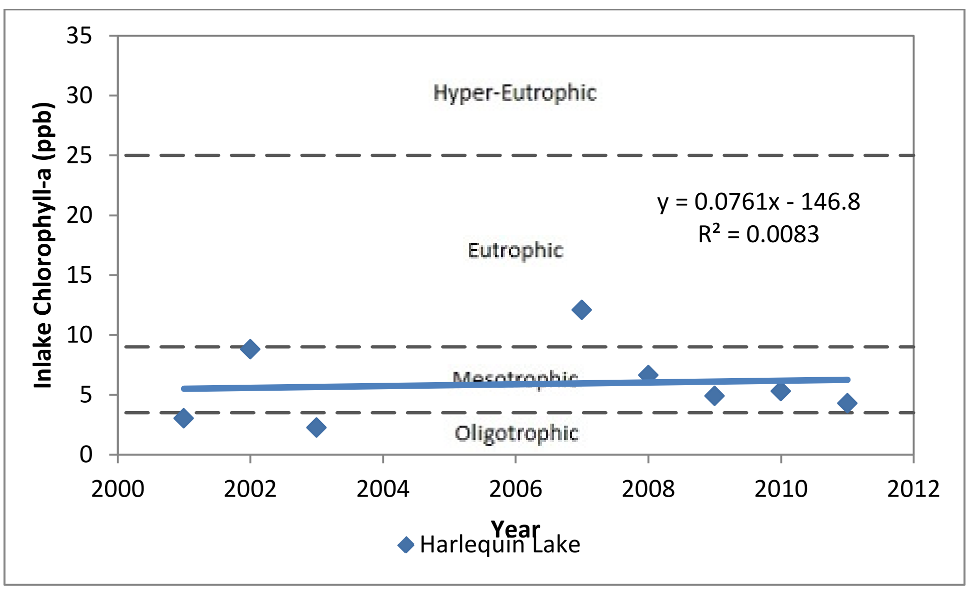

Figure 3.61: Inlake chlorophyll-a over time for Harlequin Lake

Figure 3.61 shows the average total inlake chlorophyll-a concentrations over time for Harlequin Lake. These values depict a slight increase in inlake chlorophyll-a with a weak correlation coefficient of 0.0083. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to slightly eutrophic.

3.17 **Hazle Lake**

Samples for Hazle Lake were collected in 2001, and 2010-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

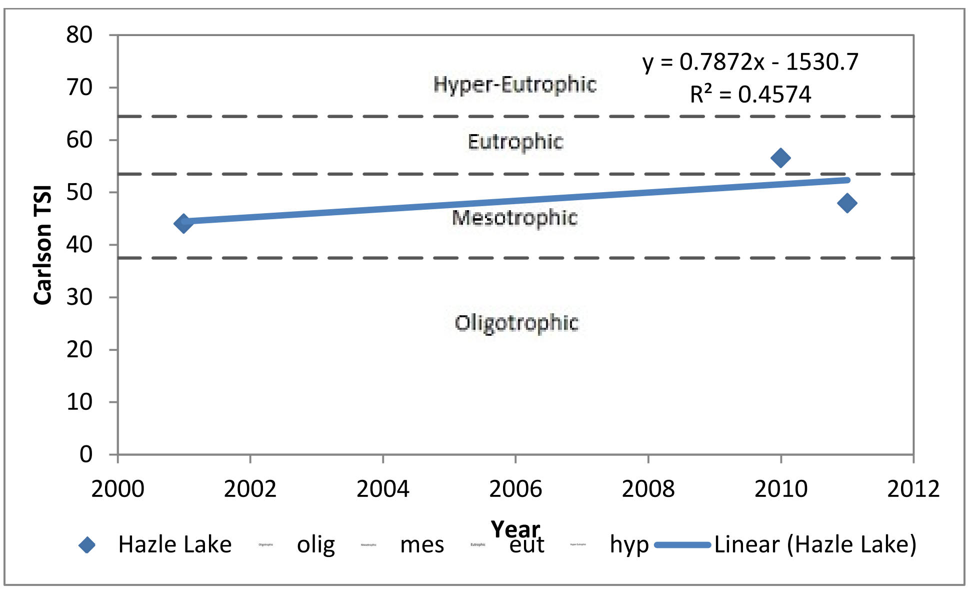

Figure 3.62: Carlson TSI over time for Hazle Lake

Figure 3.62 depicts the Carlson TSI values over time for Hazle Lake. The figure depicts a slight increase in TSI values over time with an average in strength correlation coefficient of 0.4574. The TSI values vary in the range of mesotrophic and slightly eutrophic classification.

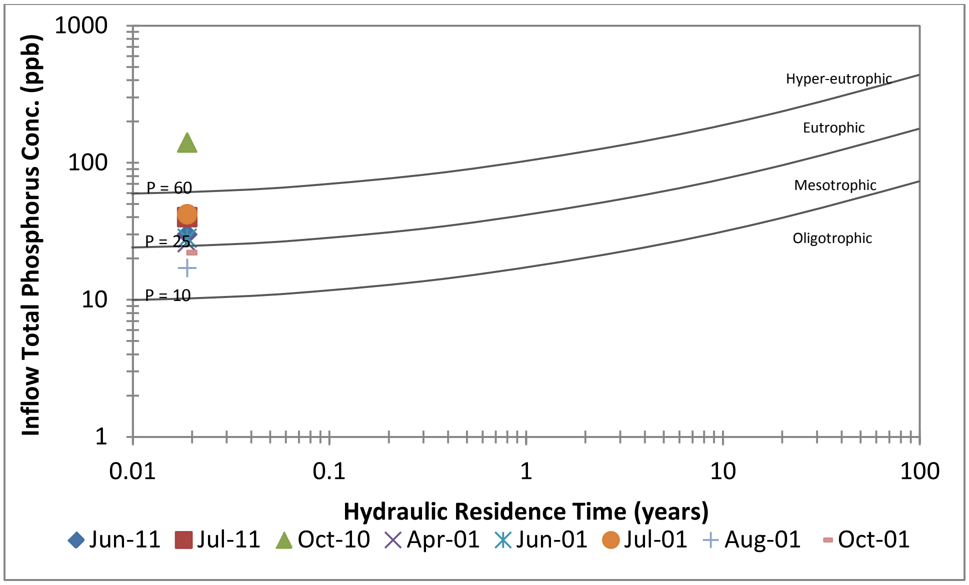

Figure 3.63: Vollenweider Model over time for Hazle Lake

Figure 3.63 depicts the results of the Vollenweider Model over time for Hazle Lake. The total phosphorus vs. hydraulic residence time data points range from mesotrophic in August 2001 to hyper-eutrophic in October 2010.

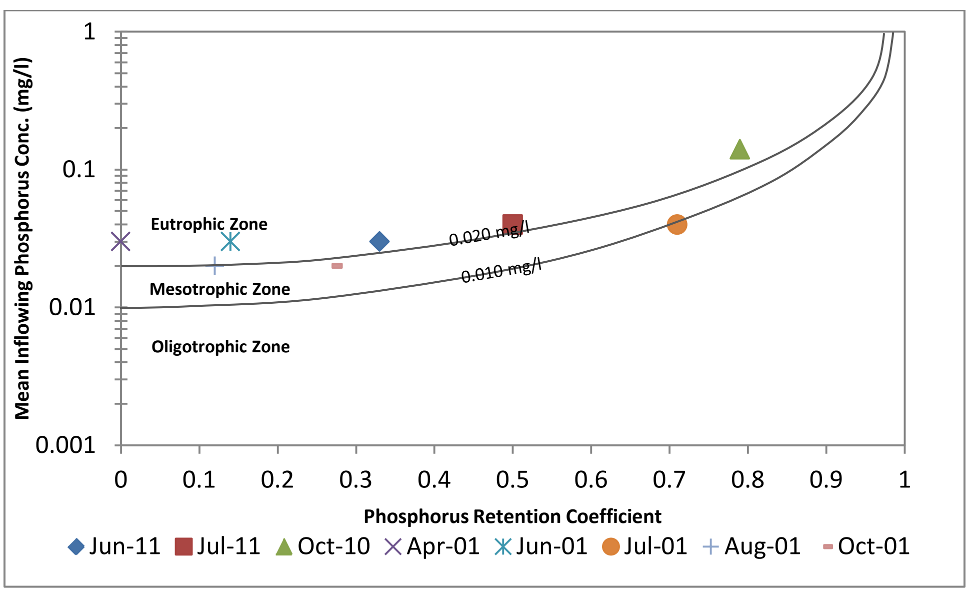

Figure 3.64: Larsen Mercier Model over time for Hazle Lake

Figure 3.64 shows the results of the Larsen Mercier Model over time for Hazle Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in July 2001 to eutrophic in June 2001. The majority of the data points are in the range of strongly mesotrophic to eutrophic.

Figure 3.65 shows the average total inlake phosphorus concentrations over time for Hazle Lake. These values depict an increase in inlake phosphorus with a weak correlation coefficient of 0.1806. The phosphorus concentrations vary in the range of mesotrophic to hyper-eutrophic.

Figure 3.66 shows the average total inlake chlorophyll-a concentrations over time for Hazle Lake. These values depict an increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.3604. The chlorophyll-a concentrations vary in the range of oligotrophic to hyper-eutrophic.

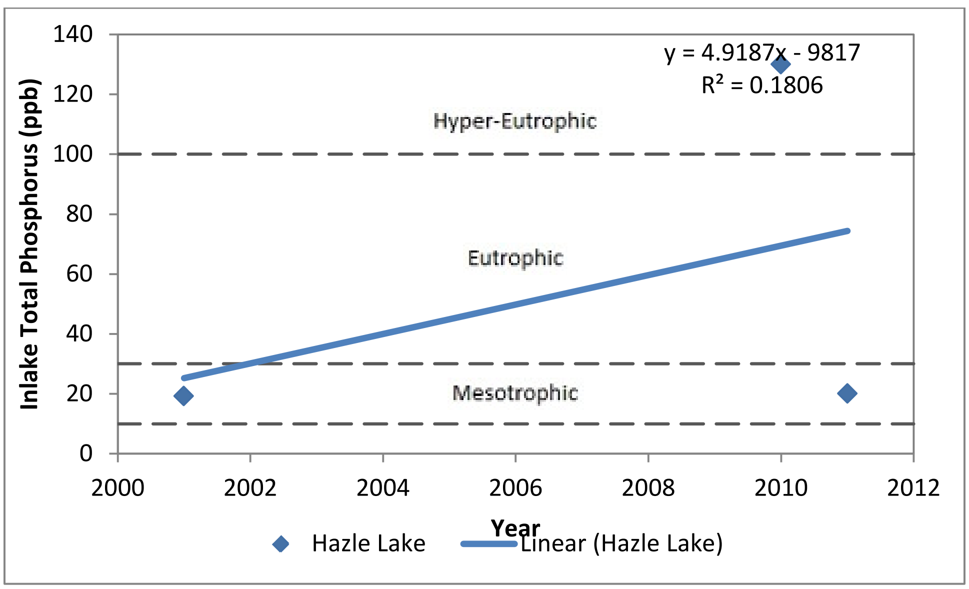

Figure 3.65: Inlake total phosphorus over time for Hazle Lake

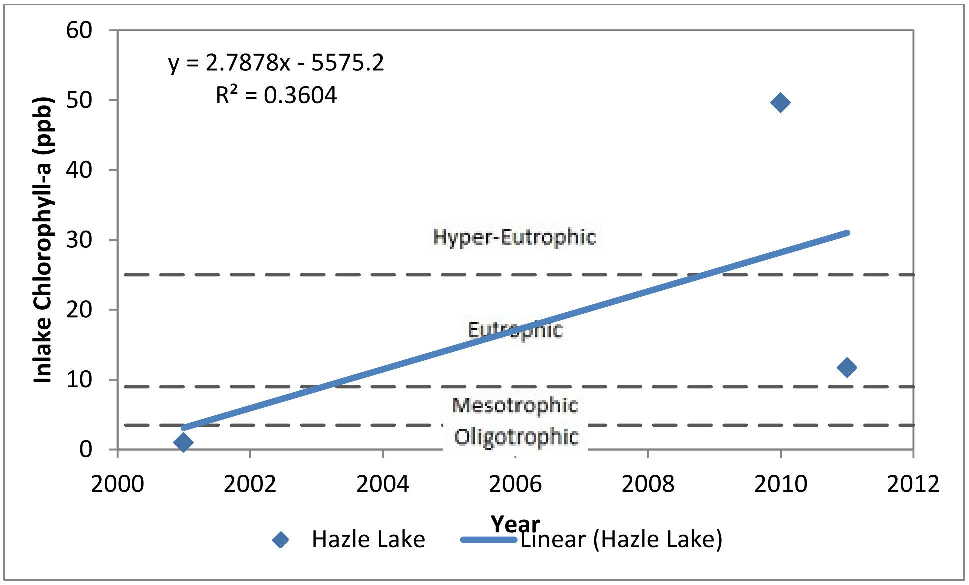

Figure 3.66: Inlake chlorophyll-a over time for Hazle Lake

3.18 **Heart Lake**

Samples for Heart Lake were collected in the year 1999. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.67 depicts the Carlson TSI values over time for Heart Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the slightly oligotrophic classification based on the Carlson Model.

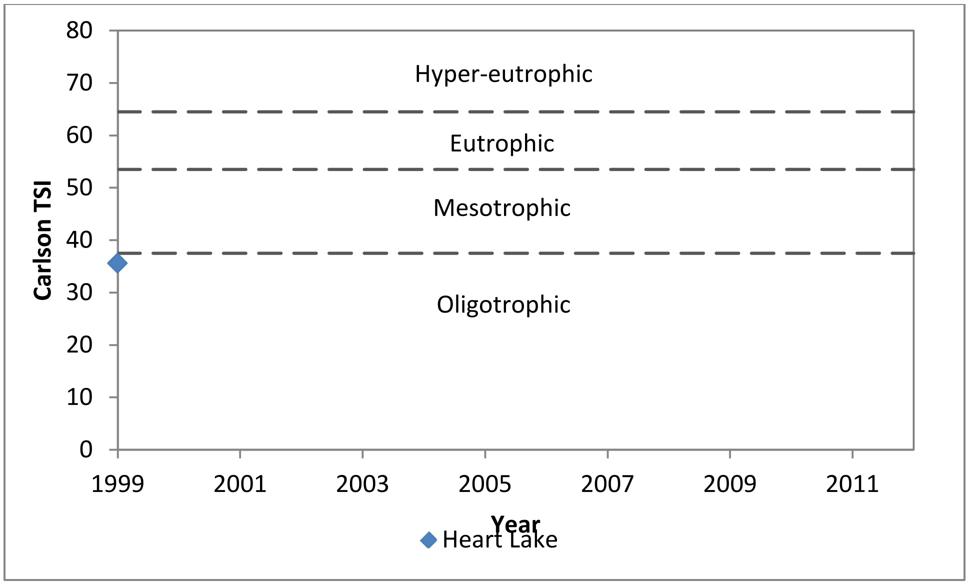

Figure 3.67: Carlson TSI over time for Heart Lake

Figure 3.68 depicts the results of the Vollenweider Model over time for Heart Lake. The two data points for total phosphorus vs. hydraulic residence time fall in the slightly oligotrophic classification in July 1999 and slightly mesotrophic in August 1999.

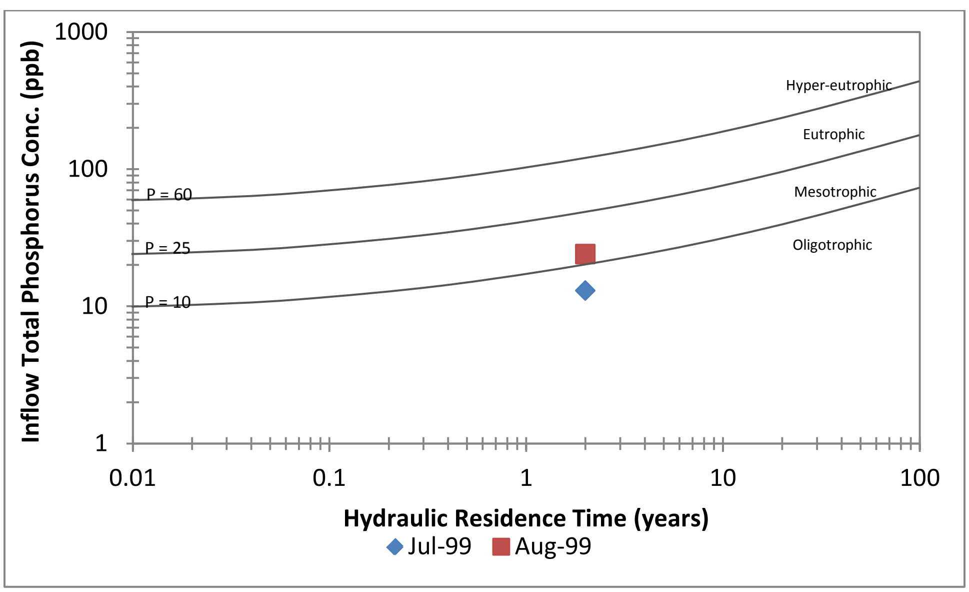

Figure 3.68: Vollenweider Model over time for Heart Lake

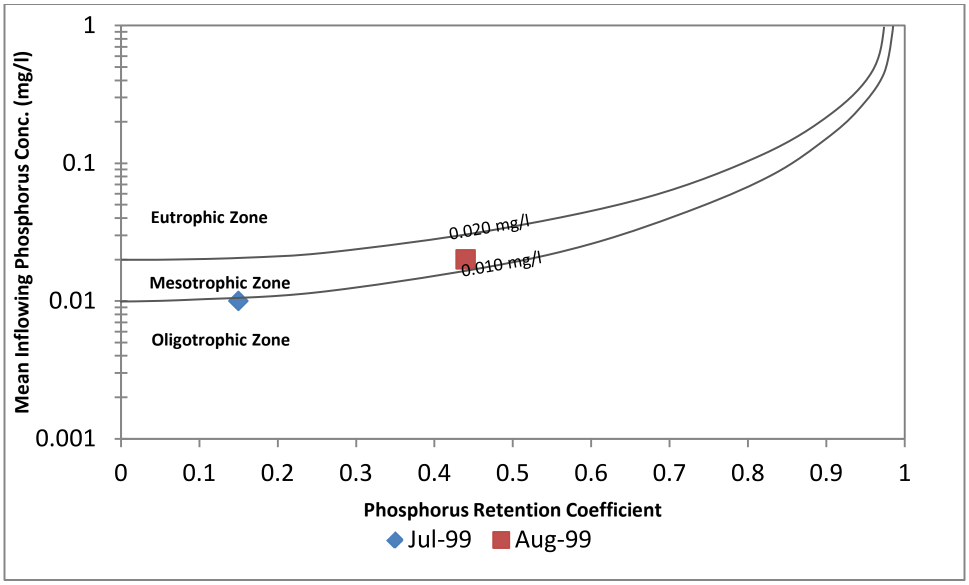

Figure 3.69: Larsen Mercier Model over time for Heart Lake

Figure 3.69 shows the results of the Larsen Mercier Model over time for Heart Lake. The two data points for total phosphorus vs. phosphorus retention coefficient fall in the slightly oligotrophic classification in July 1999 and mesotrophic in August 1999.

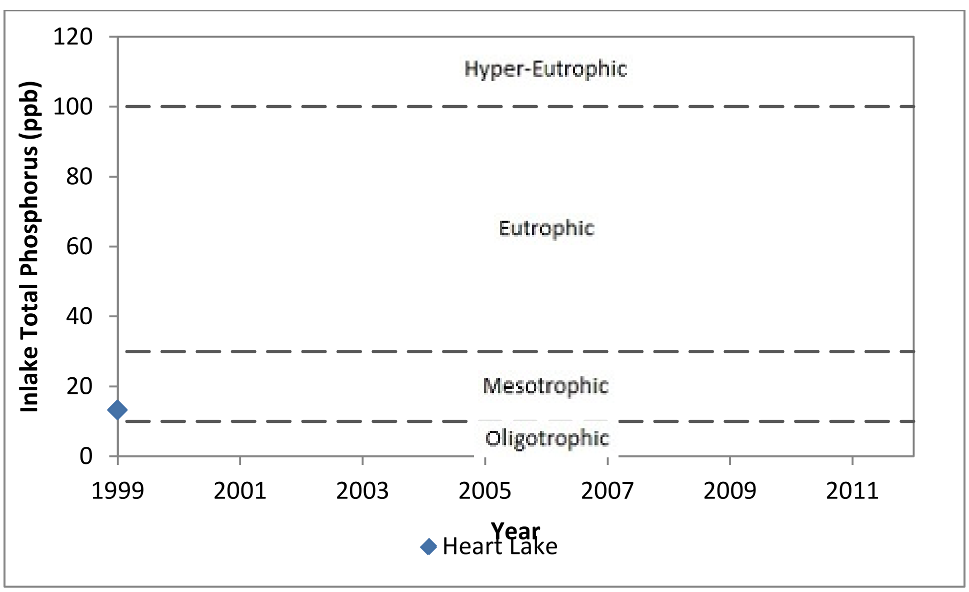

Figure 3.70: Inlake total phosphorus over time for Heart Lake

Figure 3.70 shows the average total inlake phosphorus concentrations over time for Heart Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake phosphorus concentrations. The one TP value falls under the slightly mesotrophic classification based on the TP Model.

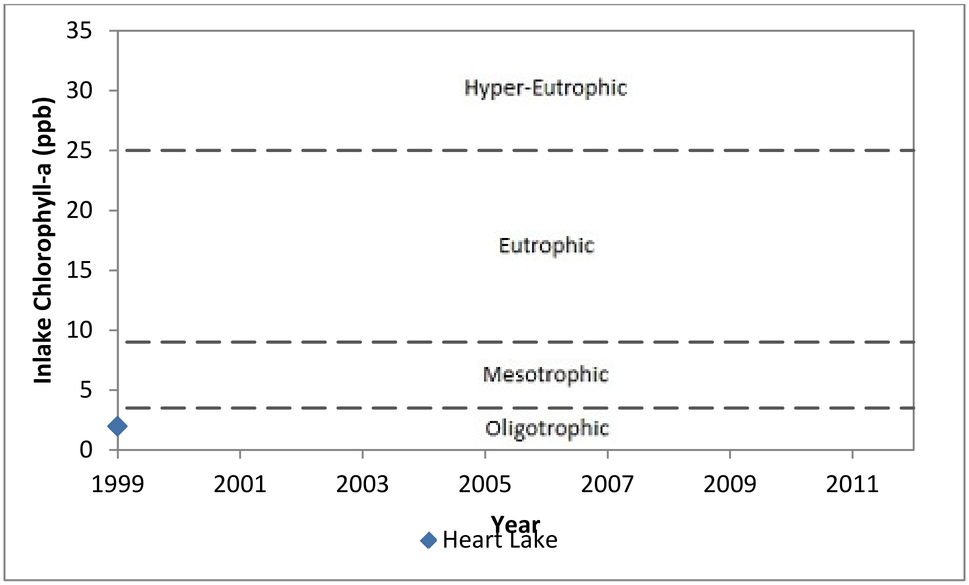

Figure 3.71: Inlake chlorophyll-a over time for Heart Lake

Figure 3.71 shows the average total inlake chlorophyll-a concentrations over time for Heart Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake chlorophyll-a concentrations. The one value falls under the oligotrophic classification based on the chlorophyll-a model.

3.19 **Hot Beach Pond**

Samples for Hot Beach Pond were collected in 2004, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

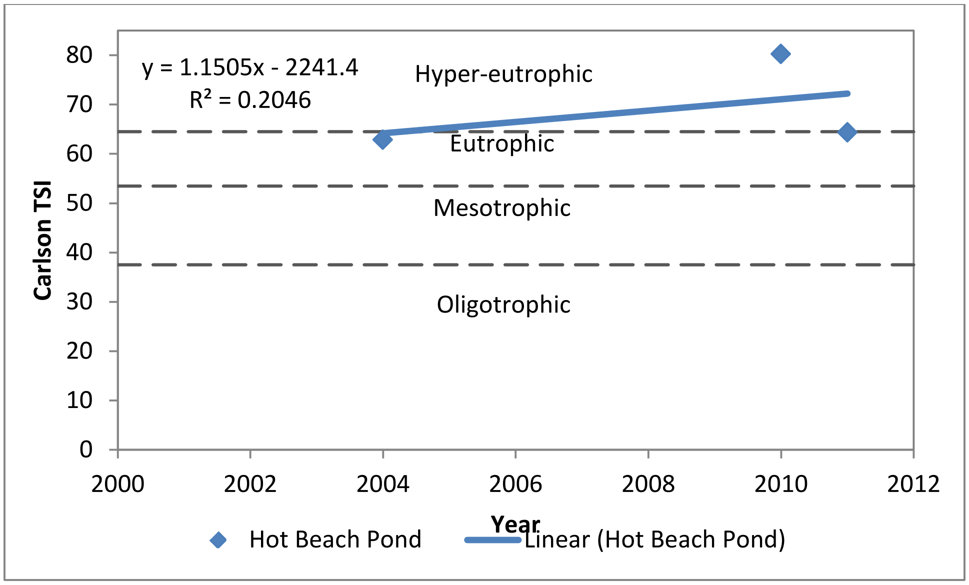

Figure 3.72: Carlson TSI over time for Hot Beach Pond

Figure 3.72 depicts the Carlson TSI values over time for Hot Beach Pond. The figure depicts an increase in TSI values over time with a relatively weak correlation coefficient of 0.2046. The TSI values vary in the range of strongly eutrophic and hyper-eutrophic classification.

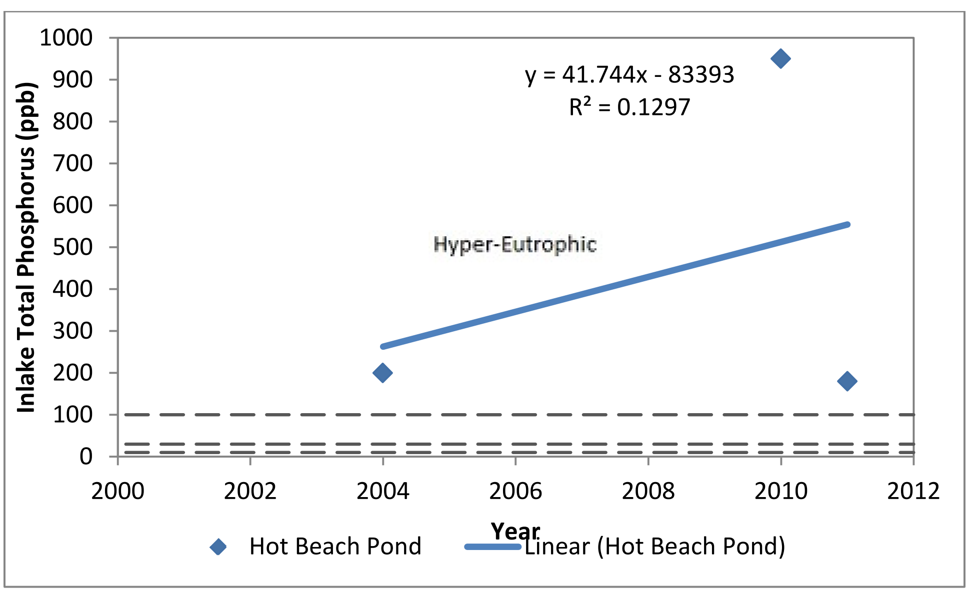

Figure 3.73: Inlake total phosphorus over time for Hot Beach Pond

Figure 3.73 shows the average total inlake phosphorus concentrations over time for Hot Beach Pond. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.1297. The phosphorus concentrations all fall in the hyper-eutrophic classification based on the TP Model.

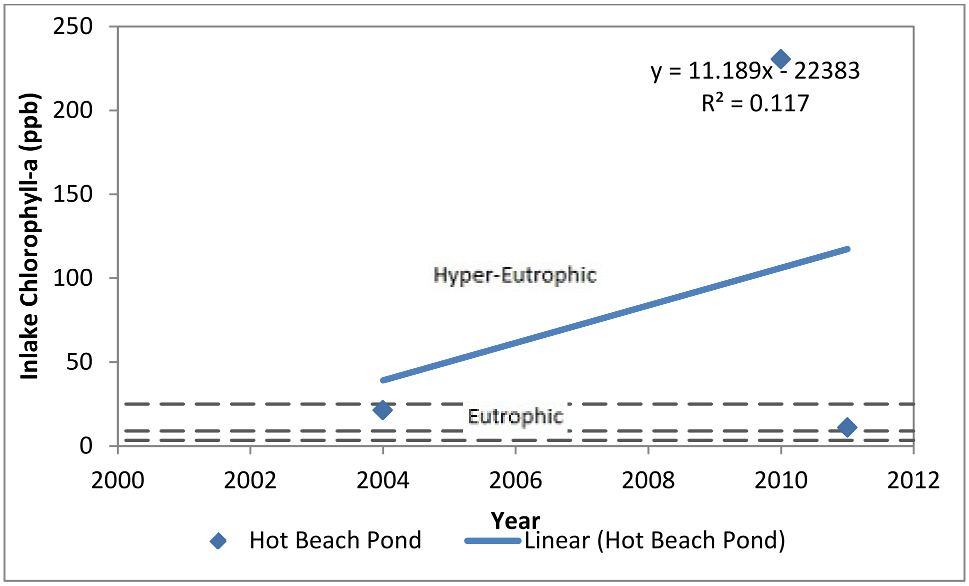

Figure 3.74: Inlake chlorophyll-a over time for Hot Beach Pond

Figure 3.74 shows the average total inlake chlorophyll-a concentrations over time for Hot Beach Pond. These values depict an increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.117. The chlorophyll-a concentrations vary in the range of slightly eutrophic to hyper-eutrophic.

3.20 **Hot Lake**

Samples for Hot Lake were collected in 2001, and 2010. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

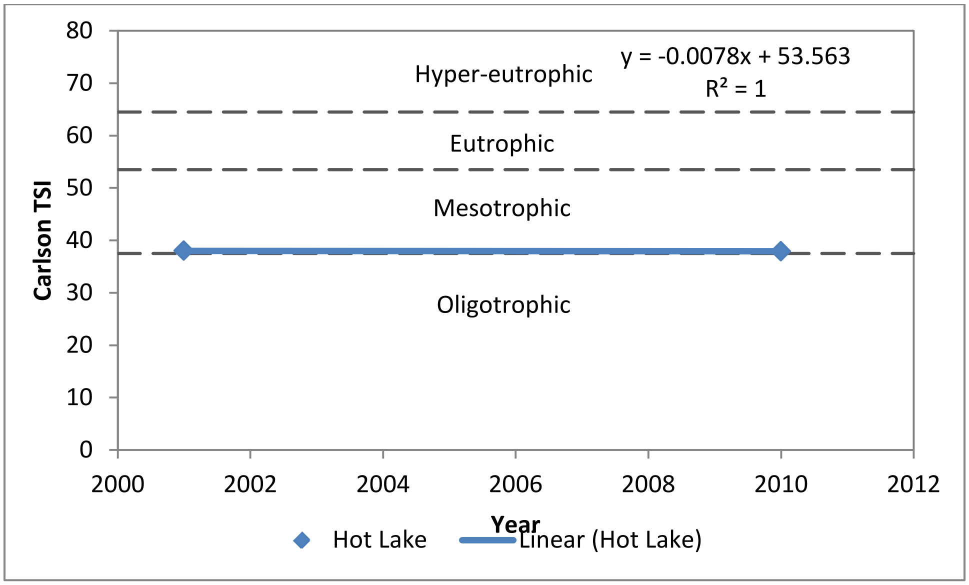

Figure 3.75: Carlson TSI over time for Hot Lake

Figure 3.75 depicts the Carlson TSI values over time for Hot Lake. The figure depicts a slight decrease in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as both slightly mesotrophic.

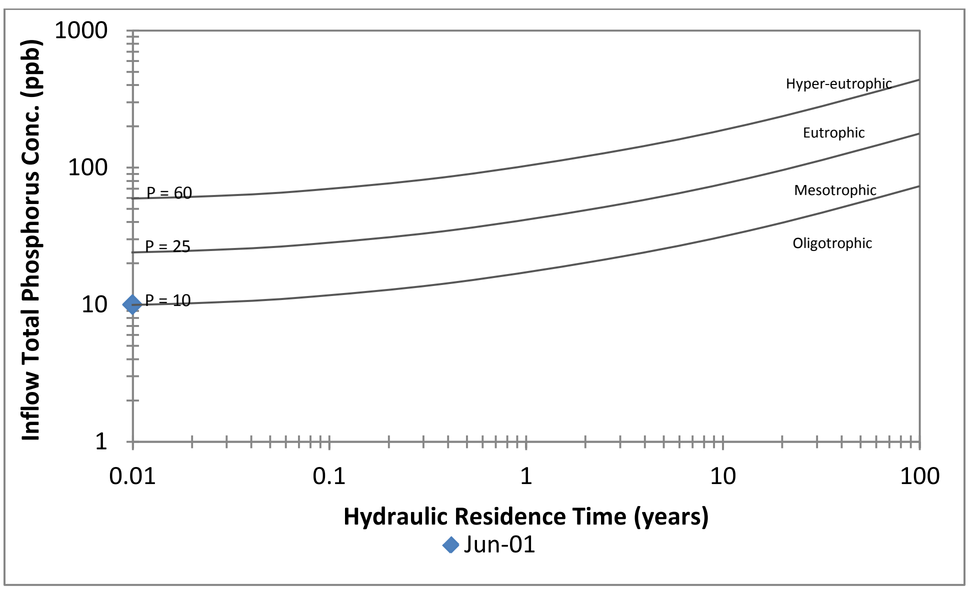

Figure 3.76: Vollenweider Model over time for Hot Lake

Figure 3.76 depicts the results of the Vollenweider Model over time for Hot Lake. Only one total phosphorus vs. hydraulic residence time data point was calculated in June 2001 and it falls under the slightly mesotrophic classification.

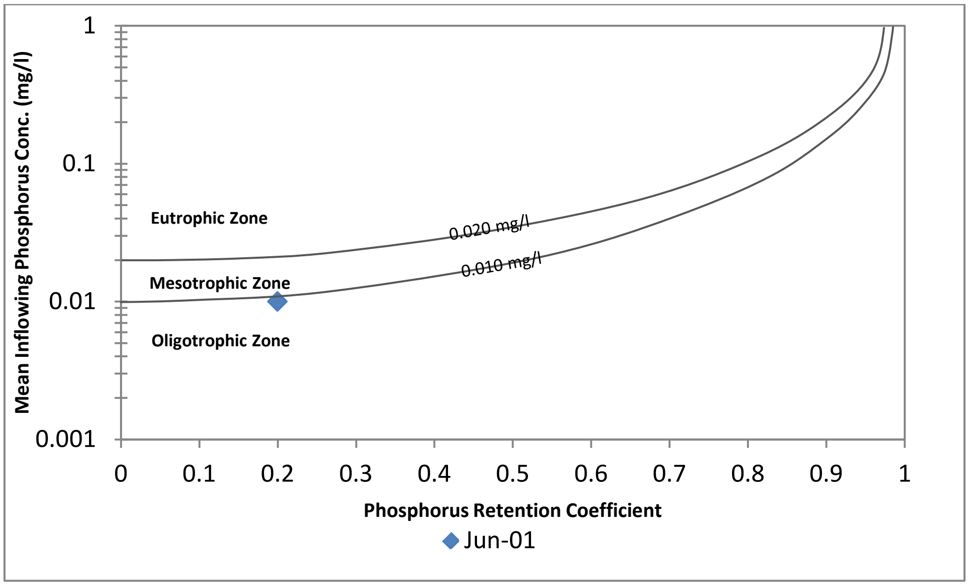

Figure 3.77: Larsen Mercier Model over time for Hot Lake

Figure 3.77 shows the results of the Larsen Mercier Model over time for Hot Lake. Only one total inlake phosphorus vs. phosphorus retention coefficient data point was calculated in June 2001 and it falls under the slightly oligotrophic classification.

Figure 3.78 shows the average total inlake phosphorus concentrations over time for Hot Lake. These values depict an increase in inlake phosphorus. As only two data points were collected, a correlation is difficult to determine. The TP values were classified as slightly oligotrophic and strongly mesotrophic.

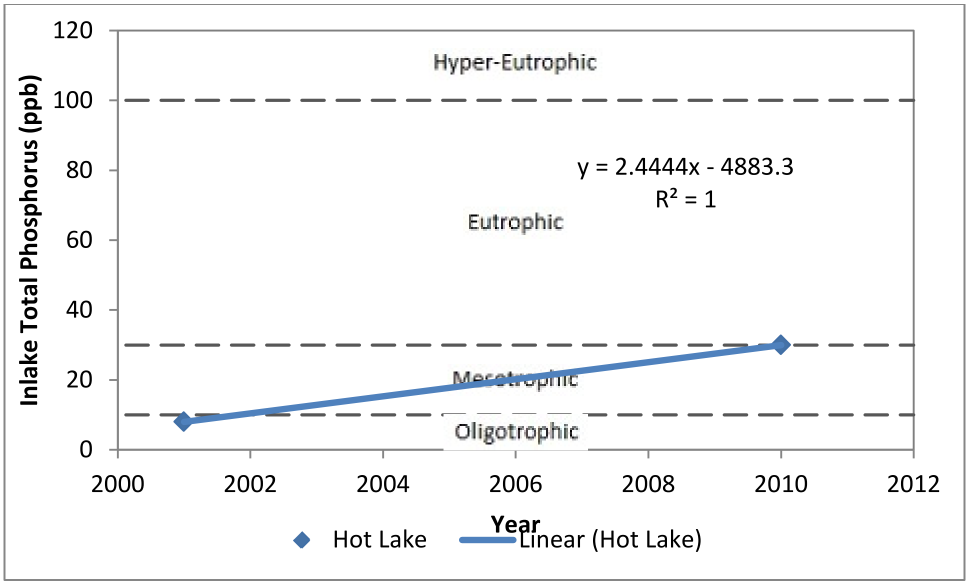

Figure 3.78: Inlake total phosphorus over time for Hot Lake

Figure 3.79 shows the average total inlake chlorophyll-a concentrations over time for Hot Lake. These values depict a slight increase in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The chlorophyll-a values were classified as both oligotrophic.

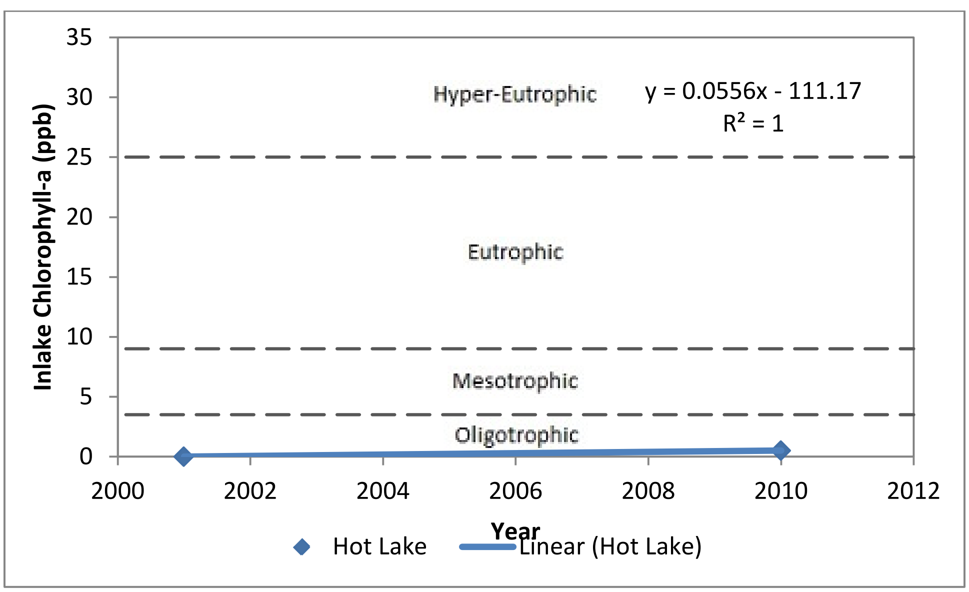

Figure 3.79: Inlake chlorophyll-a over time for Hot Lake

3.21 **Ice Lake**

Samples for Ice Lake were collected in 2000, and 2009-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.80 depicts the Carlson TSI values over time for Ice Lake. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.0498. The TSI values vary in the range of slightly oligotrophic to slightly mesotrophic classification.

Figure 3.81 depicts the results of the Vollenweider Model over time for Ice Lake. The total phosphorus vs. hydraulic residence time data points range from slightly mesotrophic in October 2000 to slightly eutrophic in July 2009.

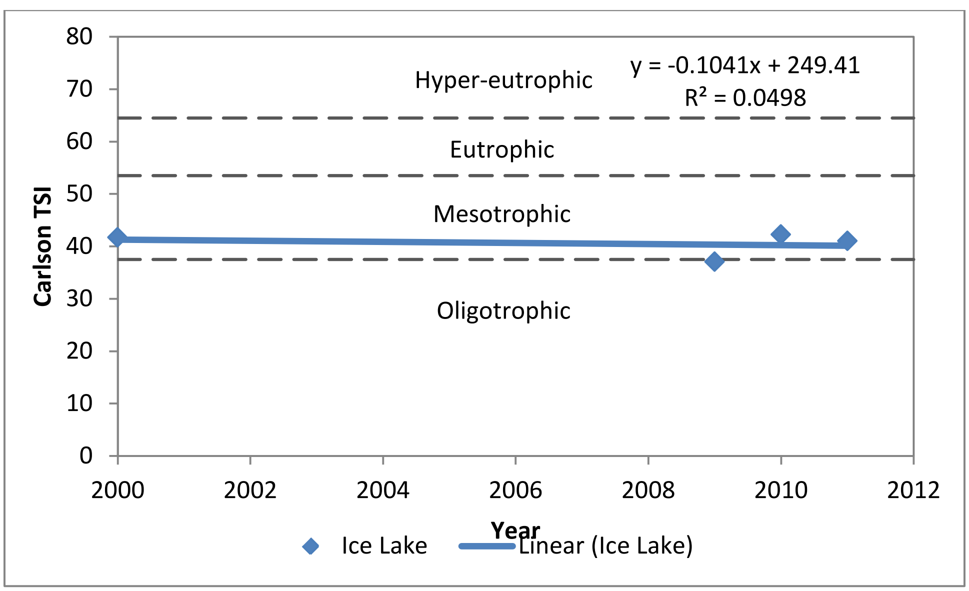

Figure 3.80: Carlson TSI over time for Ice Lake

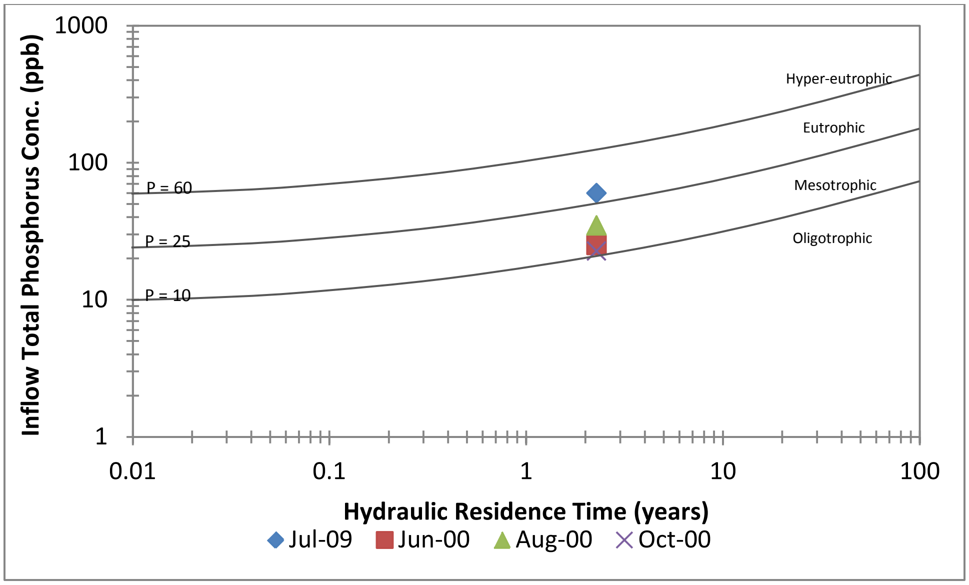

Figure 3.81: Vollenweider Model over time for Ice Lake

Figure 3.82 shows the results of the Larsen Mercier Model over time for Ice Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in July 2009 to eutrophic in August 2000.

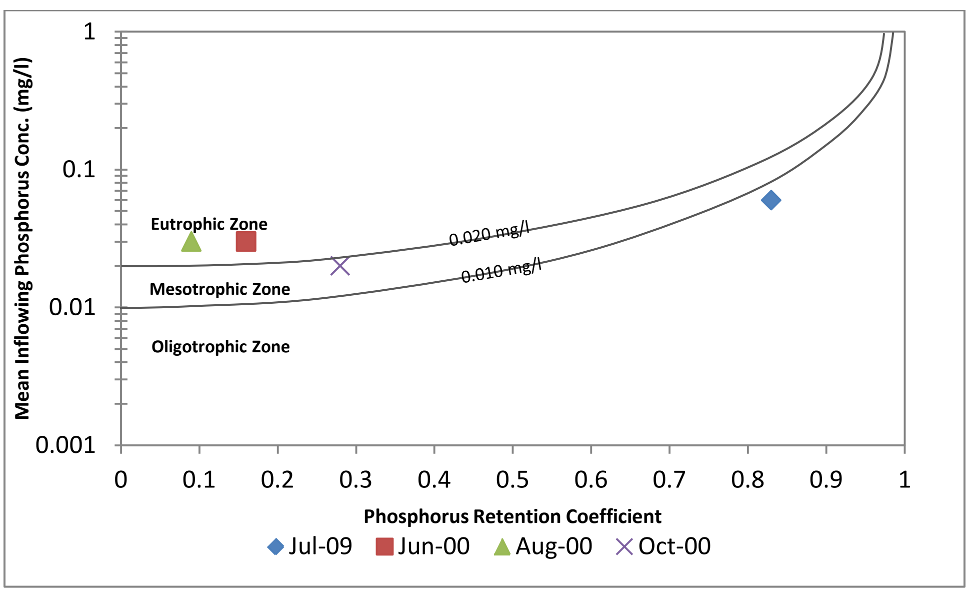

Figure 3.82: Larsen Mercier Model over time for Ice Lake

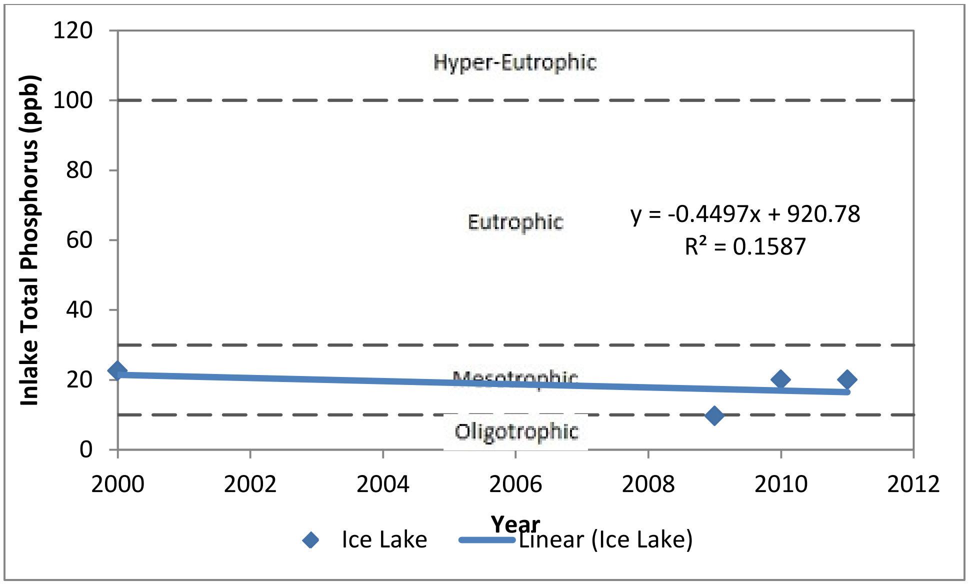

Figure 3.83: Inlake total phosphorus over time for Ice Lake

Figure 3.83 shows the average total inlake phosphorus concentrations over time for Ice Lake. These values depict a slight decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.1587. The phosphorus concentrations vary in the range of slightly oligotrophic to mesotrophic.

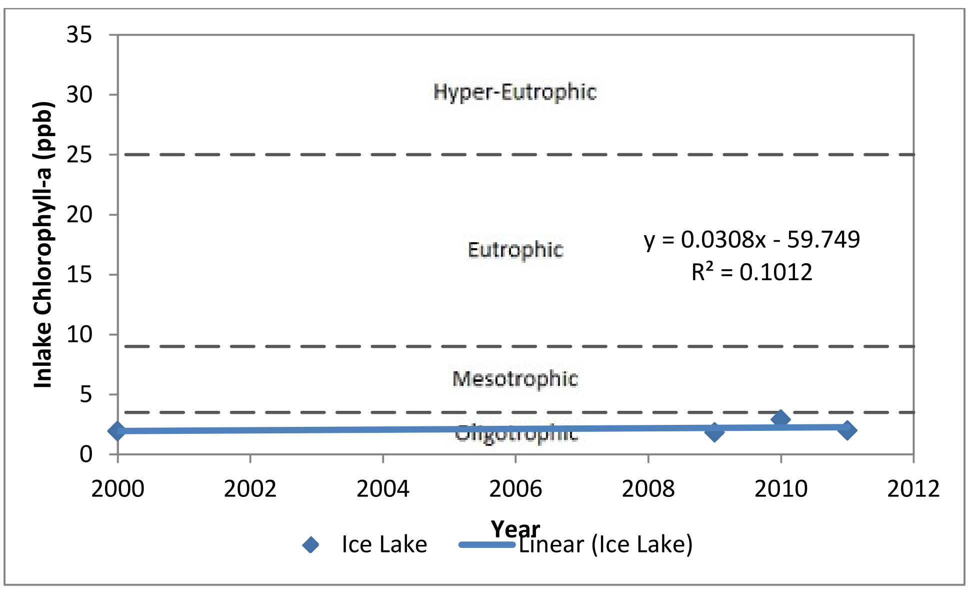

Figure 3.84: Inlake chlorophyll-a over time for Ice Lake

Figure 3.84 shows the average total inlake chlorophyll-a concentrations over time for Ice Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.1012. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly oligotrophic.

3.22 **Indian Pond**

Samples for Indian Pond were collected in 2004-2006, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.85 depicts the Carlson TSI values over time for Indian Pond. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.0812. The TSI values vary in the range of eutrophic and strongly eutrophic.

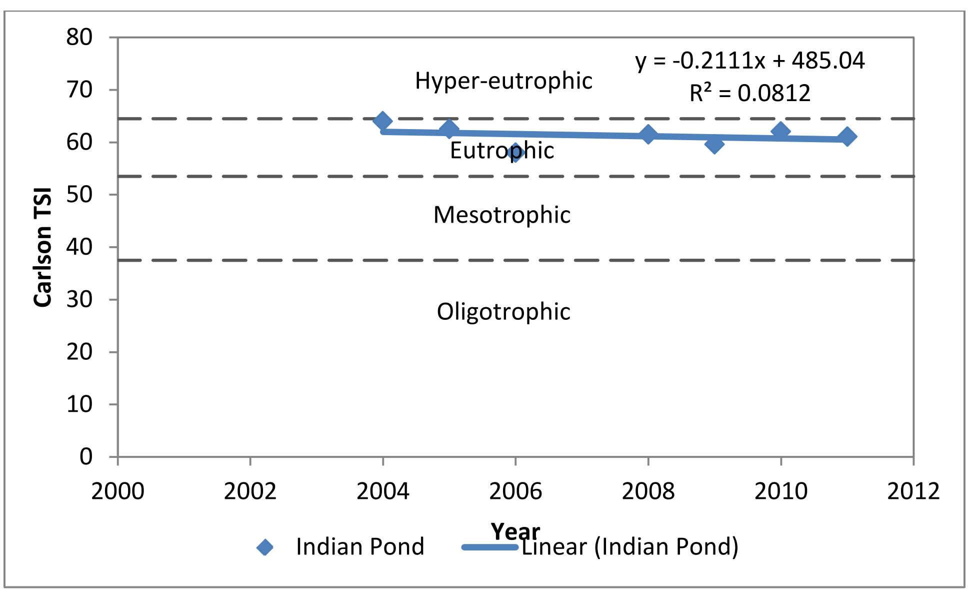

Figure 3.85: Carlson TSI over time for Indian Pond

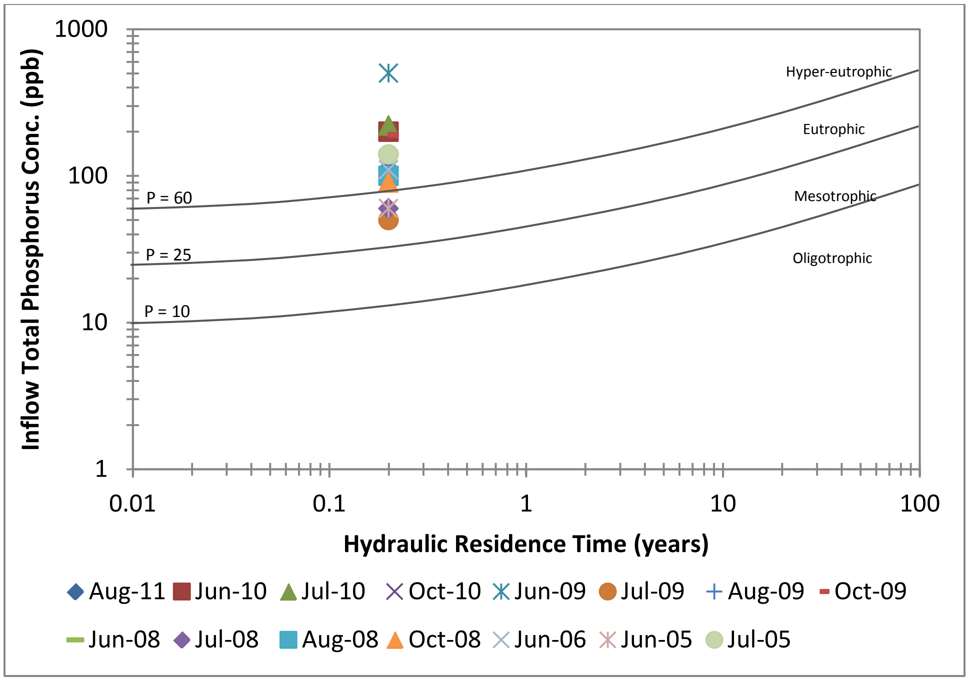

Figure 3.86: Vollenweider Model over time for Indian Pond

Figure 3.86 depicts the results of the Vollenweider Model over time for Indian Pond. The total phosphorus vs. hydraulic residence time data points range from eutrophic in July 2009 to hyper-eutrophic in June 2009.

Figure 3.87 shows the results of the Larsen Mercier Model over time for Indian Pond. The total inlet phosphorus vs. phosphorus retention coefficient data points range from strongly eutrophic in July 2009 to hyper-eutrophic in July 2010.

Figure 3.88 shows the average total inlake phosphorus concentrations over time for Indian Pond. These values depict a decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.2632. All the phosphorus concentrations fall under the hyper-eutrophic classification.

Figure 3.89 shows the average total inlake chlorophyll-a concentrations over time for Indian Pond. These values depict a decrease in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0736. The chlorophyll-a concentrations vary in the range of oligotrophic to eutrophic.

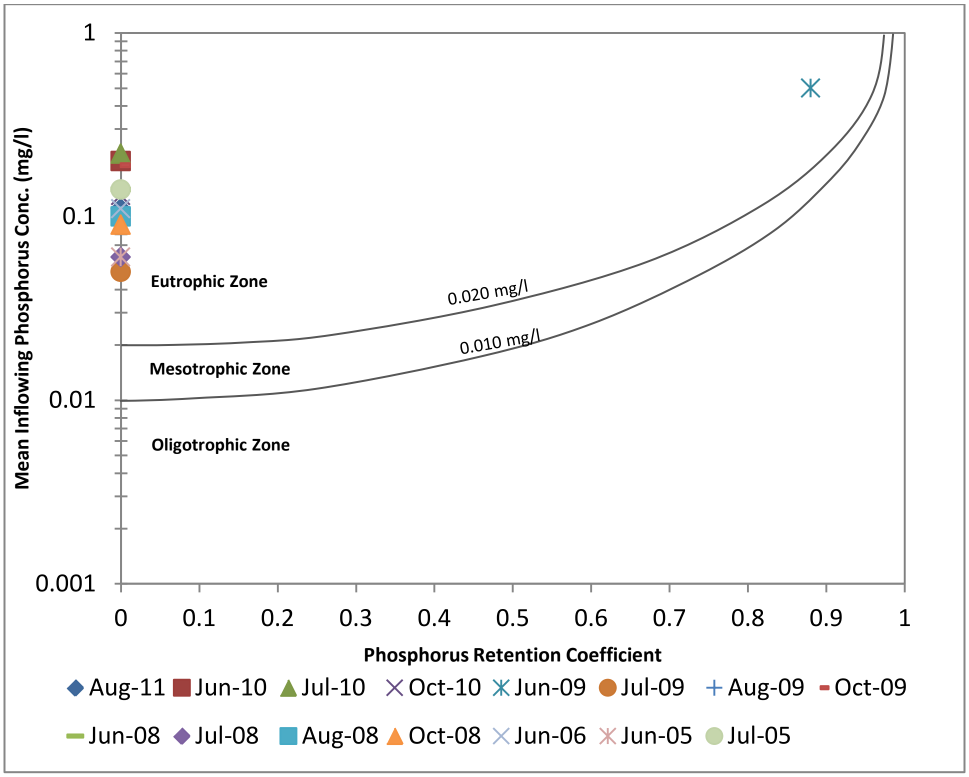

Figure 3.87: Larsen Mercier Model over time for Indian Pond

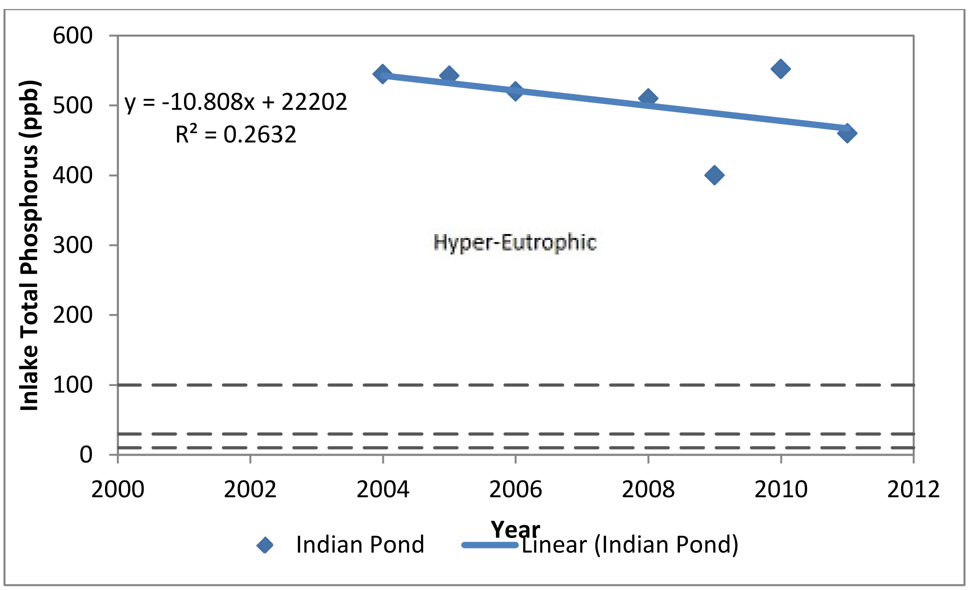

Figure 3.88: Inlake total phosphorus over time for Indian Pond

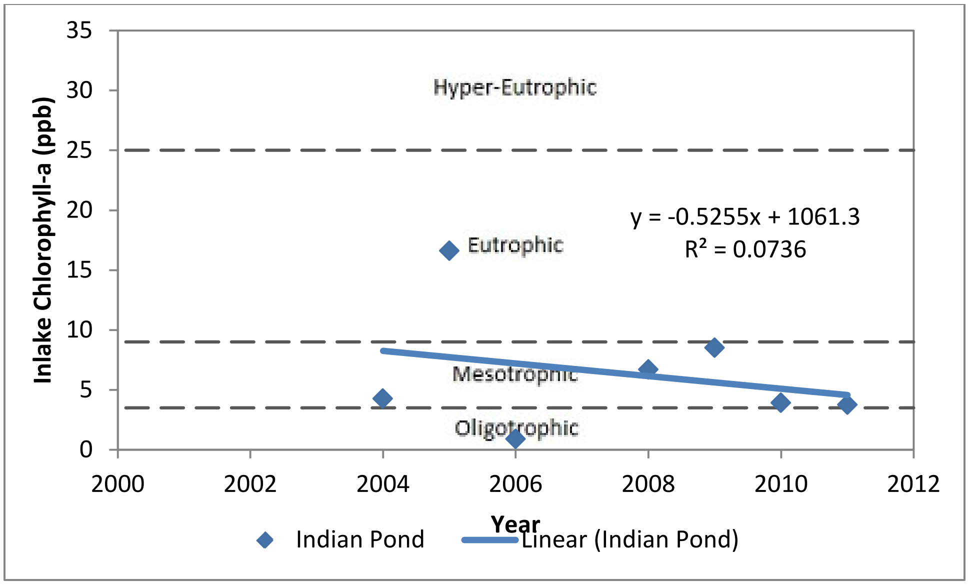

Figure 3.89: Inlake chlorophyll-a over time for Indian Pond

3.23 **Isa Lake**

Samples for Isa Lake were collected in 1999, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

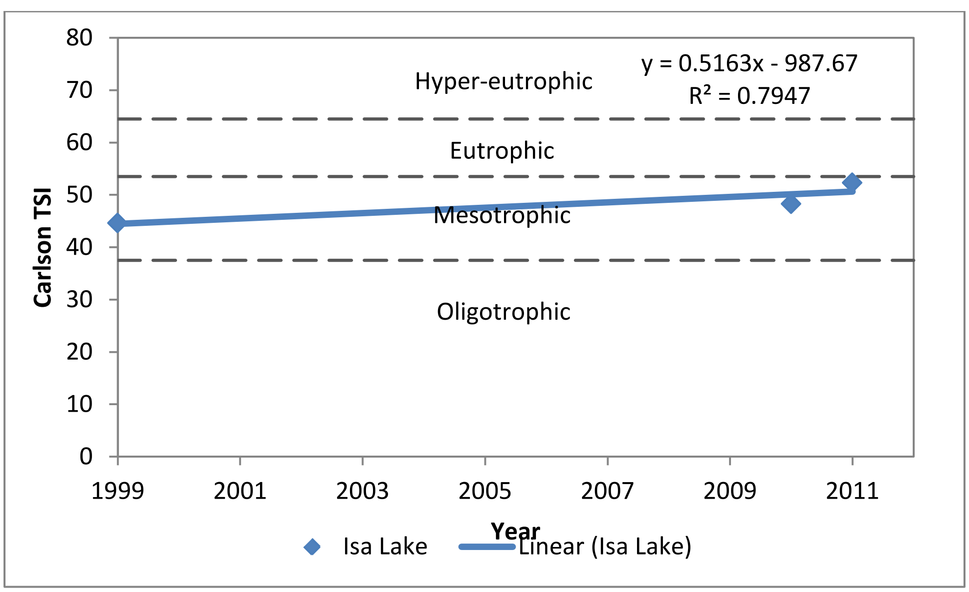

Figure 3.90: Carlson TSI over time for Isa Lake

Figure 3.90 depicts the Carlson TSI values over time for Isa Lake. The figure depicts a slight increase in TSI values over time with a relatively strong correlation coefficient of 0.7947. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

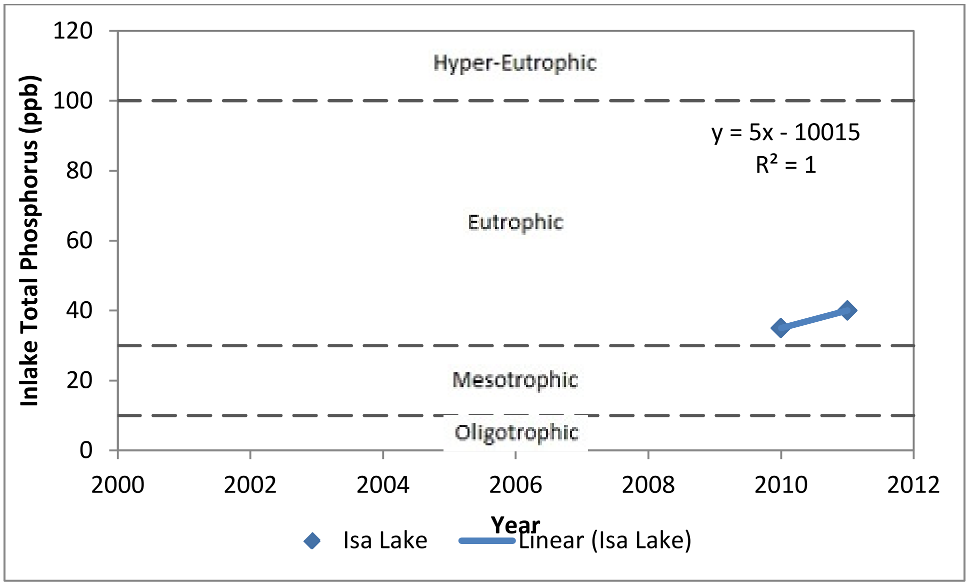

Figure 3.91: Inlake total phosphorus over time for Isa Lake

Figure 3.91 shows the average total inlake phosphorus concentrations over time for Isa Lake. These values depict an increase in inlake phosphorus. As only two data points exist for the years sampled, a correlation is difficult to determine. Both phosphorus concentrations fall under the slightly eutrophic classification.

Figure 3.92 shows the average total inlake chlorophyll-a concentrations over time for Isa Lake. These values depict a slight decrease in inlake chlorophyll-a with an average in strength correlation coefficient of 0.5403. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to slightly mesotrophic.

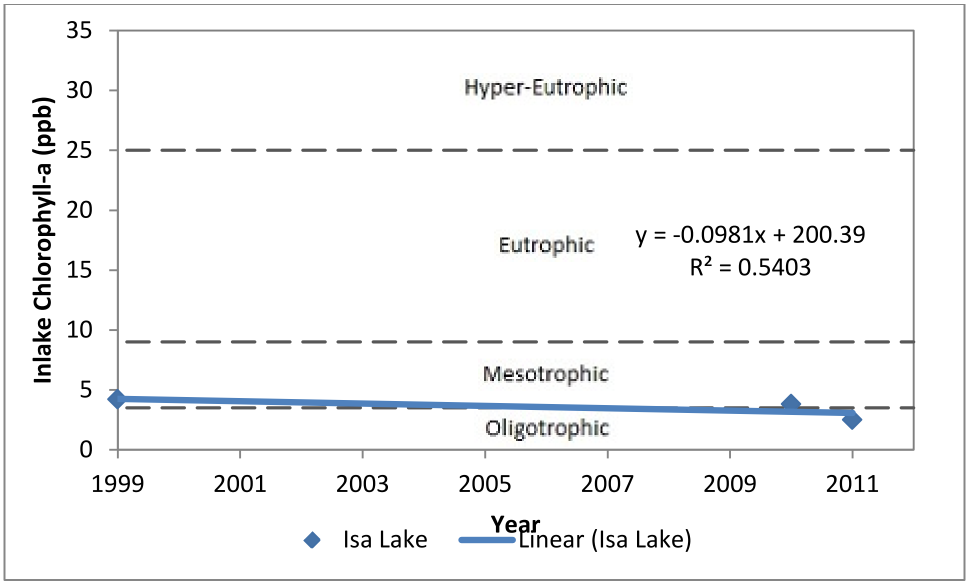

Figure 3.92: Inlake chlorophyll-a over time for Isa Lake

3.24 Lake of the Woods

Samples for Lake of the Woods were collected in 2001, and 2010. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.93 depicts the Carlson TSI values over time for Lake of the Woods. The figure depicts an increase in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as mesotrophic and hyper-eutrophic.

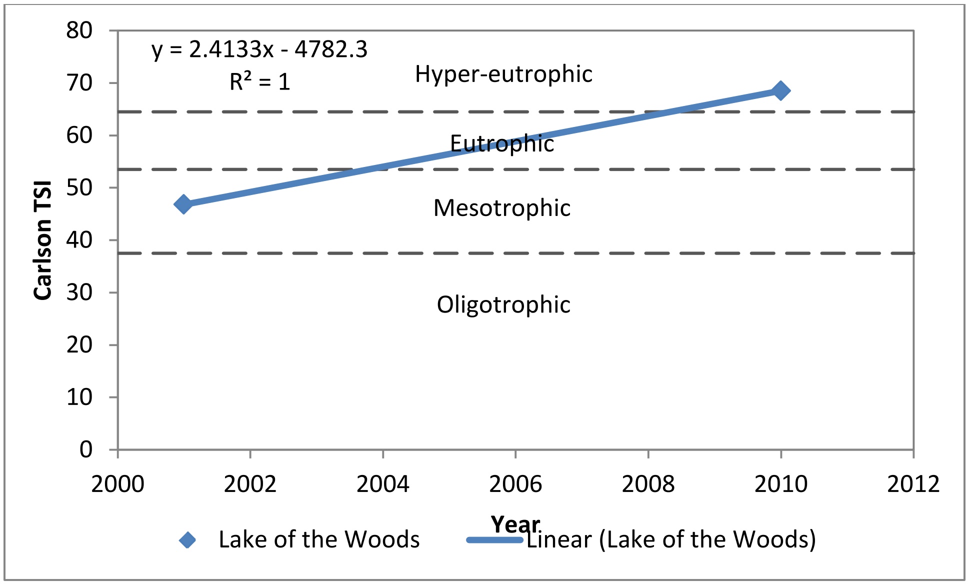

Figure 3.93: Carlson TSI over time for Lake of the Woods

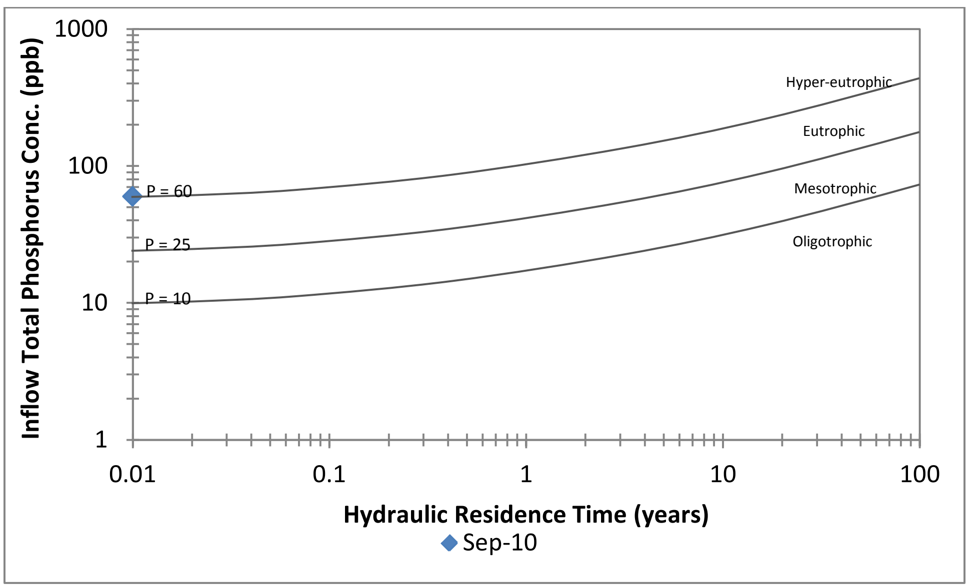

Figure 3.94: Vollenweider Model over time for Lake of the Woods

Figure 3.94 depicts the results of the Vollenweider Model over time for Lake of the Woods. Only one inlet total phosphorus point exists and it falls under the slightly hyper-eutrophic classification.

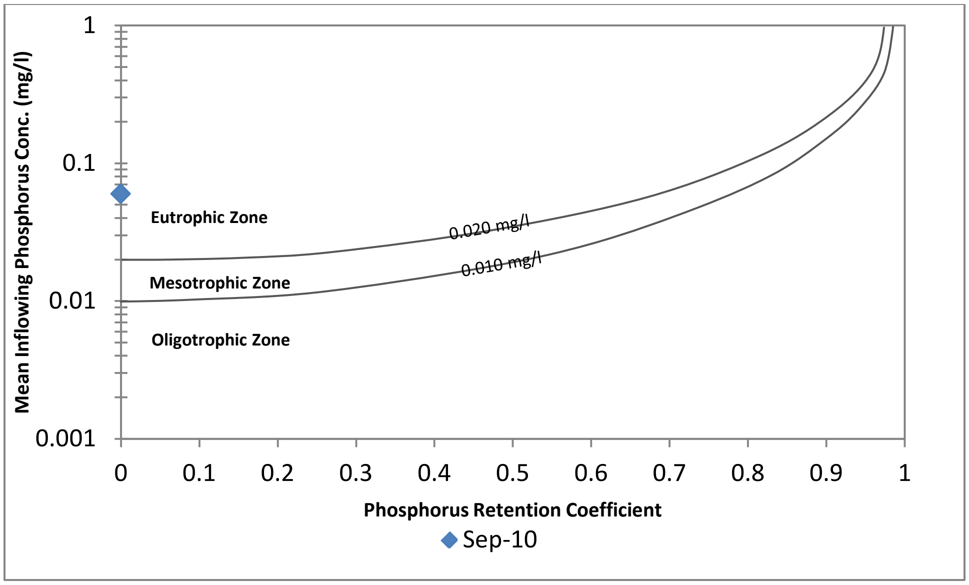

Figure 3.95: Larsen Mercier Model over time for Lake of the Woods

Figure 3.95 shows the results of the Larsen Mercier Model over time for Lake of the Woods. Only one inlet total phosphorus point exists and it falls under the slightly hyper-eutrophic classification.

Figure 3.96 shows the average total inlake phosphorus concentrations over time for Lake of the Woods. These values depict an increase in inlake phosphorus. As only two data points were collected, a correlation is difficult to determine. The TP values were classified as strongly mesotrophic and hyper-eutrophic.

Figure 3.97 shows the average total inlake chlorophyll-a concentrations over time for Lake of the Woods. These values depict an increase in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The total chlorophyll-a values were classified as mesotrophic and hyper-eutrophic.

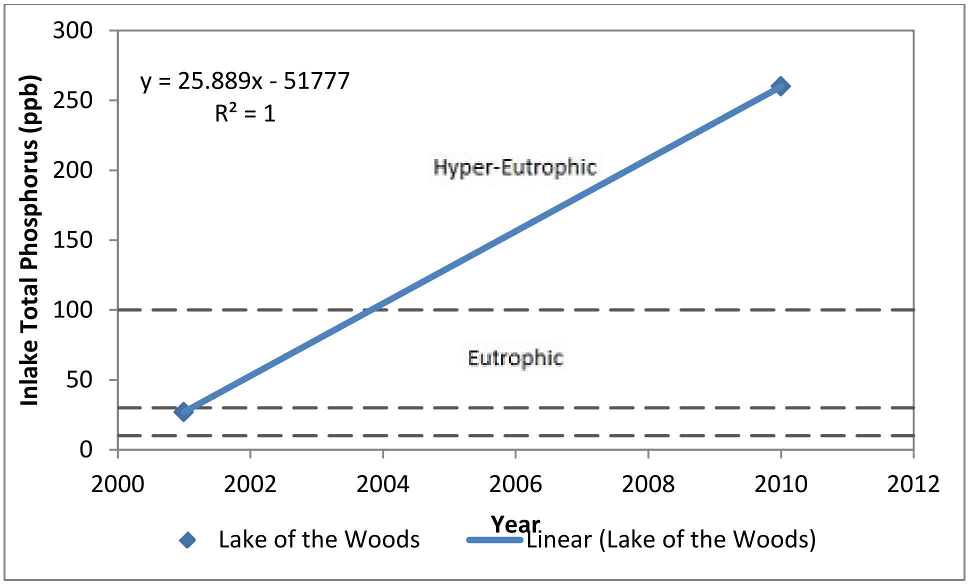

Figure 3.96: Inlake total phosphorus over time for Lake of the Woods

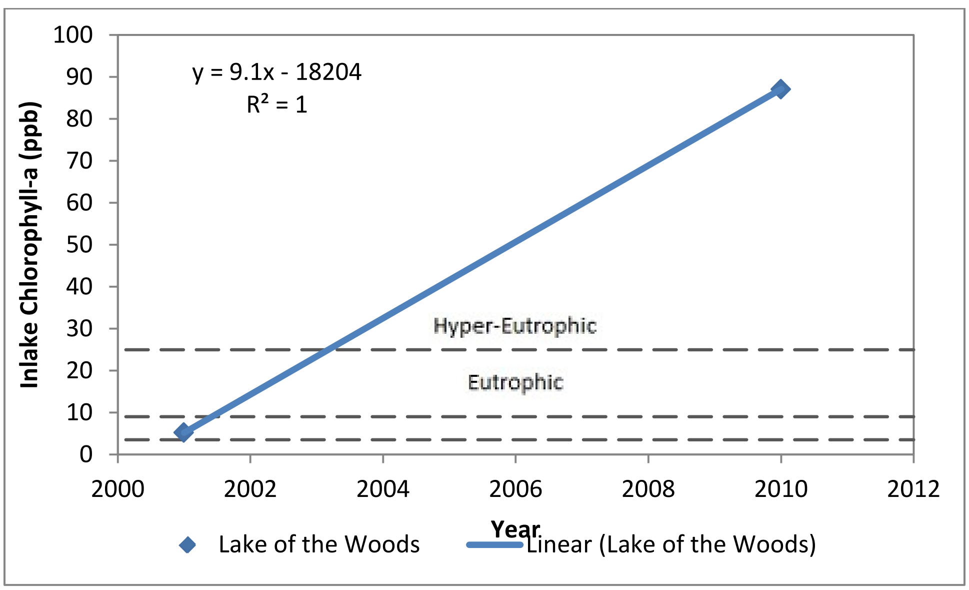

Figure 3.97: Inlake chlorophyll-a over time for Lake of the Woods

3.25 Lewis Lake

Samples for Lewis Lake were collected in 1998-1999, and 2009-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen

Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

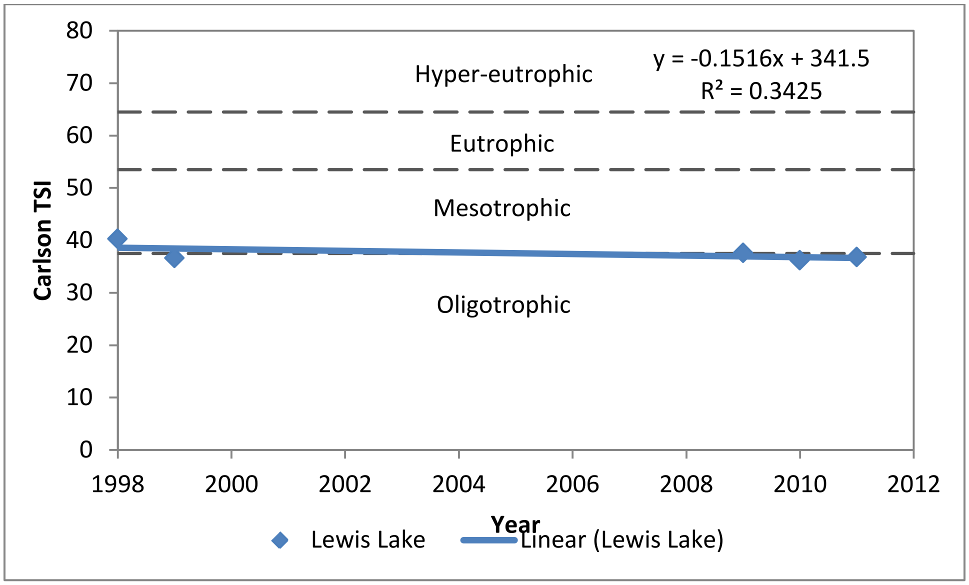

Figure 3.98: Carlson TSI over time for Lewis Lake

Figure 3.98 depicts the Carlson TSI values over time for Lewis Lake. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.3425. The TSI values vary in the range of slightly oligotrophic and slightly mesotrophic classification.

Figure 3.99 depicts the results of the Vollenweider Model over time for Lewis Lake. The total phosphorus vs. hydraulic residence time data points range from oligotrophic in July 1999 to strongly mesotrophic in August 1999.

Figure 3.100 shows the results of the Larsen Mercier Model over time for Lewis Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from oligotrophic in June 1999 to strongly mesotrophic in August 1999.

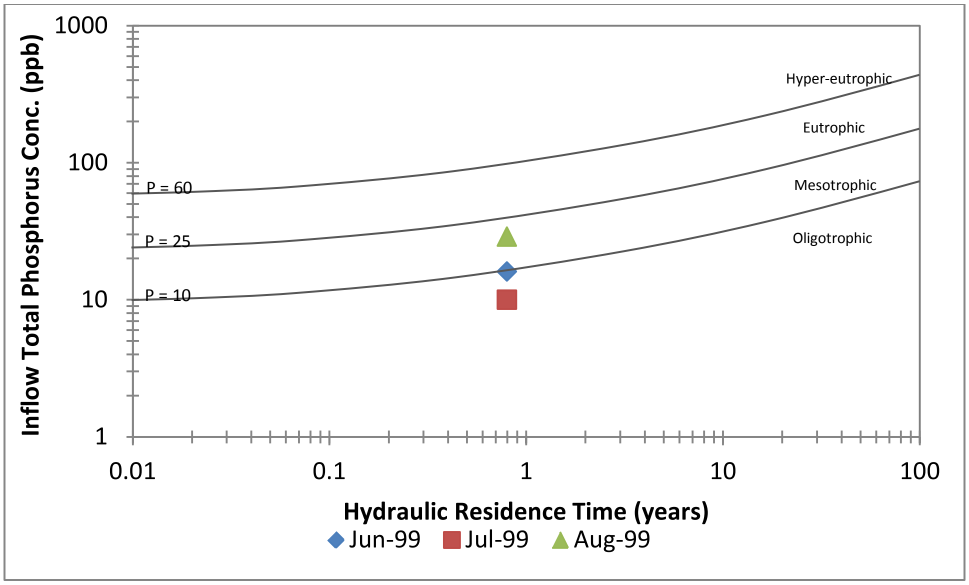

Figure 3.99: Vollenweider Model over time for Lewis Lake

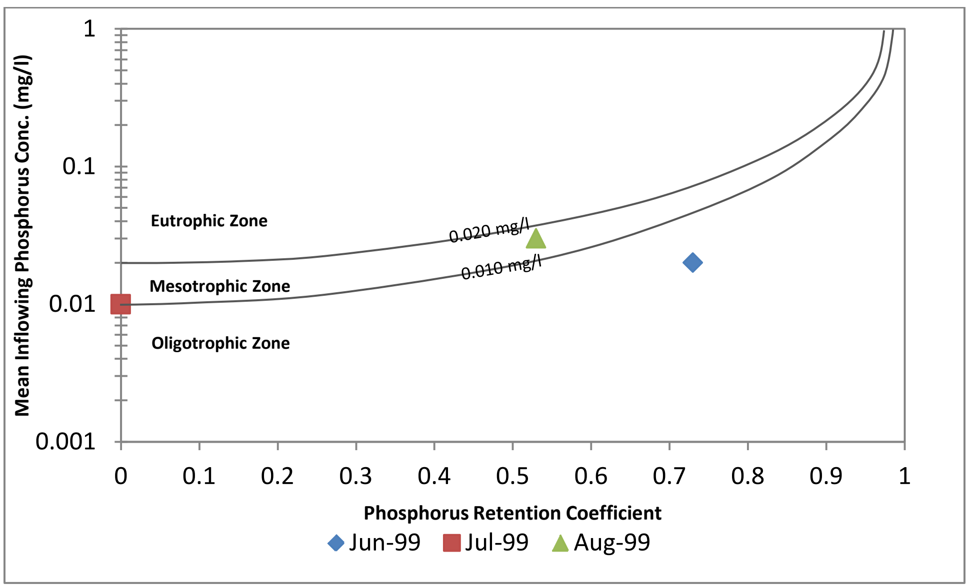

Figure 3.100: Larsen Mercier Model over time for Lewis Lake

Figure 3.101 shows the average total inlake phosphorus concentrations over time for Lewis Lake. These values depict a slight decrease in inlake phosphorus with a relatively strong correlation coefficient of 0.6788. The phosphorus concentrations vary in the range of slightly mesotrophic to mesotrophic.

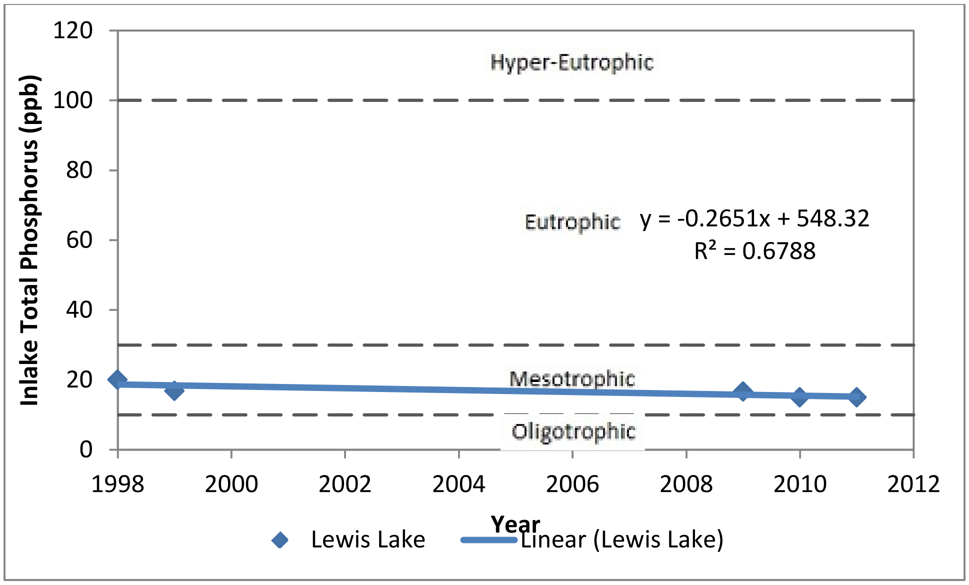

Figure 3.101: Inlake total phosphorus over time for Lewis Lake

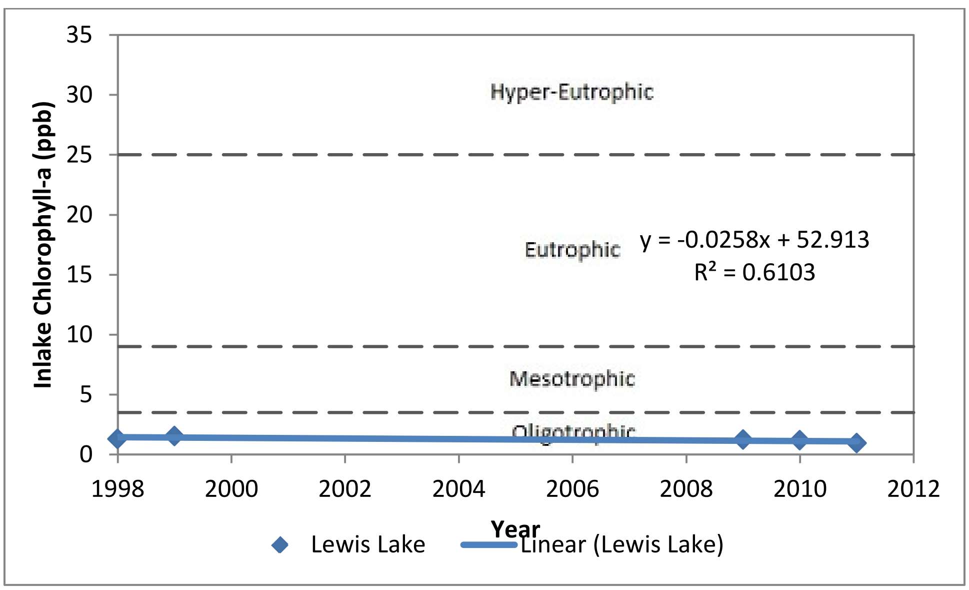

Figure 3.102: Inlake chlorophyll-a over time for Lewis Lake

Figure 3.102 shows the average total inlake chlorophyll-a concentrations over time for Lewis Lake. These values depict a slight decrease in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.6103. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly oligotrophic.

3.26 **Lily Pad Lake**

Samples for Lily Pad Lake were collected in 2004-2006, and 2008-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

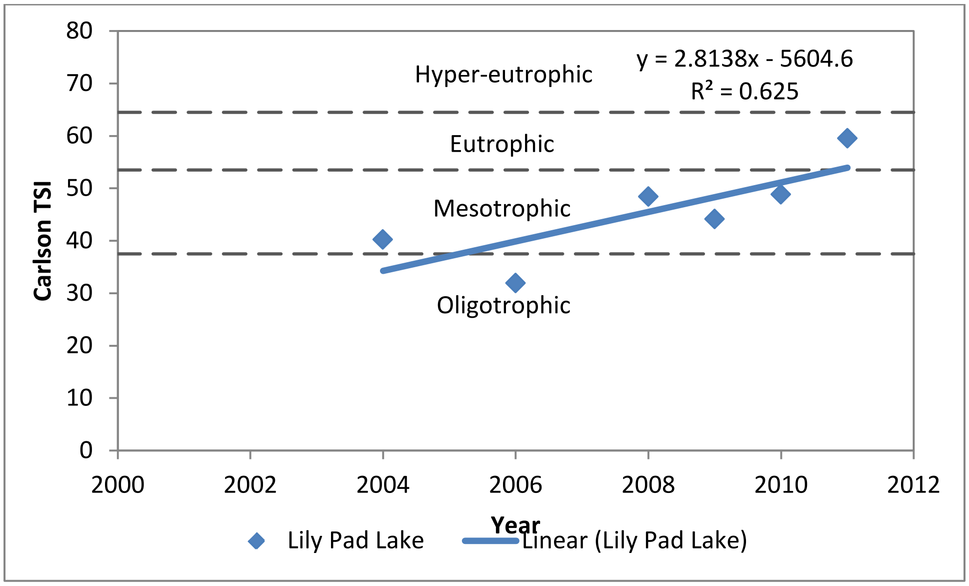

Figure 3.103: Carlson TSI over time for Lily Pad Lake

Figure 3.103 depicts the Carlson TSI values over time for Lily Pad Lake. The figure depicts an increase in TSI values over time with a relatively strong correlation coefficient of 0.625. The TSI values vary in the range of slightly oligotrophic and strongly eutrophic classification.

Figure 3.104 shows the average total inlake phosphorus concentrations over time for Lily Pad Lake. These values depict an increase in inlake phosphorus with an average in strength correlation coefficient of 0.5876. The phosphorus concentrations vary in the range of slightly mesotrophic to hyper-eutrophic.

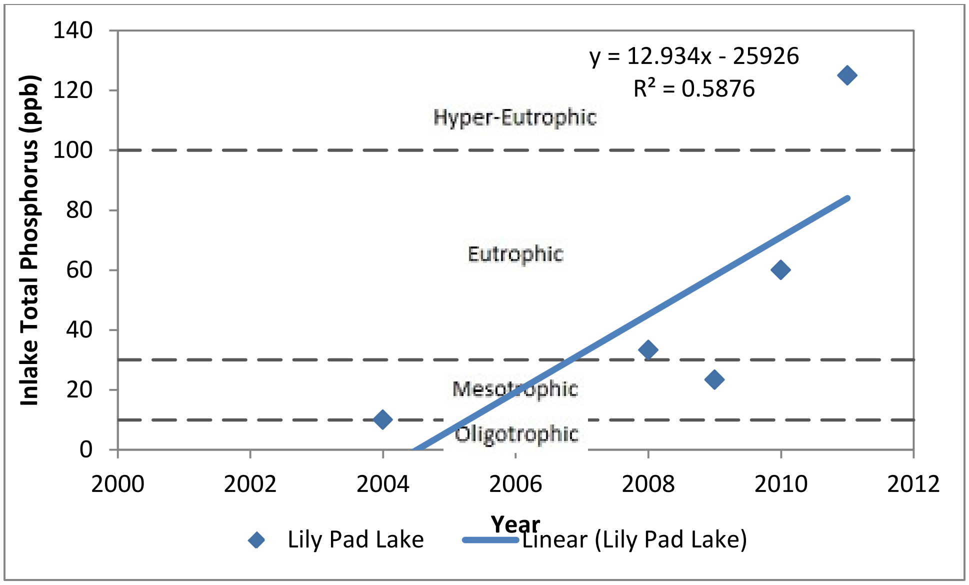

Figure 3.104: Inlake total phosphorus over time for Lily Pad Lake

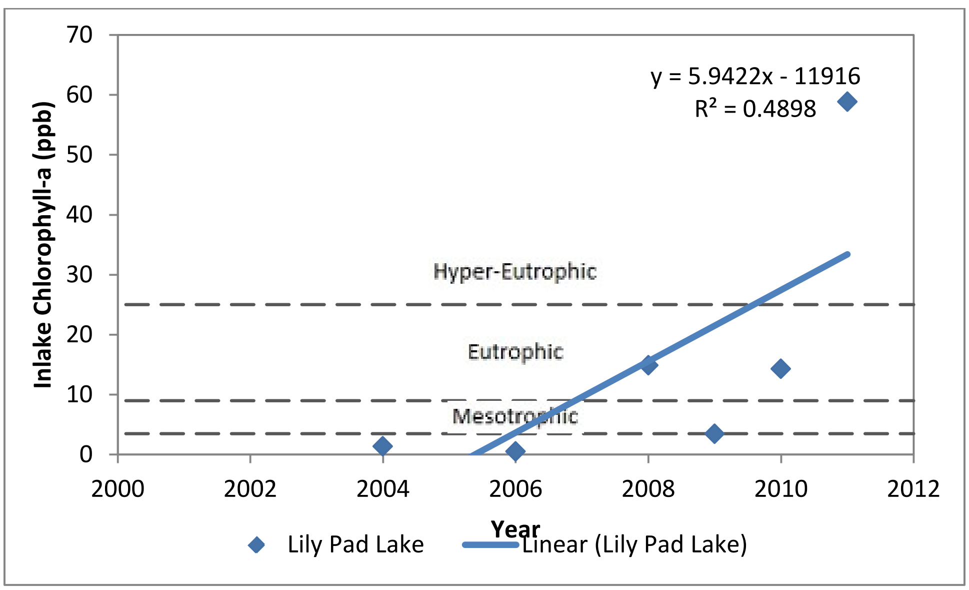

Figure 3.105: Inlake chlorophyll-a over time for Lily Pad Lake

Figure 3.105 shows the average total inlake chlorophyll-a concentrations over time for Lily Pad Lake. These values depict an increase in inlake chlorophyll-a with an average in strength correlation coefficient of 0.4898. The chlorophyll-a concentrations vary in the range of oligotrophic to hyper-eutrophic.

3.27 **Lost Lake**

Samples for Lost Lake were collected in 2004-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

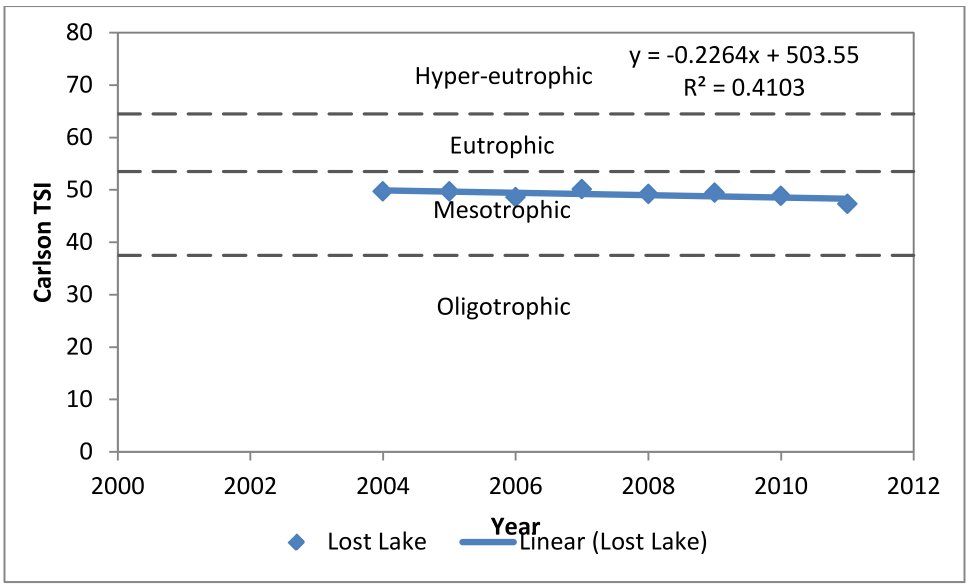

Figure 3.106: Carlson TSI over time for Lost Lake

Figure 3.106 depicts the Carlson TSI values over time for Lost Lake. The figure depicts a slight decrease in TSI values over time with an average in strength correlation coefficient of 0.4103. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

Figure 3.107 depicts the results of the Vollenweider Model over time for Lost Lake. The total phosphorus vs. hydraulic residence time data points range from strongly mesotrophic in July 2004 to slightly hyper-eutrophic in June 2004.

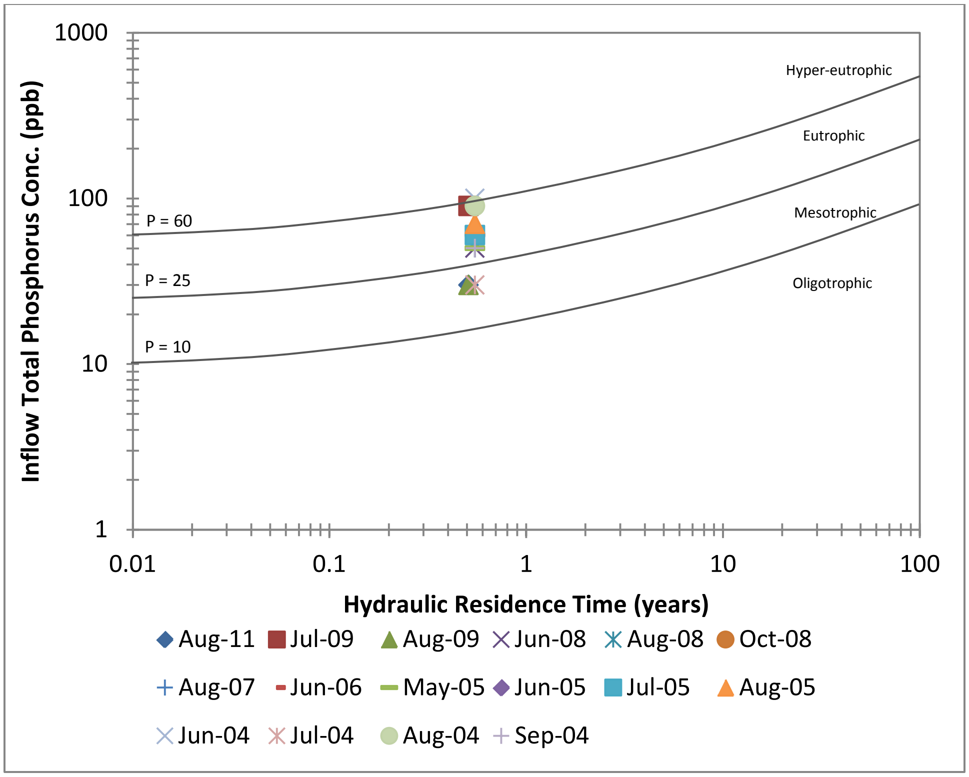

Figure 3.107: Vollenweider Model over time for Lost Lake

Figure 3.108 shows the results of the Larsen Mercier Model over time for Lost Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in August 2011 to strongly eutrophic in June 2006. The majority of the data points are in the range of slightly eutrophic to strongly eutrophic.

Figure 3.109 shows the average total inlake phosphorus concentrations over time for Lost Lake. These values depict a slight increase in inlake phosphorus with a relatively weak correlation coefficient of 0.0317. The phosphorus concentrations vary in the range of slightly mesotrophic to eutrophic.

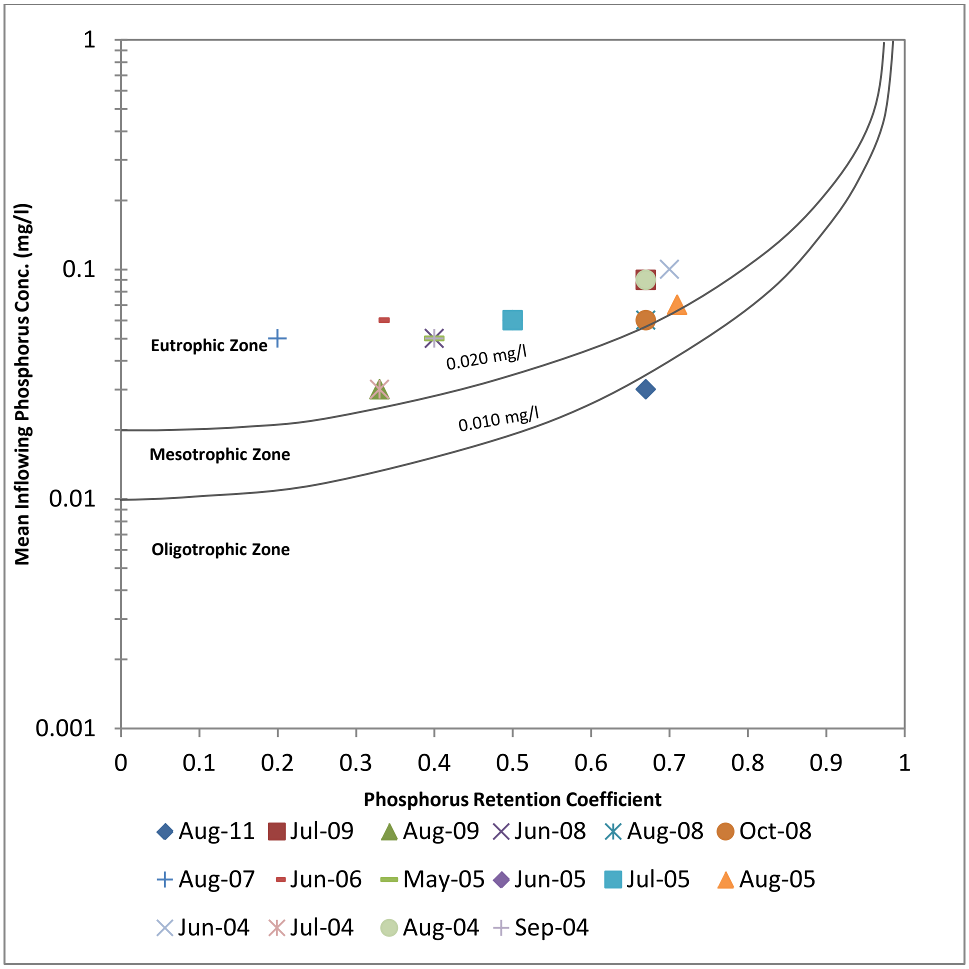

Figure 3.108: Larsen Mercier Model over time for Lost Lake

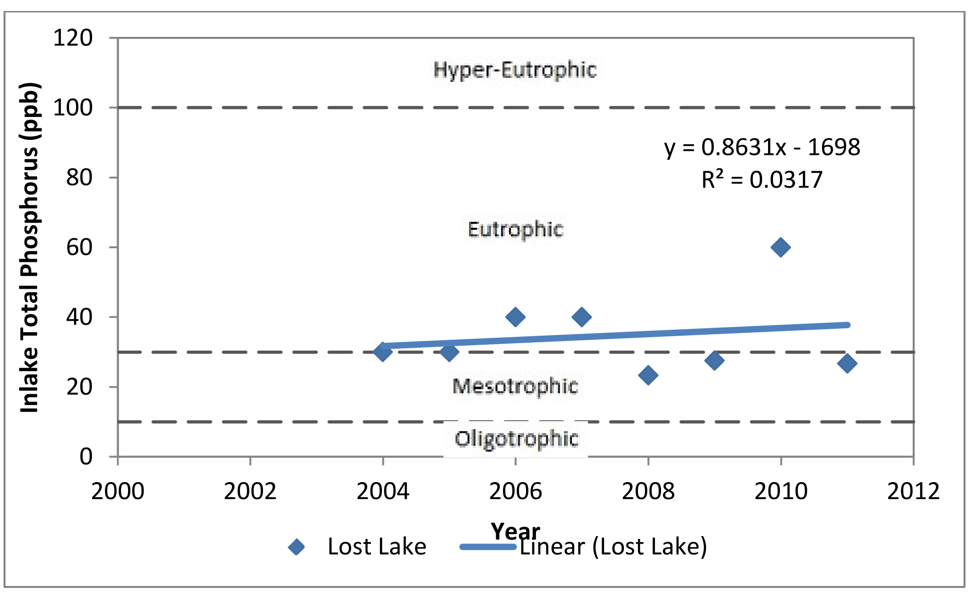

Figure 3.109: Inlake total phosphorus over time for Lost Lake

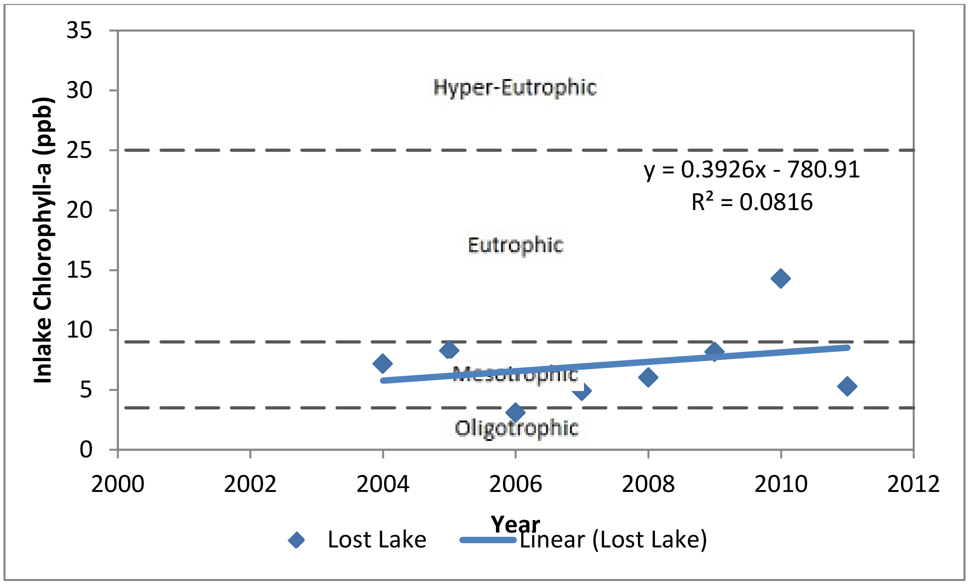

Figure 3.110: Inlake chlorophyll-a over time for Lost Lake

Figure 3.110 shows the average total inlake chlorophyll-a concentrations over time for Lost Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0816. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to eutrophic.

3.28 **Mallard Lake**

Samples for Mallard Lake were collected in 2010. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

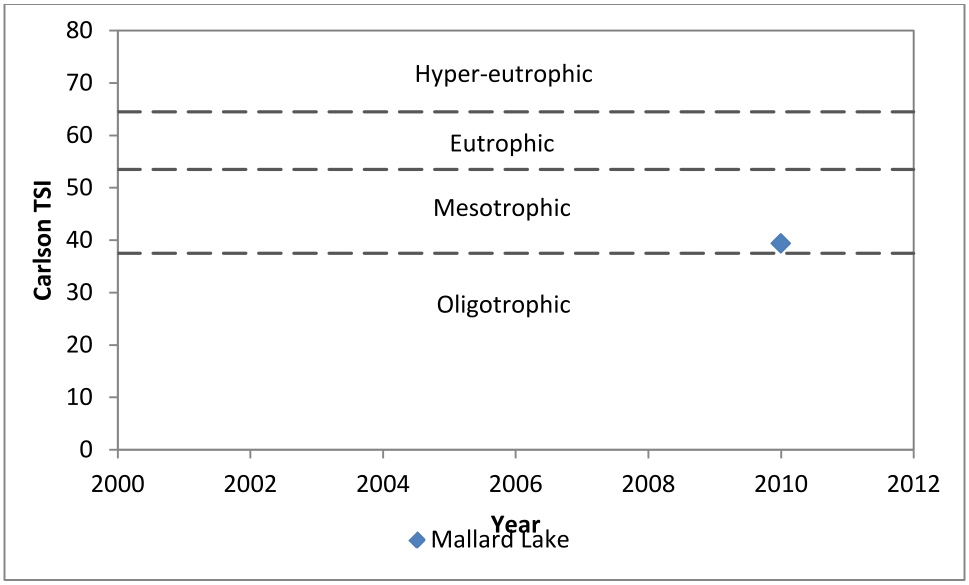

Figure 3.111: Carlson TSI over time for Mallard Lake

Figure 3.111 depicts the Carlson TSI values over time for Mallard Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the slightly mesotrophic classification based on the Carlson Model.

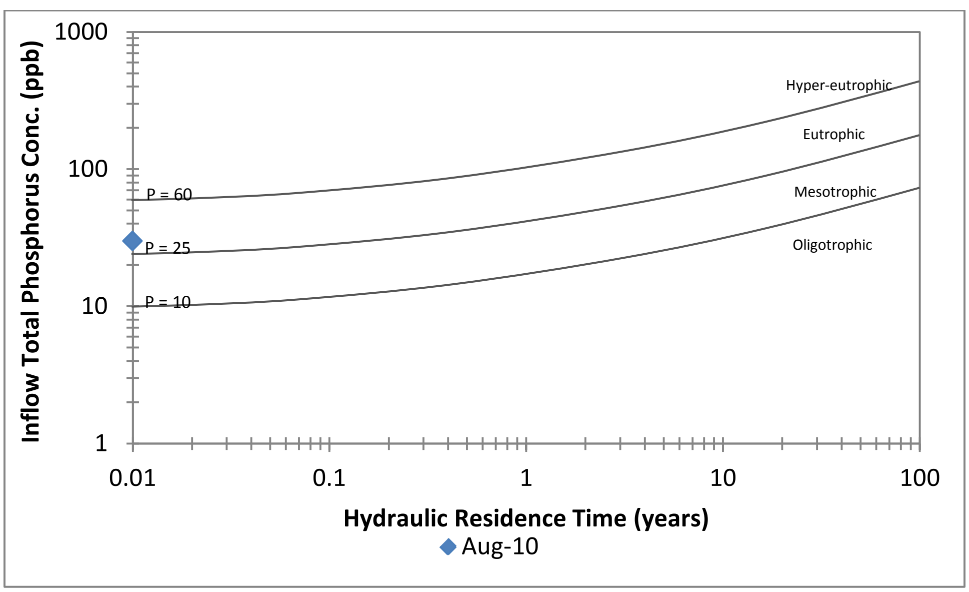

Figure 3.112: Vollenweider Model over time for Mallard Lake

Figure 3.112 depicts the results of the Vollenweider Model over time for Mallard Lake. Only one inlet total phosphorus point exists and it falls under the slightly eutrophic classification.

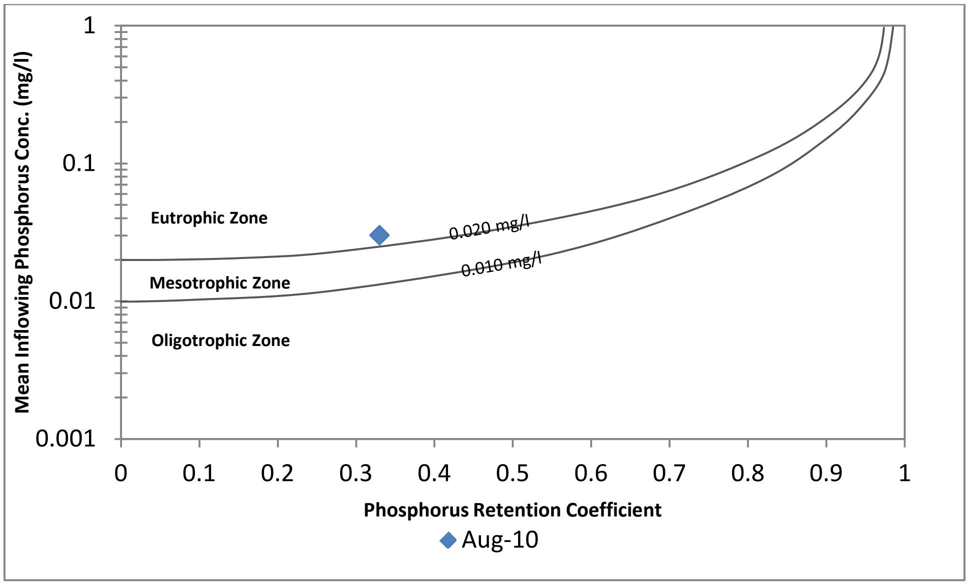

Figure 3.113: Larsen Mercier Model over time for Mallard Lake

Figure 3.113 shows the results of the Larsen Mercier Model over time for Mallard Lake. Only one inlet total phosphorus point exists for August 2010 and it falls under the slightly eutrophic classification.

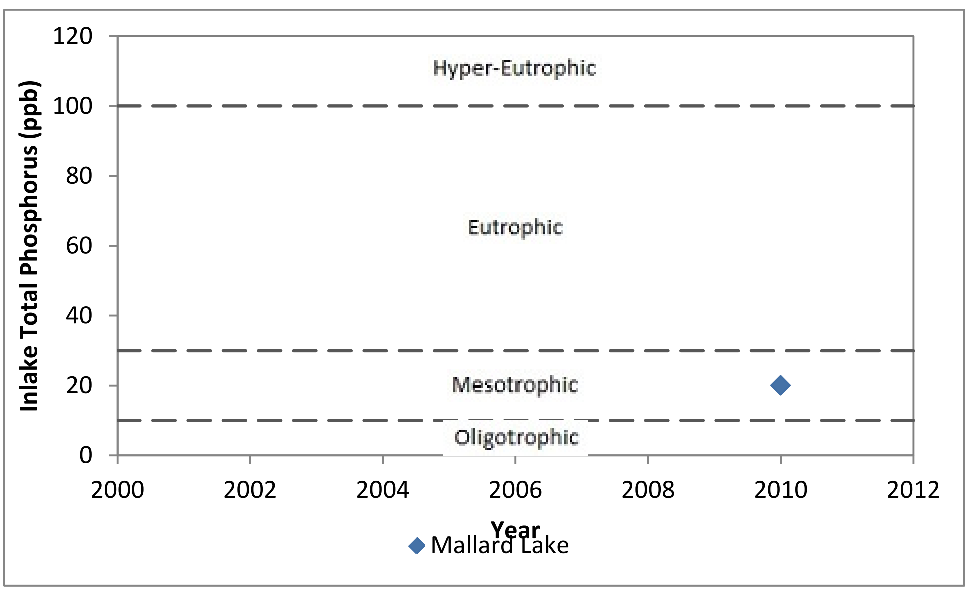

Figure 3.114: Inlake total phosphorus over time for Mallard Lake

Figure 3.114 shows the average total inlake phosphorus concentrations over time for Mallard Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for TP values. The one TP value falls under the mesotrophic classification based on the TP Model.

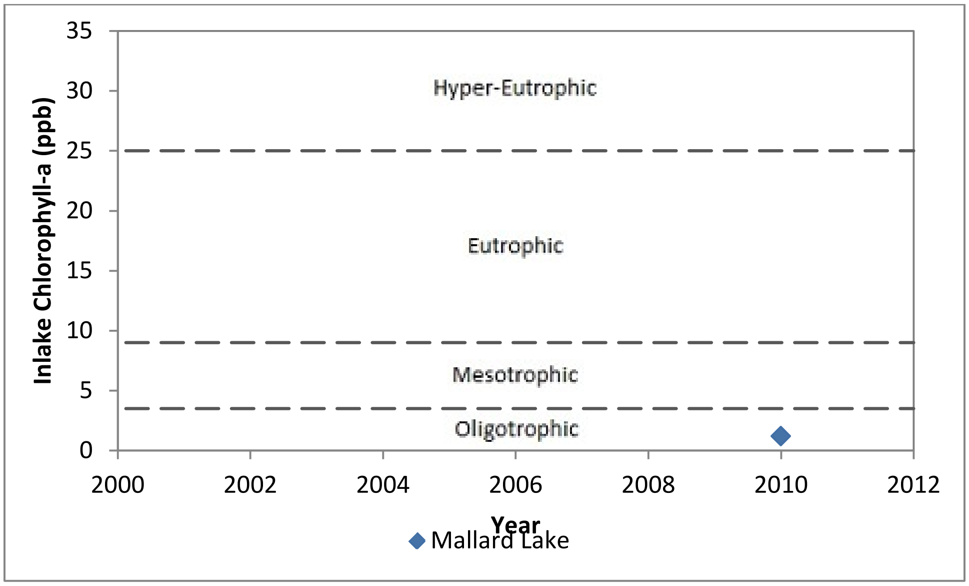

Figure 3.115: Inlake chlorophyll-a over time for Mallard Lake

Figure 3.115 shows the average total inlake chlorophyll-a concentrations over time for Mallard Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total chlorophyll-a values. The one chlorophyll-a value falls under the oligotrophic classification based on the total chlorophyll-a model.

3.29 North Twin Lake

Samples for North Twin Lake were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen

Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

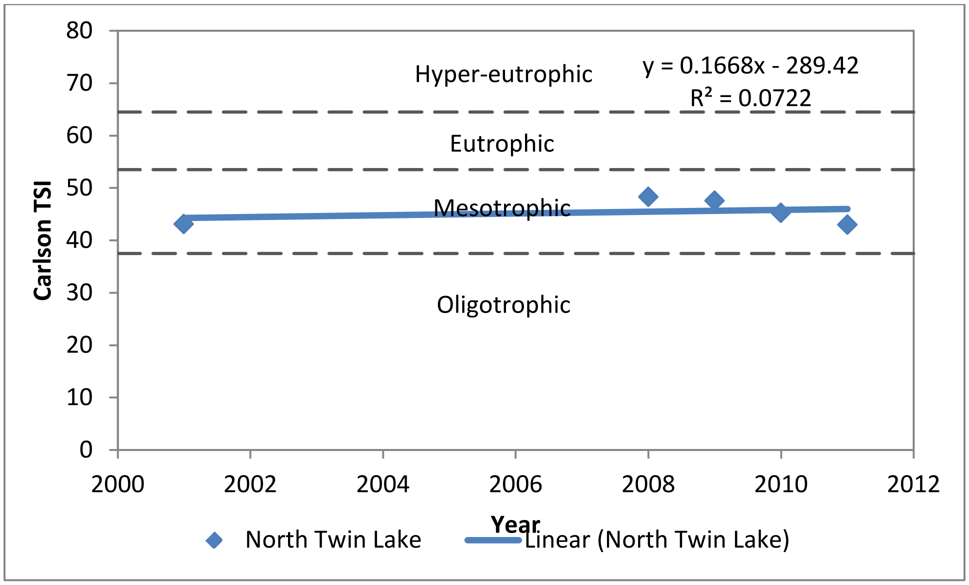

Figure 3.116: Carlson TSI over time for North Twin Lake

Figure 3.116 depicts the Carlson TSI values over time for North Twin Lake. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.0722. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

Figure 3.117 depicts the results of the Vollenweider Model over time for North Twin Lake. The total phosphorus vs. hydraulic residence time data points range from slightly eutrophic in July 2009 to hyper-eutrophic in July 2008.

Figure 3.118 shows the results of the Larsen Mercier Model over time for North Twin Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in August 2001 to slightly hyper-eutrophic in August 2008. The majority of the data points are in the range of slightly eutrophic to slightly hyper-eutrophic.

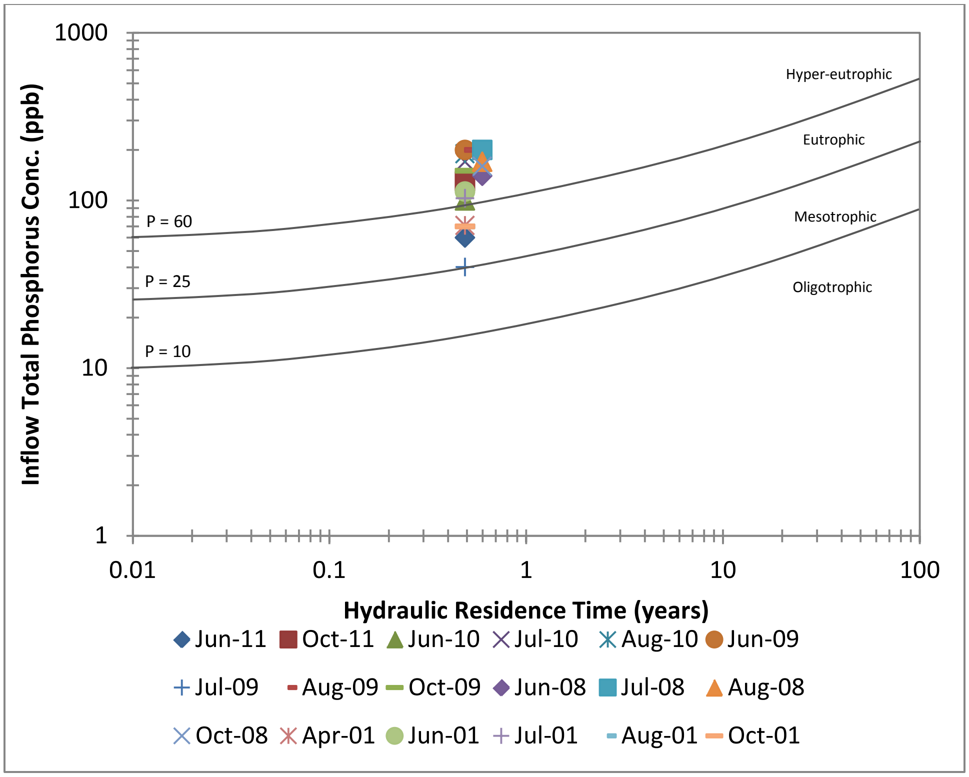

Figure 3.117: Vollenweider Model over time for North Twin Lake

Figure 3.119 shows the average total inlake phosphorus concentrations over time for North Twin Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.2247. The phosphorus concentrations vary in the range of slightly mesotrophic to strongly eutrophic.

Figure 3.120 shows the average total inlake chlorophyll-a concentrations over time for North Twin Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0118. The chlorophyll-a concentrations vary in the range of oligotrophic to mesotrophic.

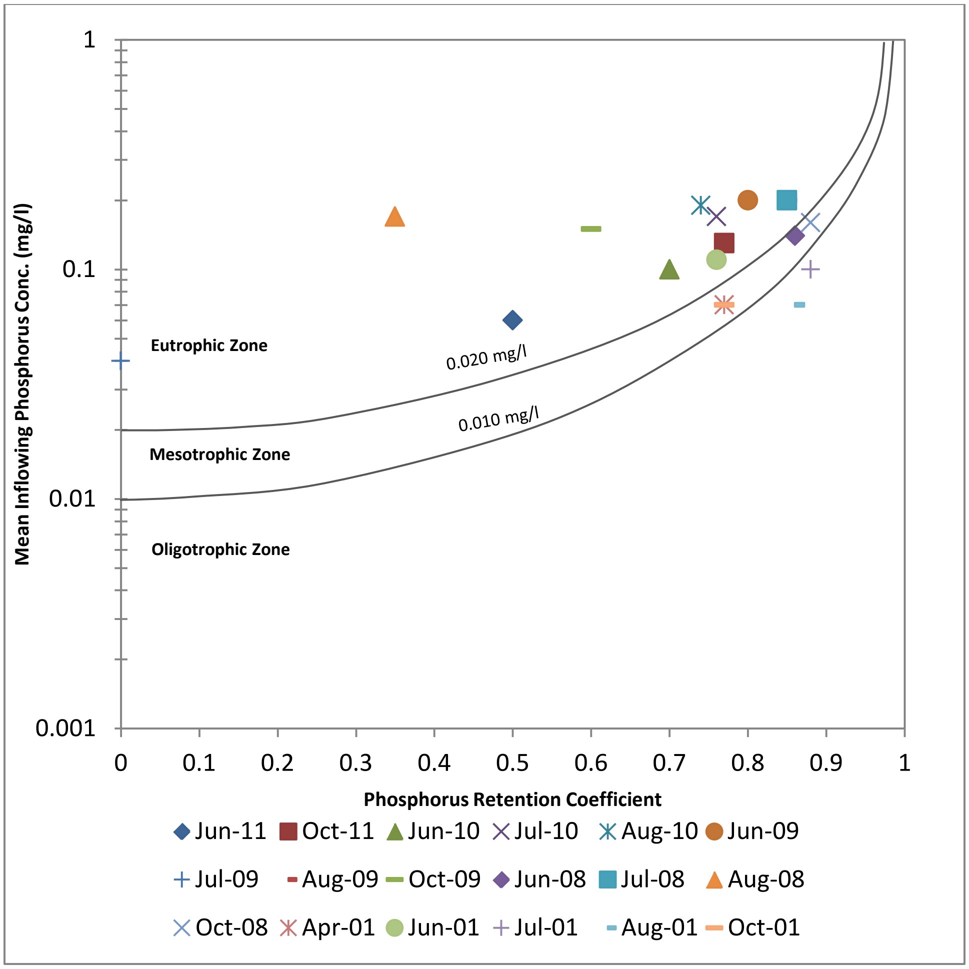

Figure 3.118: Larsen Mercier Model over time for North Twin Lake

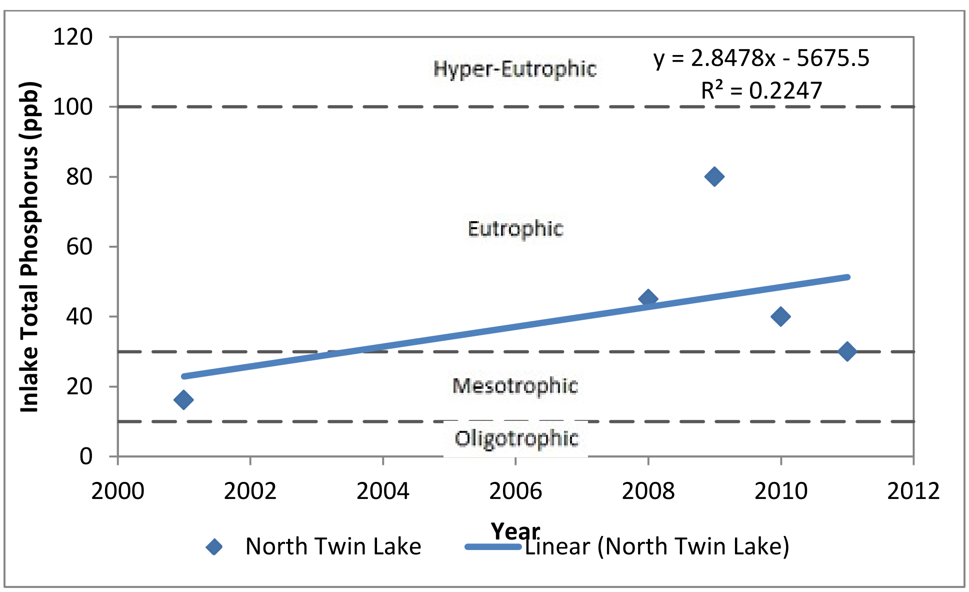

Figure 3.119: Inlake total phosphorus over time for North Twin Lake

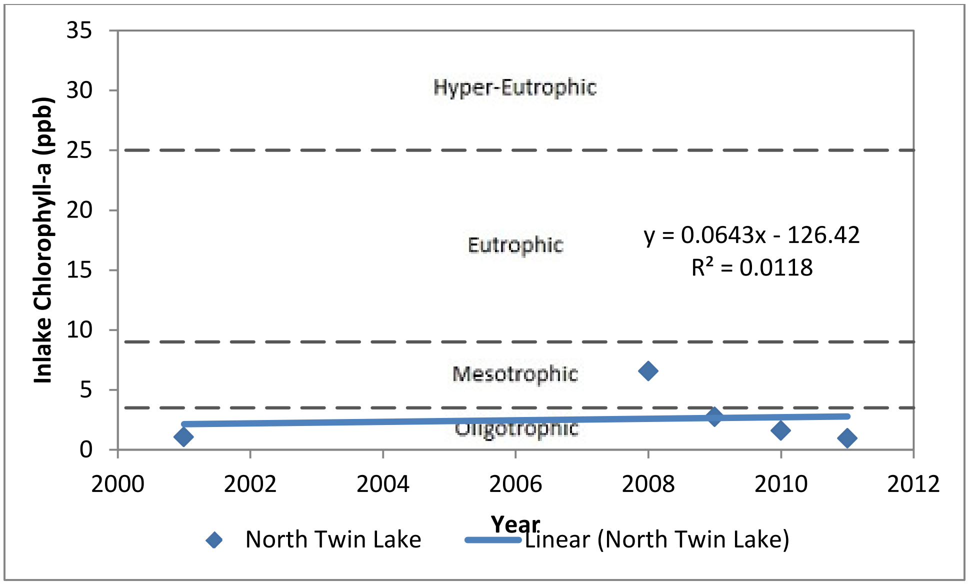

Figure 3.120: Inlake chlorophyll-a over time for North Twin Lake

3.30 Nymph Lake

Samples for Nymph Lake were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.121 depicts the Carlson TSI values over time for Nymph Lake. The figure depicts a slight decrease in TSI values over time with an average in strength correlation coefficient of 0.409. The TSI values vary in the range of slightly eutrophic and strongly eutrophic classification.

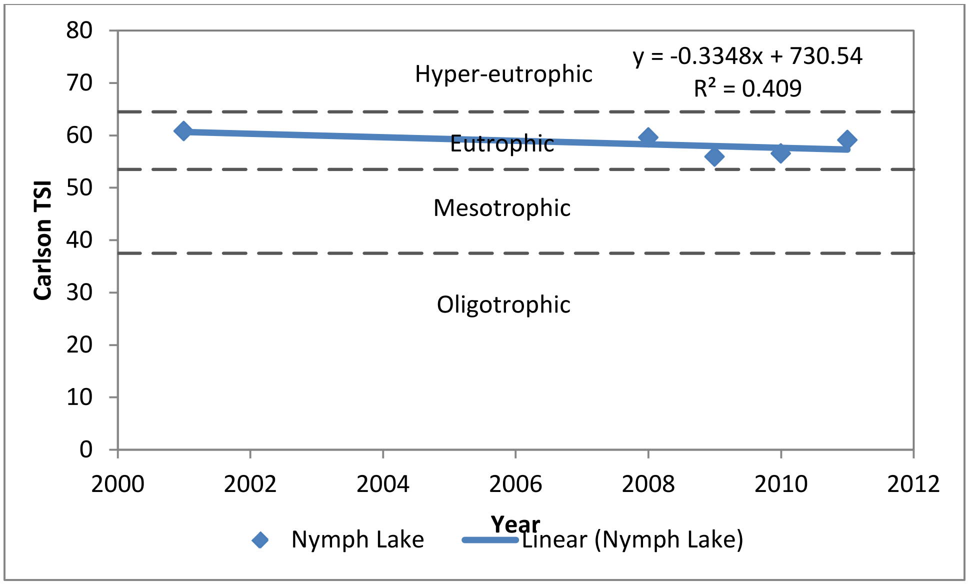

Figure 3.121: Carlson TSI over time for Nymph Lake

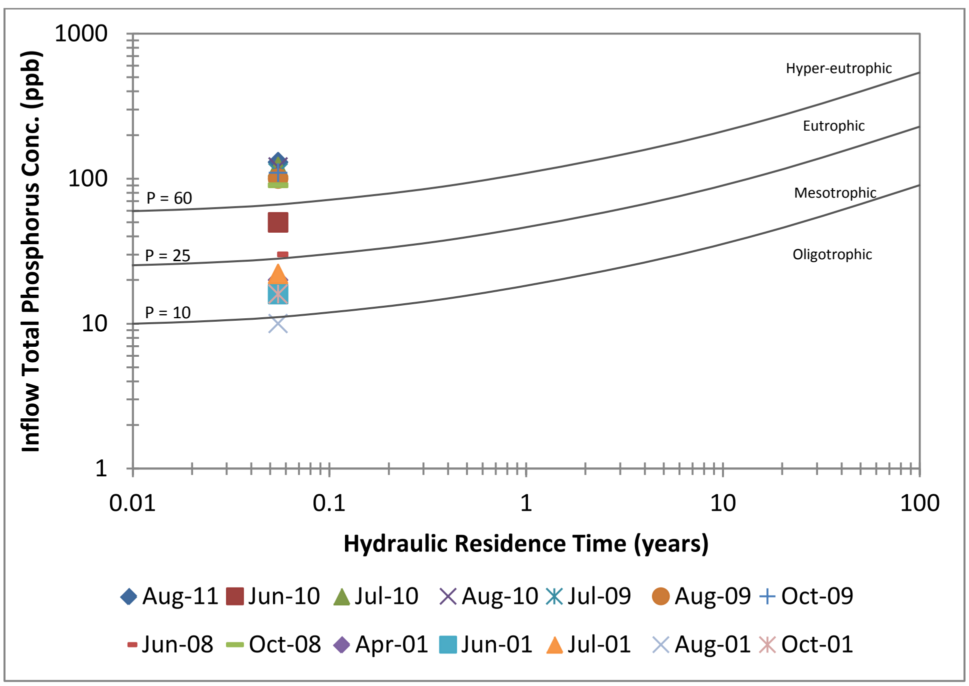

Figure 3.122: Vollenweider Model over time for Nymph Lake

Figure 3.122 depicts the results of the Vollenweider Model over time for Nymph Lake. The total phosphorus vs. hydraulic residence time data points range from slightly oligotrophic in August 2001 to hyper-eutrophic in August 2011.

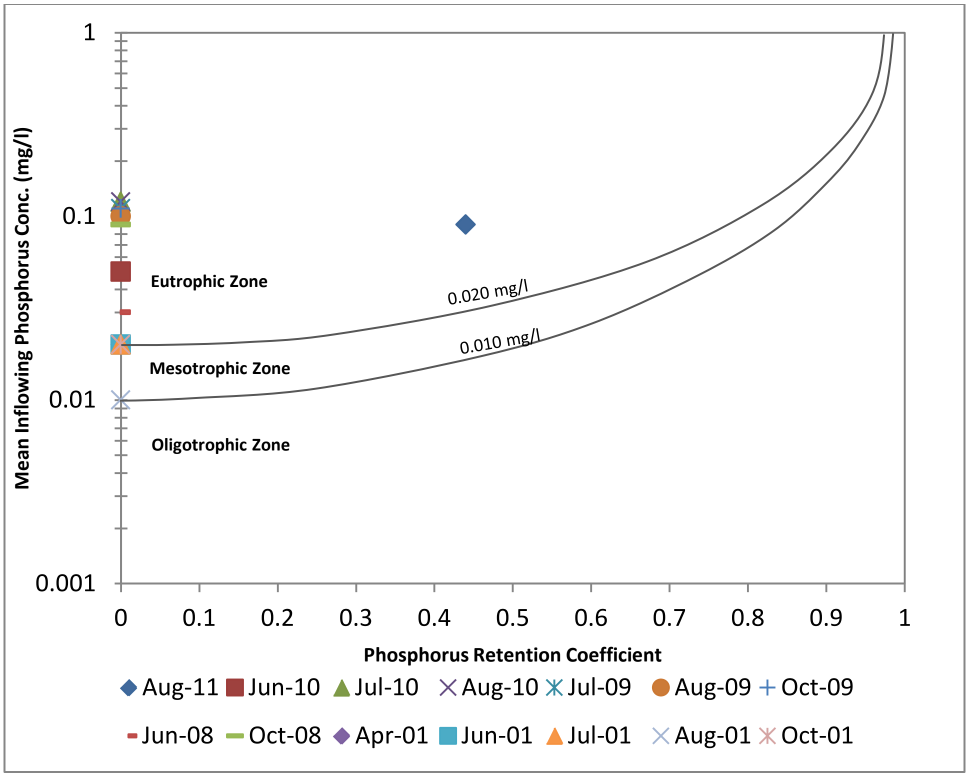

Figure 3.123: Larsen Mercier Model over time for Nymph Lake

Figure 3.123 shows the results of the Larsen Mercier Model over time for Nymph Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly mesotrophic in August 2001 to hyper-eutrophic in August 2010. The majority of the data points are in the range of slightly eutrophic to hyper-eutrophic.

Figure 3.124 shows the average total inlake phosphorus concentrations over time for Nymph Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.1387. The phosphorus concentrations vary in the range of strongly eutrophic to hyper-eutrophic.

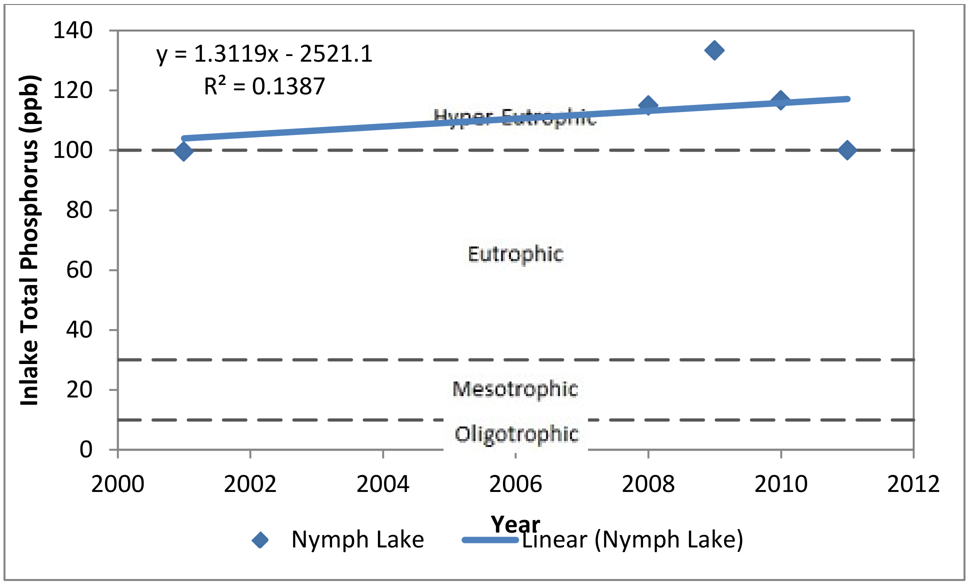

Figure 3.124: Inlake total phosphorus over time for Nymph Lake

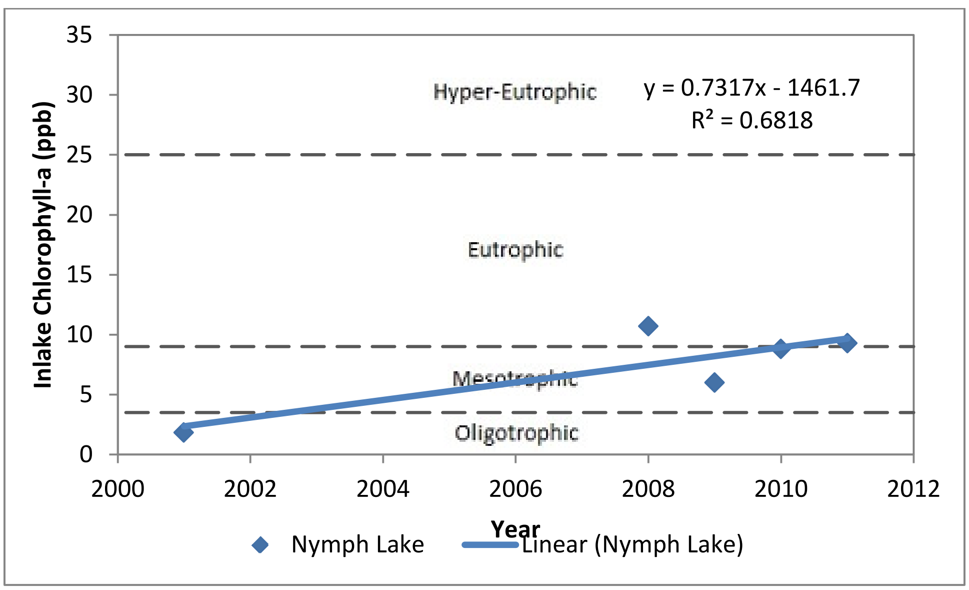

Figure 3.125: Inlake chlorophyll-a over time for Nymph Lake

Figure 3.125 shows the average total inlake chlorophyll-a concentrations over time for Nymph Lake. These values depict an increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.6818. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to slightly eutrophic.

3.31 **Pool by Morning Glory Pool**

Samples for the Pool by Morning Glory Pool were collected in 2001 and 2010. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

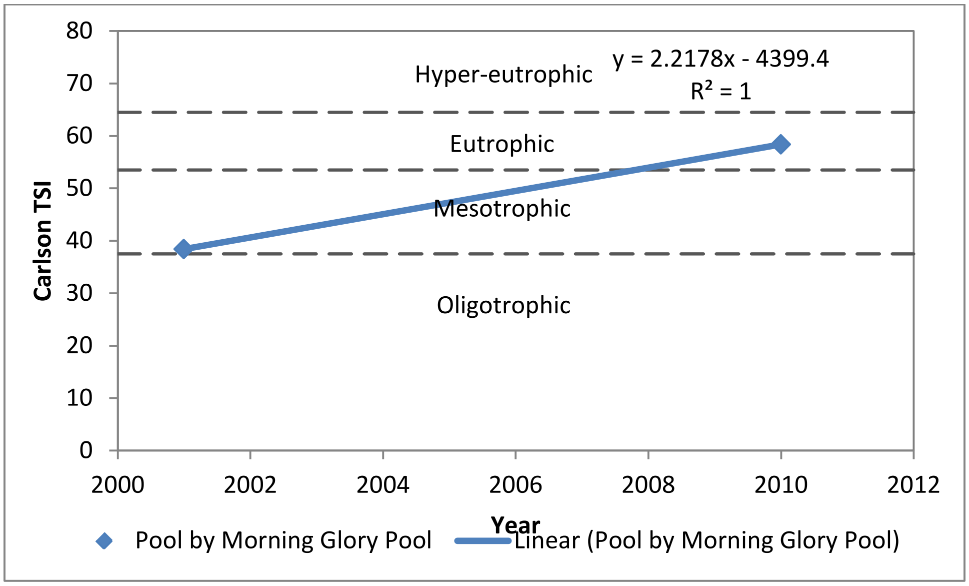

Figure 3.126: Carlson TSI over time for the Pool by Morning Glory Pool

Figure 3.126 depicts the Carlson TSI values over time for the Pool by Morning Glory Pool. The figure depicts an increase in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as slightly mesotrophic and eutrophic.

Figure 3.127 shows the average total inlake phosphorus concentrations over time for the Pool by Morning Glory Pool. These values depict an increase in inlake phosphorus. As only two data points were collected, a correlation is difficult to determine. The total inlake phosphorus values were classified as slightly mesotrophic and hyper-eutrophic.

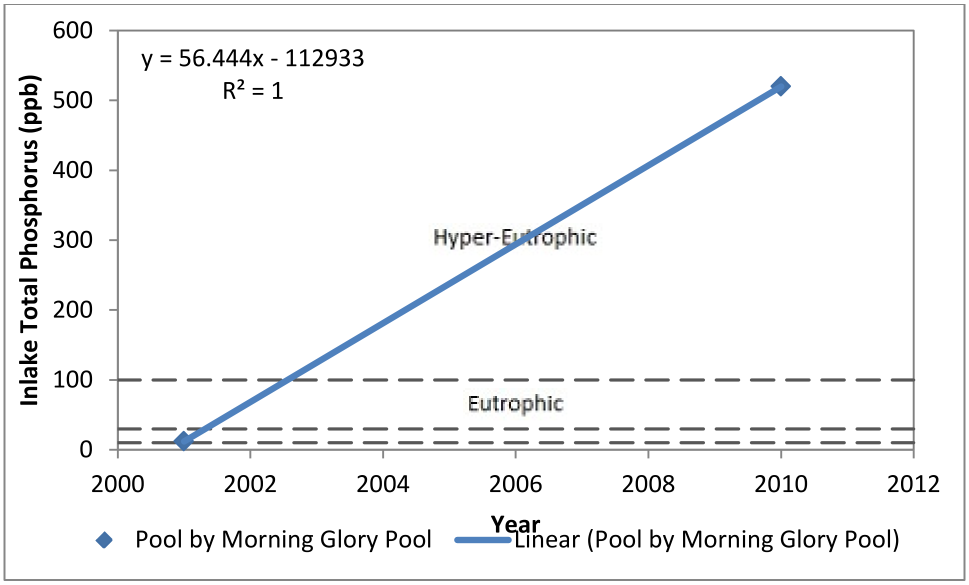

Figure 3.127: Inlake total phosphorus over time for the Pool by Morning Glory Pool

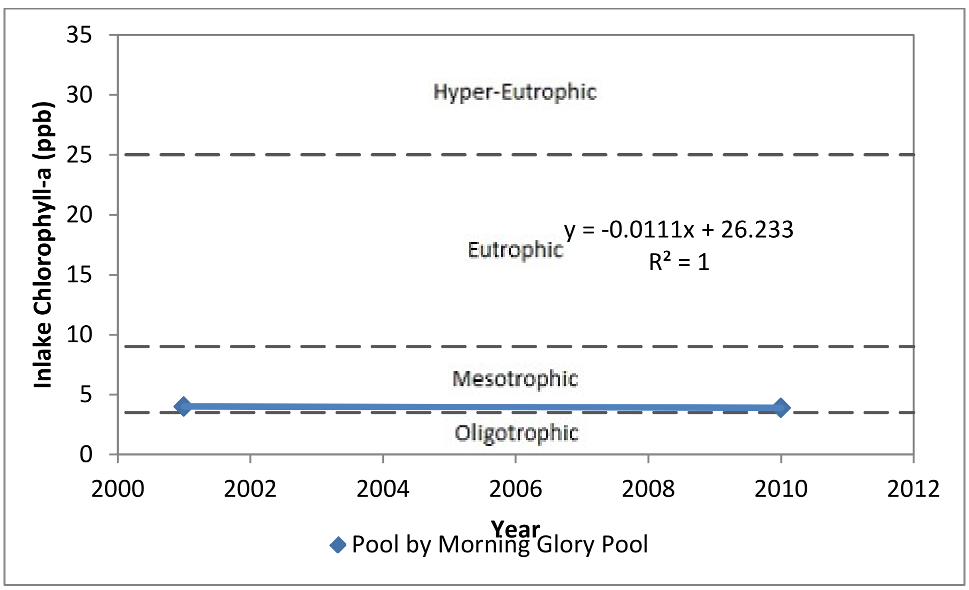

Figure 3.128: Inlake chlorophyll-a over time for the Pool by Morning Glory Pool

Figure 3.128 shows the average total inlake chlorophyll-a concentrations over time for the Pool by Morning Glory Pool. These values depict a slight decrease in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The total inlake chlorophyll-a values were both classified as slightly mesotrophic.

3.32 **Ribbon Lake**

Samples for Ribbon Lake were collected in 2006 and 2010. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

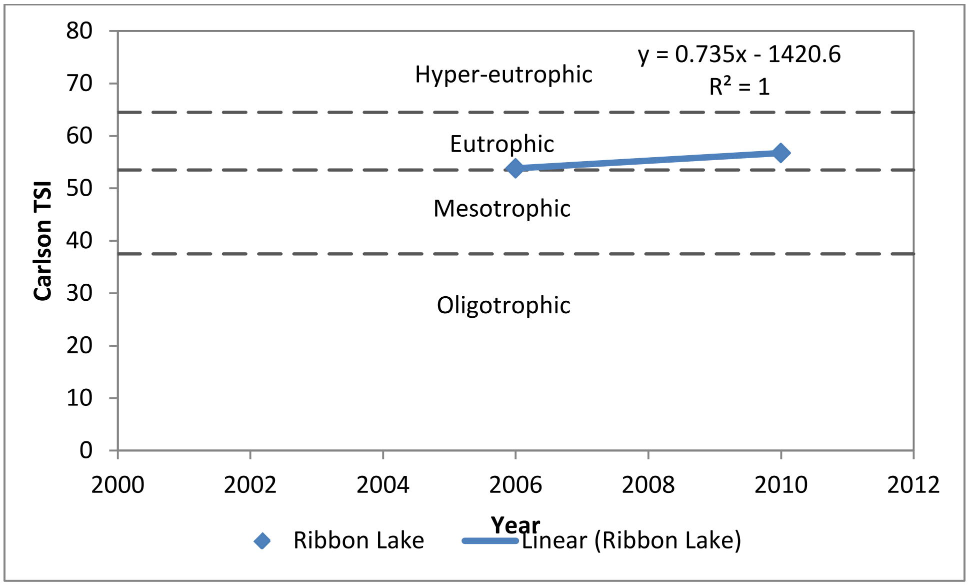

Figure 3.129: Carlson TSI over time for Ribbon Lake

Figure 3.129 depicts the Carlson TSI values over time for Ribbon Lake. The figure depicts a slight increase in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as slightly eutrophic and eutrophic.

Figure 3.130 shows the average total inlake phosphorus concentrations over time for Ribbon Lake. These values depict no change in inlake phosphorus. As only two data points were collected, a correlation is difficult to determine. The total inlake phosphorus values were both classified as slightly eutrophic.

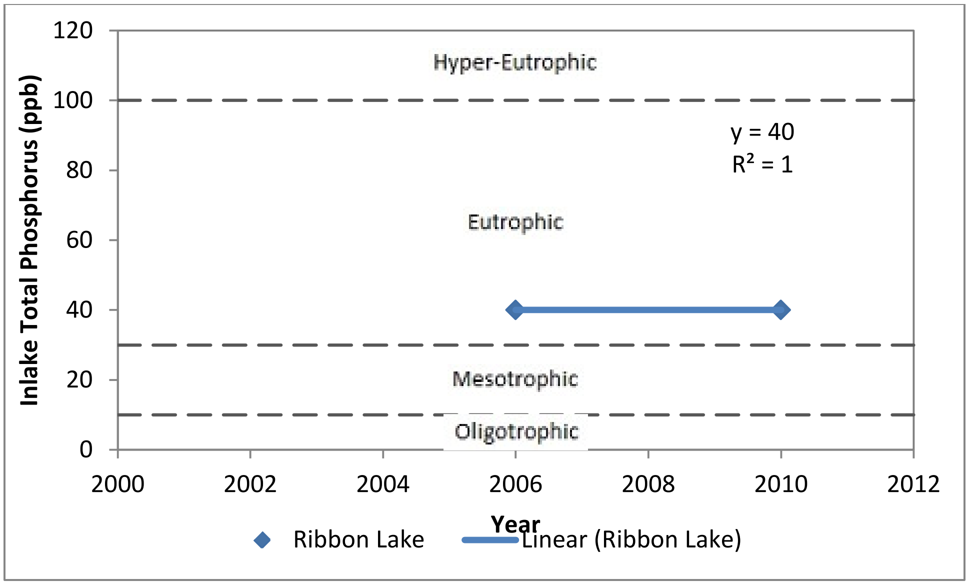

Figure 3.130: Inlake total phosphorus over time for Ribbon Lake

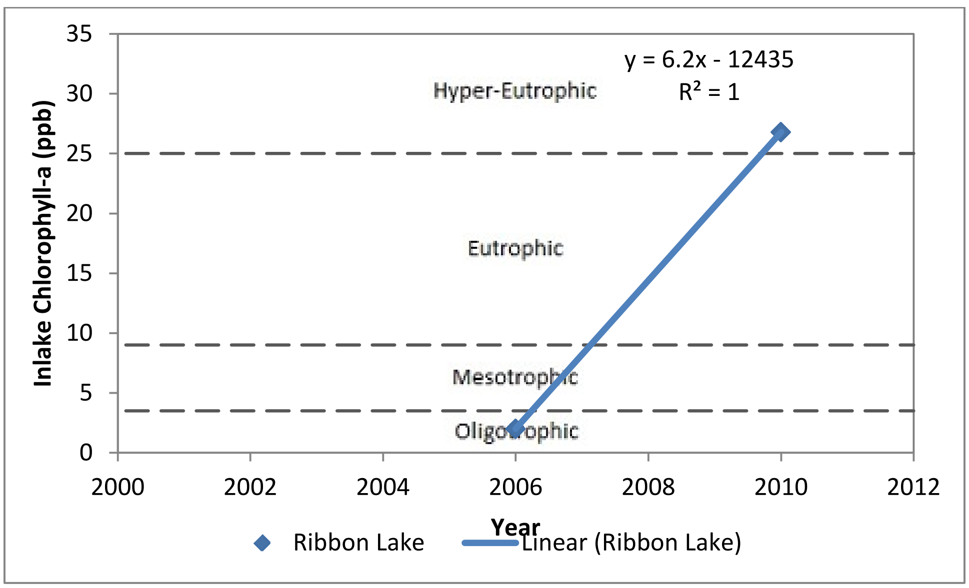

Figure 3.131: Inlake chlorophyll-a over time for Ribbon Lake

Figure 3.131 shows the average total inlake chlorophyll-a concentrations over time for Ribbon Lake. These values depict an increase in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The total inlake chlorophyll-a values were classified as slightly oligotrophic and slightly hyper-eutrophic.

3.33 **Riddle Lake**

Samples for Riddle Lake were collected in 1999, 2008, and 2010. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

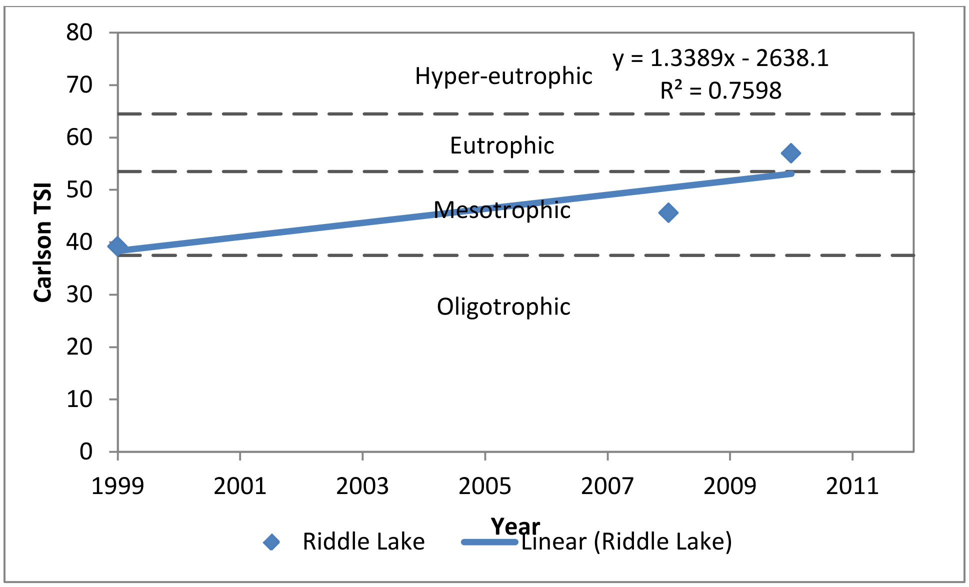

Figure 3.132: Carlson TSI over time for Riddle Lake

Figure 3.132 depicts the Carlson TSI values over time for Riddle Lake. The figure depicts an increase in TSI values over time with a relatively strong correlation coefficient of 0.7598. The TSI values vary in the range of slightly mesotrophic and eutrophic classification.

Figure 3.133 depicts the results of the Vollenweider Model over time for Riddle Lake. Only one total phosphorus vs. hydraulic residence time data point was calculated in July 2008 and it falls under the slightly hyper-eutrophic classification.

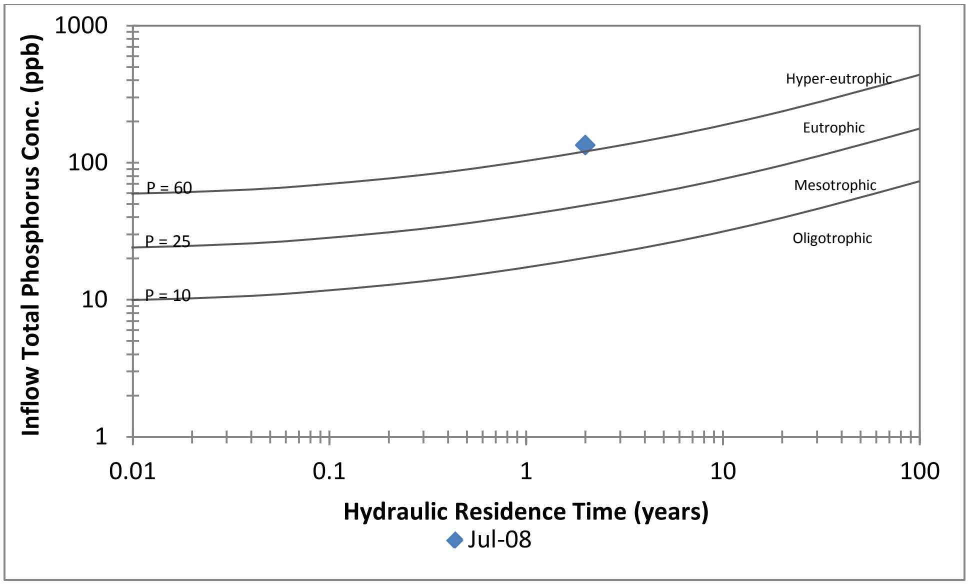

Figure 3.133: Vollenweider Model over time for Riddle Lake

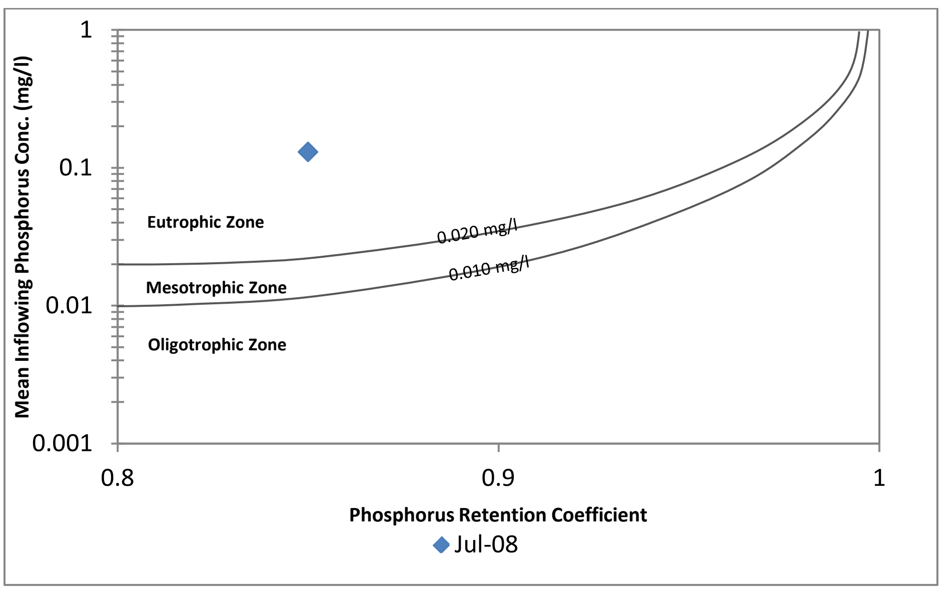

Figure 3.134: Larsen Mercier Model over time for Riddle Lake

Figure 3.134 shows the results of the Larsen Mercier Model over time for Riddle Lake. Only one total inlake phosphorus vs. phosphorus retention coefficient data point was calculated in July 2008 and it falls under the hyper-eutrophic classification.

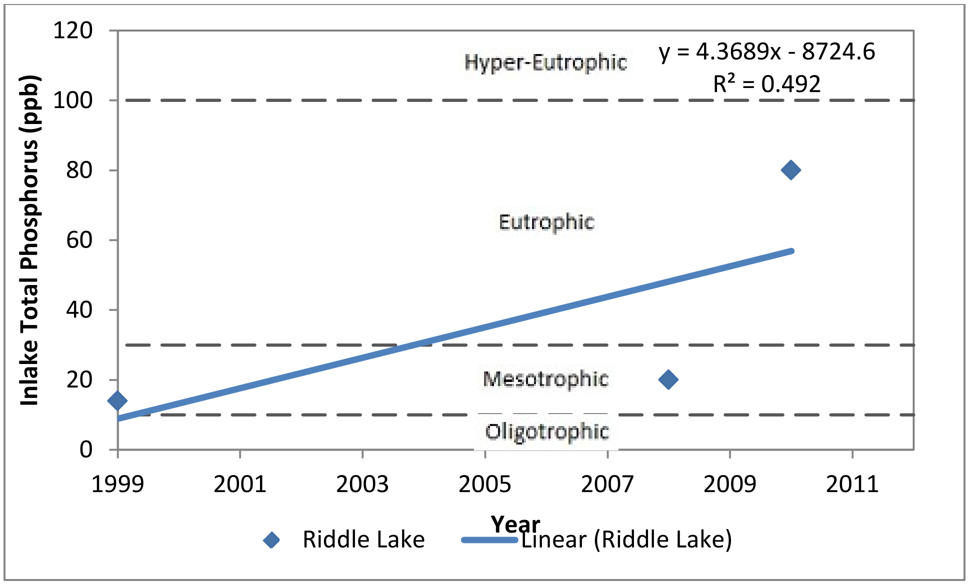

Figure 3.135: Inlake total phosphorus over time for Riddle Lake

Figure 3.135 shows the average total inlake phosphorus concentrations over time for Riddle Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.492. The phosphorus concentrations vary in the range of slightly mesotrophic to strongly eutrophic.

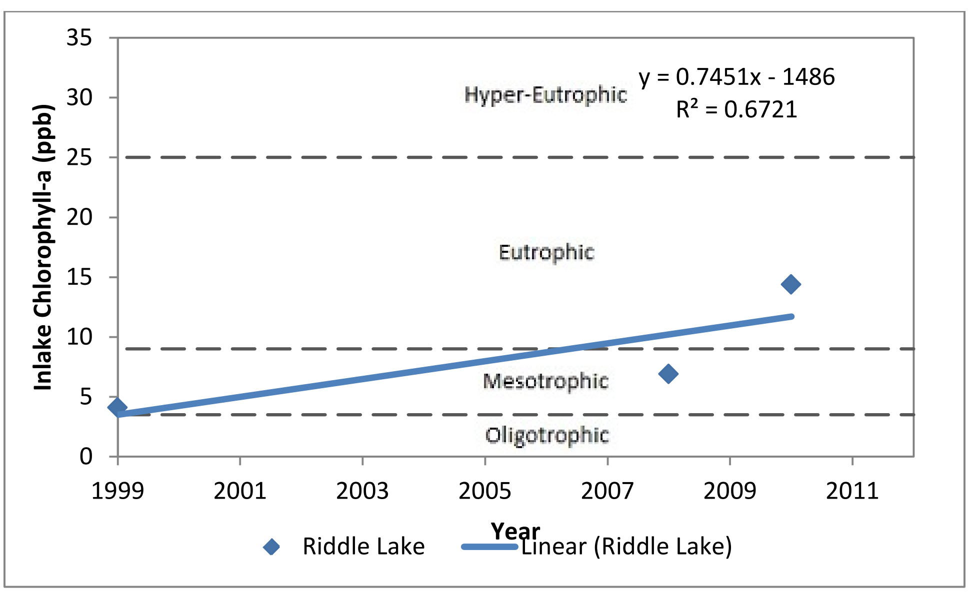

Figure 3.136: Inlake chlorophyll-a over time for Riddle Lake

Figure 3.136 shows the average total inlake chlorophyll-a concentrations over time for Riddle Lake. These values depict an increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.6721. The chlorophyll-a concentrations vary in the range of slightly mesotrophic to eutrophic.

3.34 **Scaup Lake**

Samples for Scaup Lake were collected in 2002, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

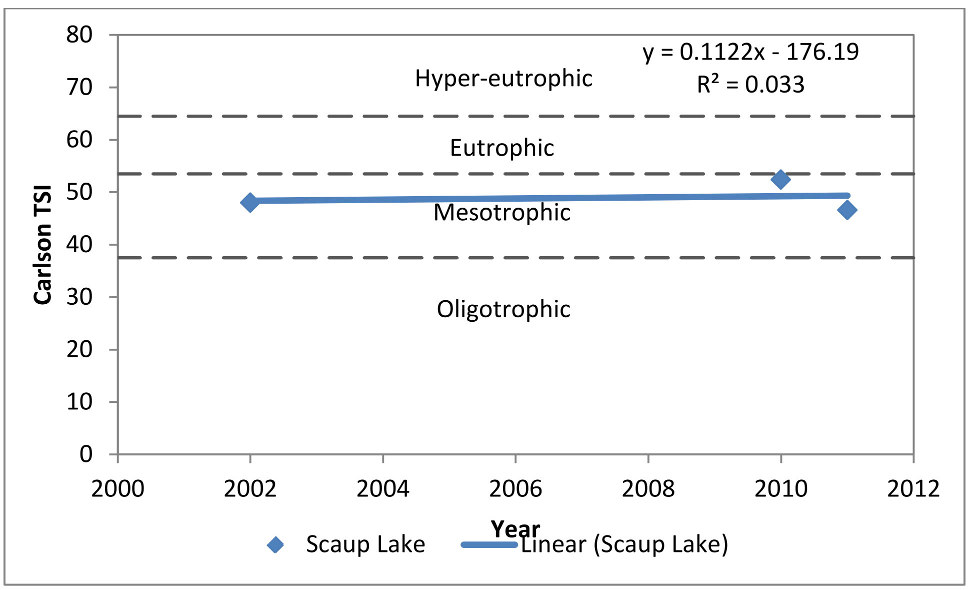

Figure 3.137: Carlson TSI over time for Scaup Lake

Figure 3.137 depicts the Carlson TSI values over time for Scaup Lake. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.033. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

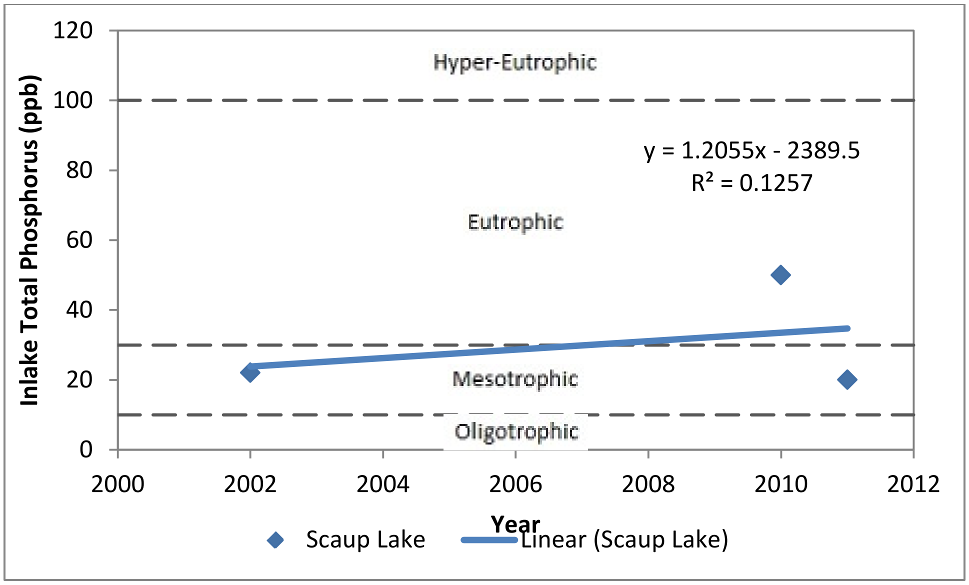

Figure 3.138: Inlake total phosphorus over time for Scaup Lake

Figure 3.138 shows the average total inlake phosphorus concentrations over time for Scaup Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.1257. The phosphorus concentrations vary in the range of mesotrophic to eutrophic.

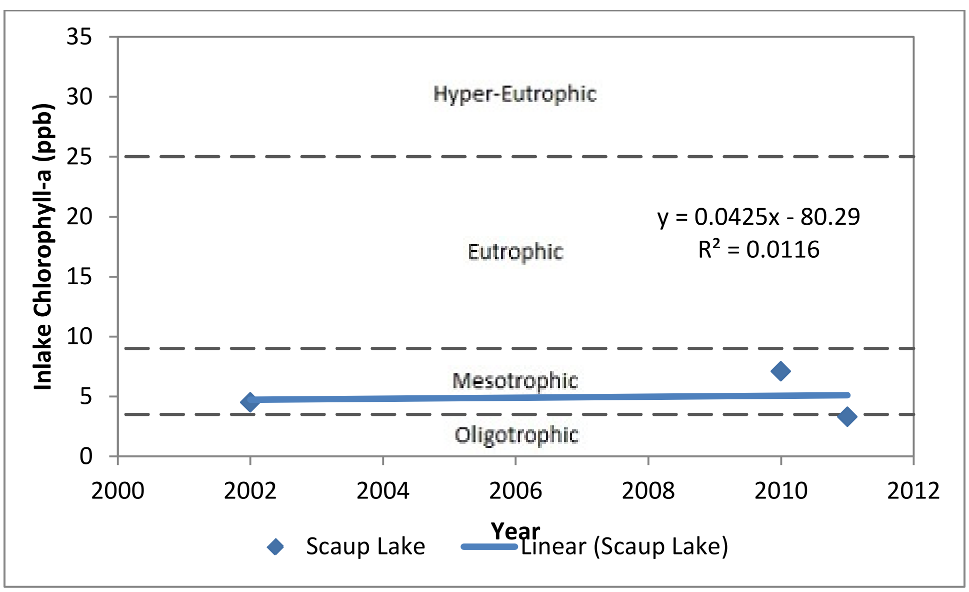

Figure 3.139: Inlake chlorophyll-a over time for Scaup Lake

Figure 3.139 shows the average total inlake chlorophyll-a concentrations over time for Scaup Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0116. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to strongly mesotrophic.

3.35 **Shoshone Lake**

Samples for Shoshone Lake were collected in 1998-1999, and 2010. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

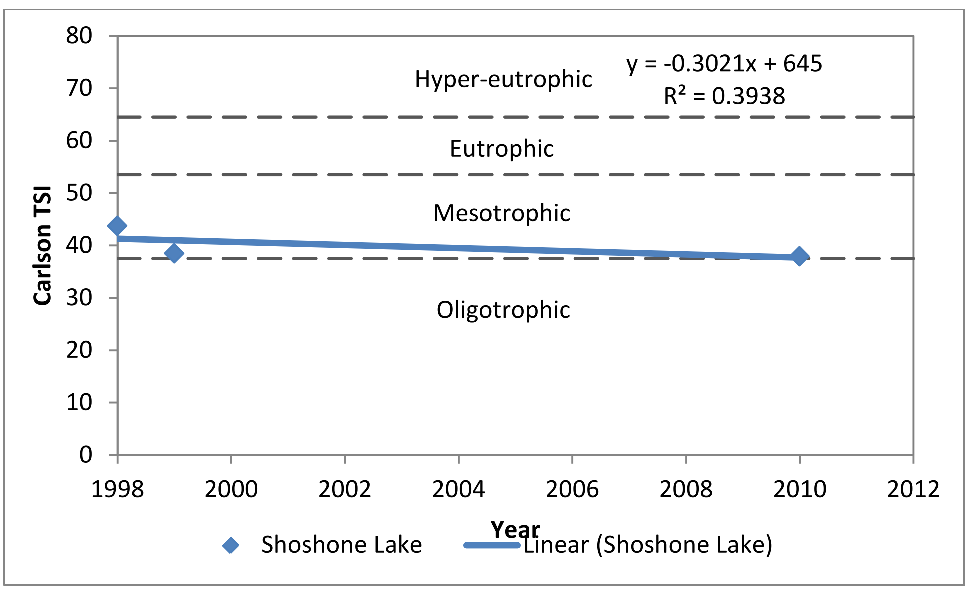

Figure 3.140: Carlson TSI over time for Shoshone Lake

Figure 3.140 depicts the Carlson TSI values over time for Shoshone Lake. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.3938. The TSI values vary in the range of slightly mesotrophic and mesotrophic classification.

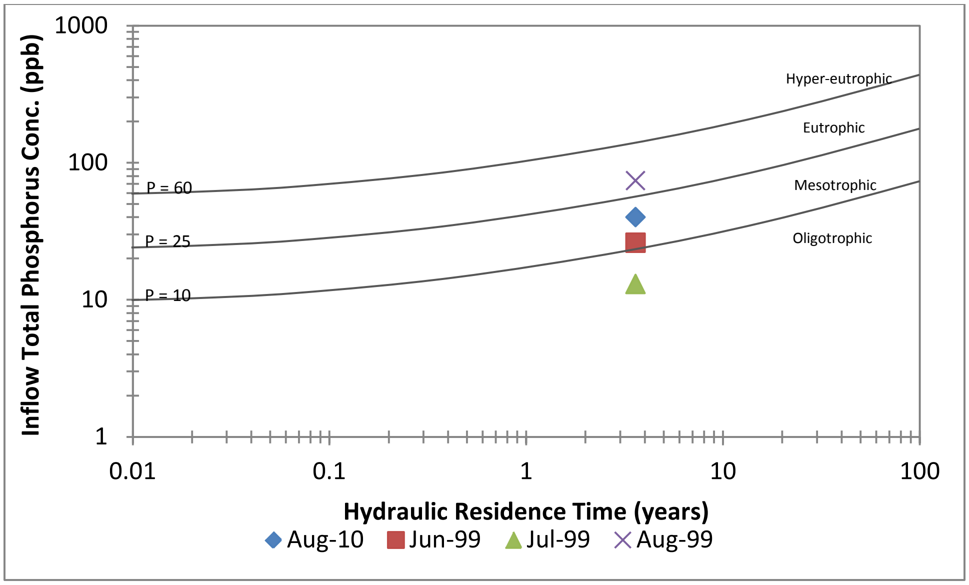

Figure 3.141: Vollenweider Model over time for Shoshone Lake

Figure 3.141 depicts the results of the Vollenweider Model over time for Shoshone Lake. The total phosphorus vs. hydraulic residence time data points range from oligotrophic in July 1999 to eutrophic in August 1999.

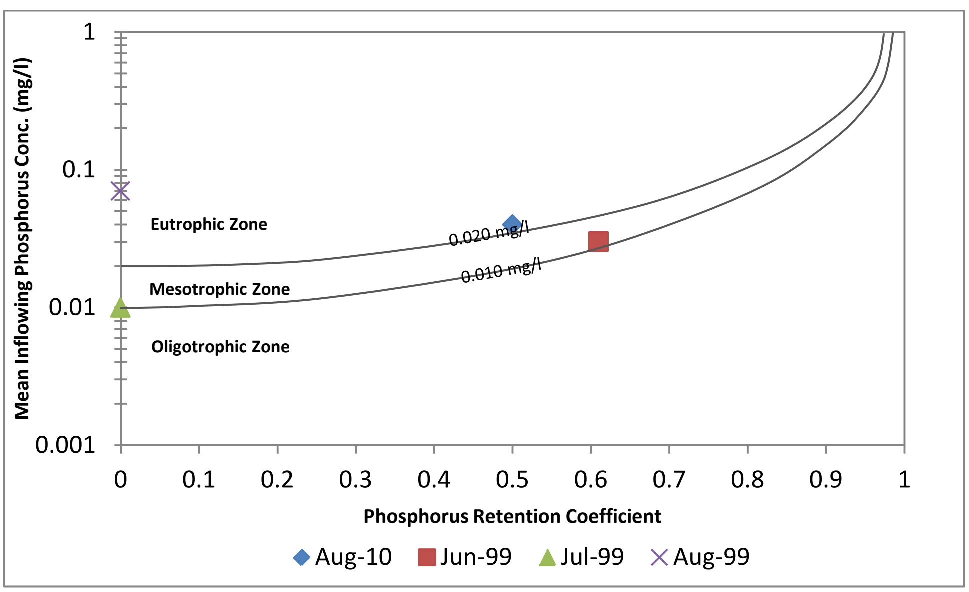

Figure 3.142: Larsen Mercier Model over time for Shoshone Lake

Figure 3.142 shows the results of the Larsen Mercier Model over time for Shoshone Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from oligotrophic in July 1999 to strongly eutrophic in August 1999.

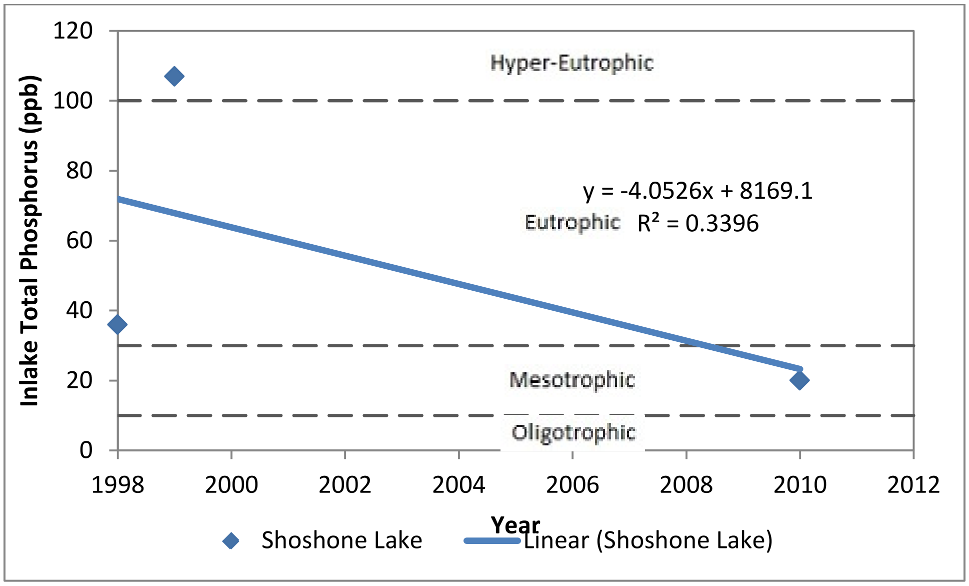

Figure 3.143: Inlake total phosphorus over time for Shoshone Lake

Figure 3.143 shows the average total inlake phosphorus concentrations over time for Shoshone Lake. These values depict a decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.3396. The phosphorus concentrations vary in the range of mesotrophic to slightly hyper-eutrophic.

Figure 3.144 shows the average total inlake chlorophyll-a concentrations over time for Shoshone Lake. These values depict a slight decrease in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.8784. The chlorophyll-a concentrations all fall in the range of oligotrophic.

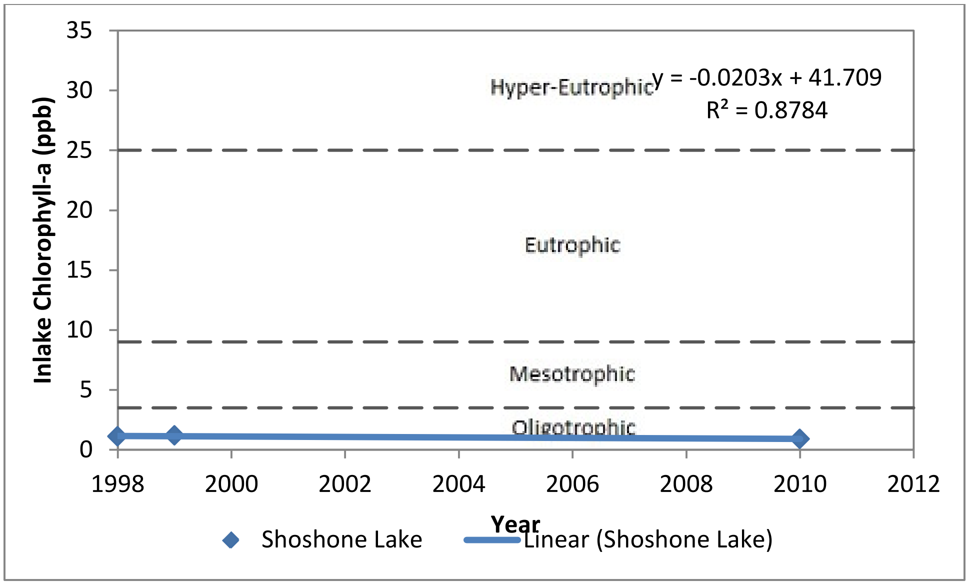

Figure 3.144: Inlake chlorophyll-a over time for Shoshone Lake

3.36 Shrimp Lake

Samples for Shrimp Lake were collected in 2004-2005, and 2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

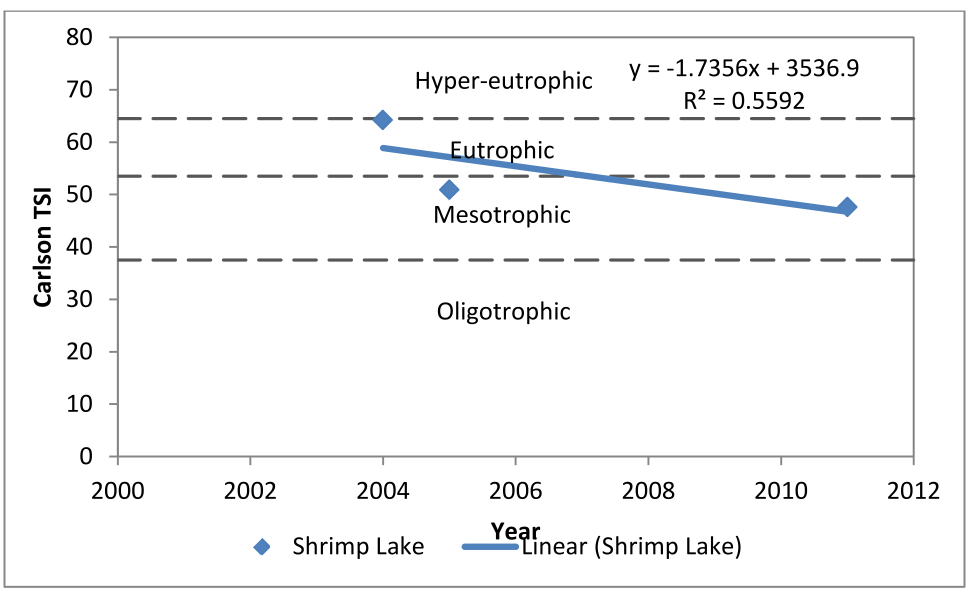

Figure 3.145: Carlson TSI over time for Shrimp Lake

Figure 3.145 depicts the Carlson TSI values over time for Shrimp Lake. The figure depicts a decrease in TSI values over time with a relatively strong correlation coefficient of 0.5592. The TSI values vary in the range of mesotrophic and strongly eutrophic classification.

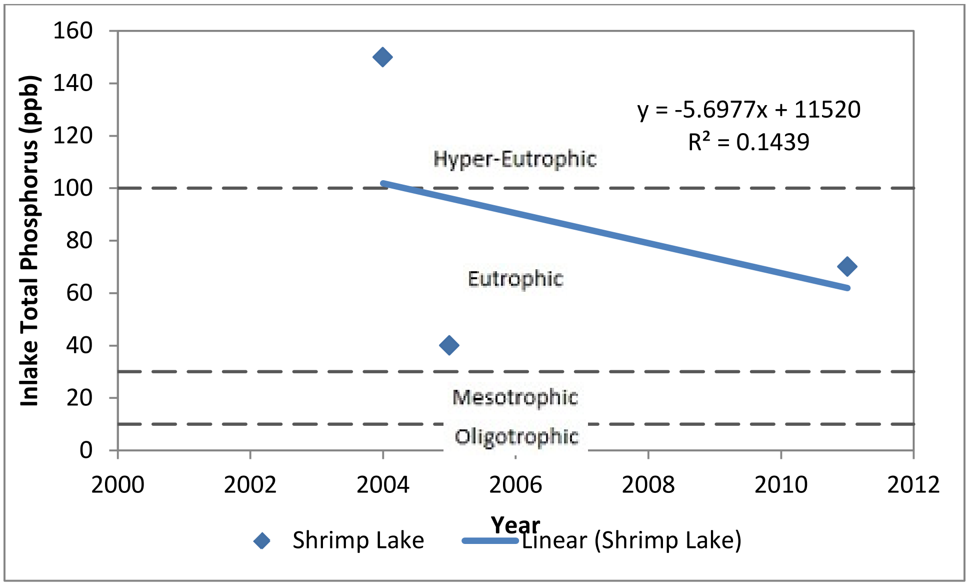

Figure 3.146: Inlake total phosphorus over time for Shrimp Lake

Figure 3.146 shows the average total inlake phosphorus concentrations over time for Shrimp Lake. These values depict a decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.1439. The phosphorus concentrations vary in the range of slightly eutrophic to hyper-eutrophic.

Figure 3.147 shows the average total inlake chlorophyll-a concentrations over time for Shrimp Lake. These values depict a decrease in inlake chlorophyll-a with a strong correlation coefficient of 0.9826. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly eutrophic.

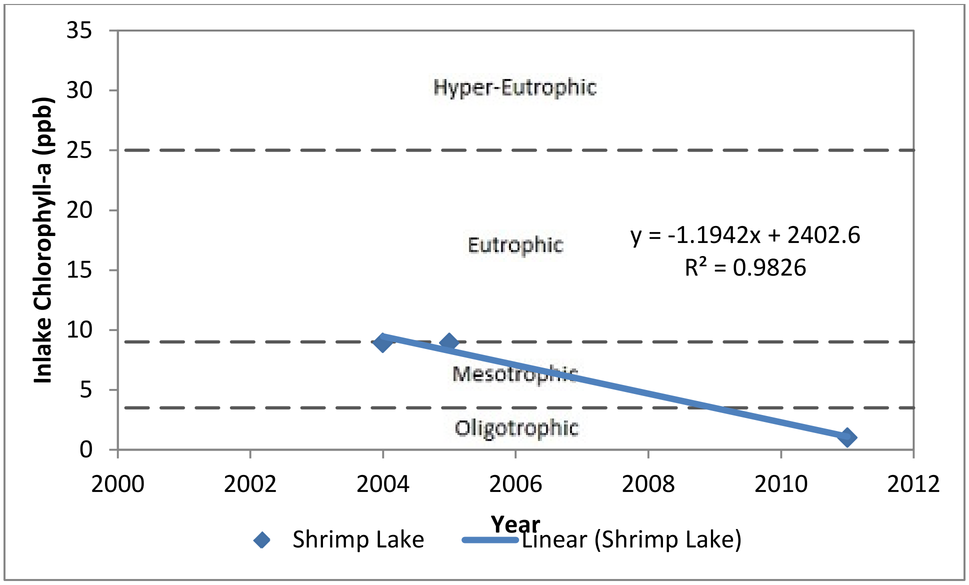

Figure 3.147: Inlake chlorophyll-a over time for Shrimp Lake

3.37 South Twin Lake

Samples for South Twin Lake were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below. The inlet values for South Twin Lake come from the inlake values of North Twin Lake as the latter feeds into the former.

Figure 3.148 depicts the Carlson TSI values over time for South Twin Lake. The figure depicts a slight increase in TSI values over time with a relatively strong correlation coefficient of 0.8038. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

Figure 3.149 depicts the results of the Vollenweider Model over time for South Twin Lake. The total phosphorus vs. hydraulic residence time data points range from slightly oligotrophic in August 2001 to hyper-eutrophic in July 2009.

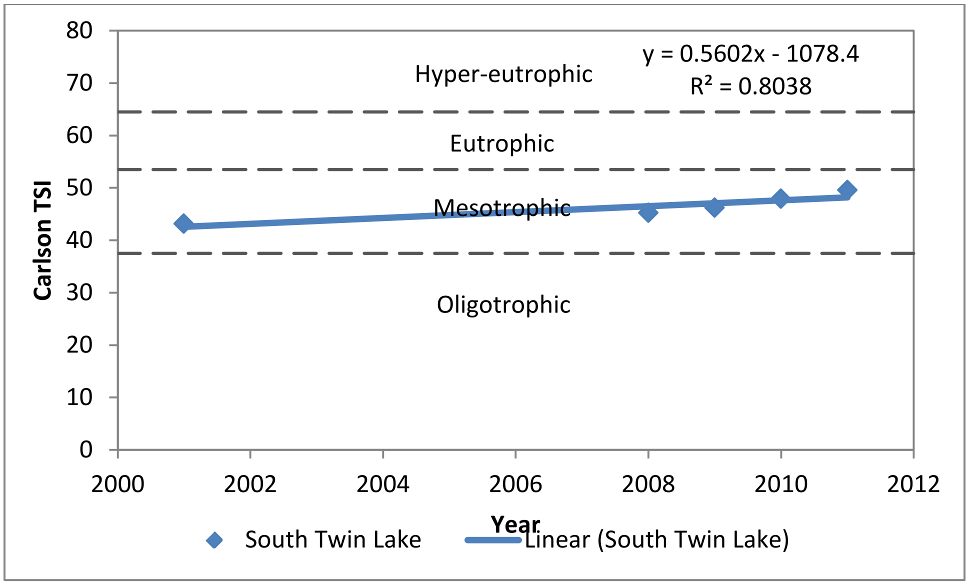

Figure 3.148: Carlson TSI over time for South Twin Lake.

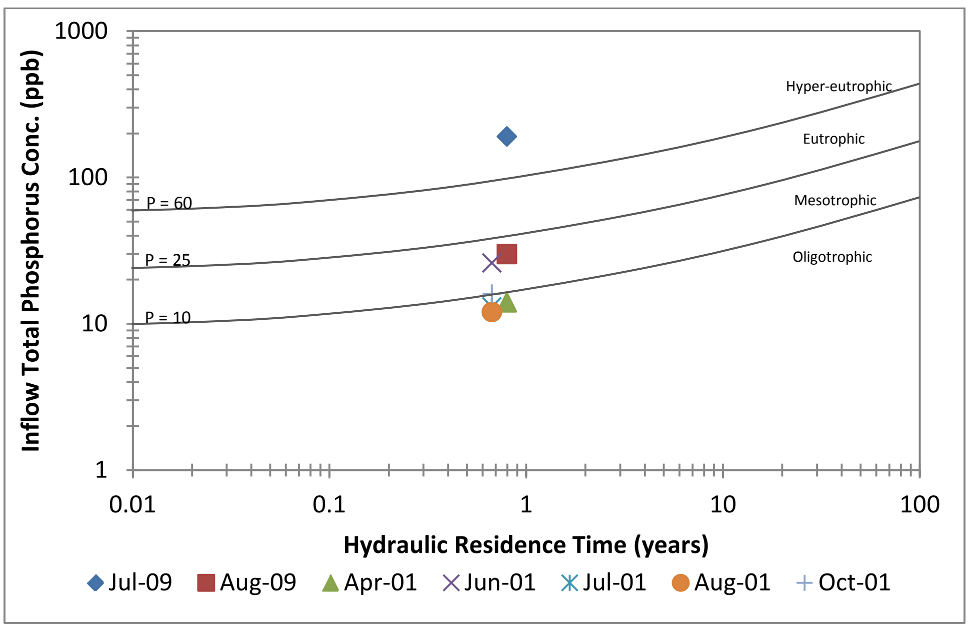

Figure 3.149: Vollenweider Model over time for South Twin Lake

Figure 3.150 shows the results of the Larsen Mercier Model over time for South Twin Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from slightly oligotrophic in August 2001 to eutrophic in July 2009. The majority of the data points are in the range of slightly eutrophic to strongly eutrophic.

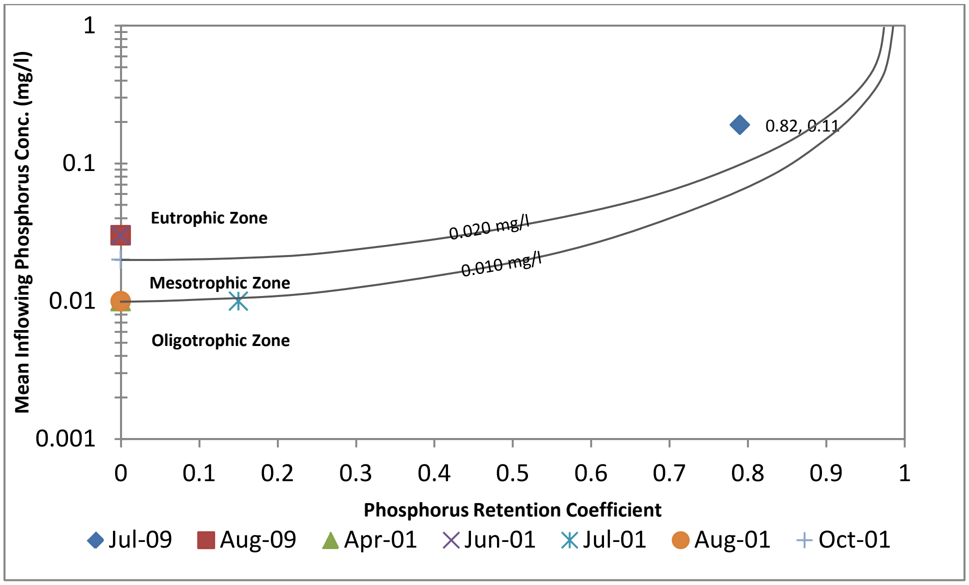

Figure 3.150: Larsen Mercier Model over time for South Twin Lake

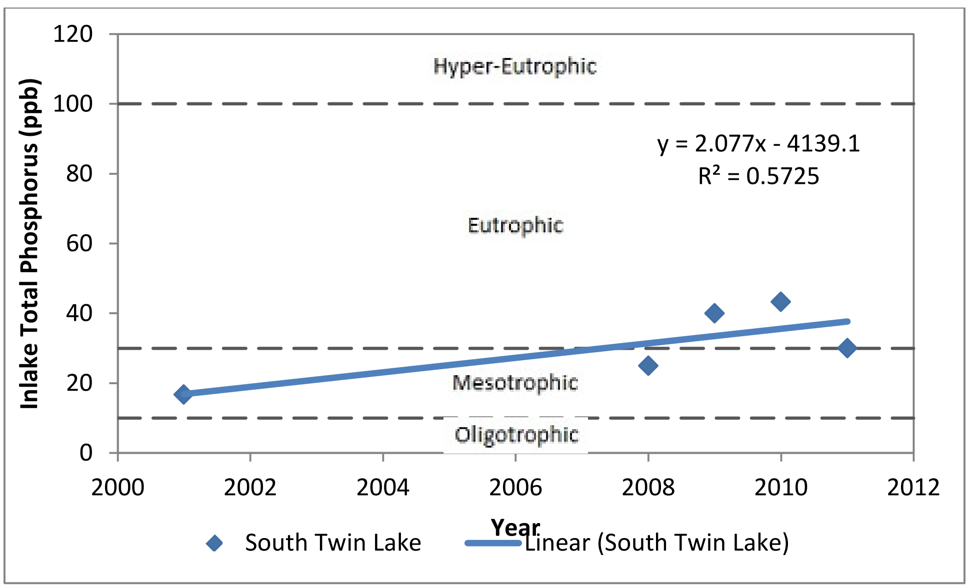

Figure 3.151: Inlake total phosphorus over time for South Twin Lake

Figure 3.151 shows the average total inlake phosphorus concentrations over time for South Twin Lake. These values depict an increase in inlake phosphorus with a relatively strong correlation coefficient of 0.5725. The phosphorus concentrations vary in the range of mesotrophic to eutrophic.

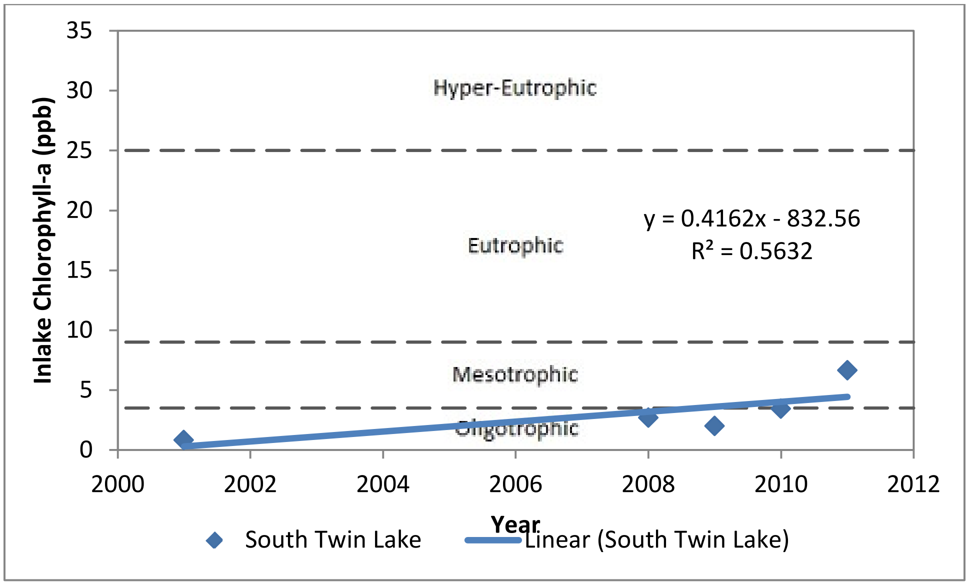

Figure 3.152: Inlake chlorophyll-a over time for South Twin Lake

Figure 3.152 shows the average total inlake chlorophyll-a concentrations over time for South Twin Lake. These values depict an increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.5632. The chlorophyll-a concentrations vary in the range of oligotrophic to strongly mesotrophic.

3.38 **Swan Lake**

Samples for Swan Lake were collected in 2001, and 2008-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.153 depicts the Carlson TSI values over time for Swan Lake. The figure depicts a slight increase in TSI values over time with a relatively strong correlation coefficient of 0.7844. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

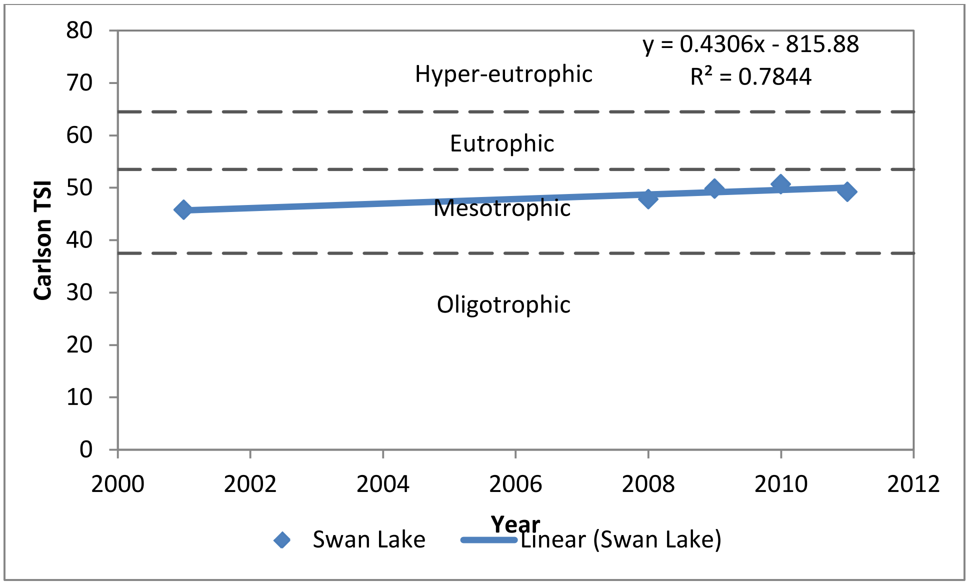

Figure 3.153: Carlson TSI over time for Swan Lake

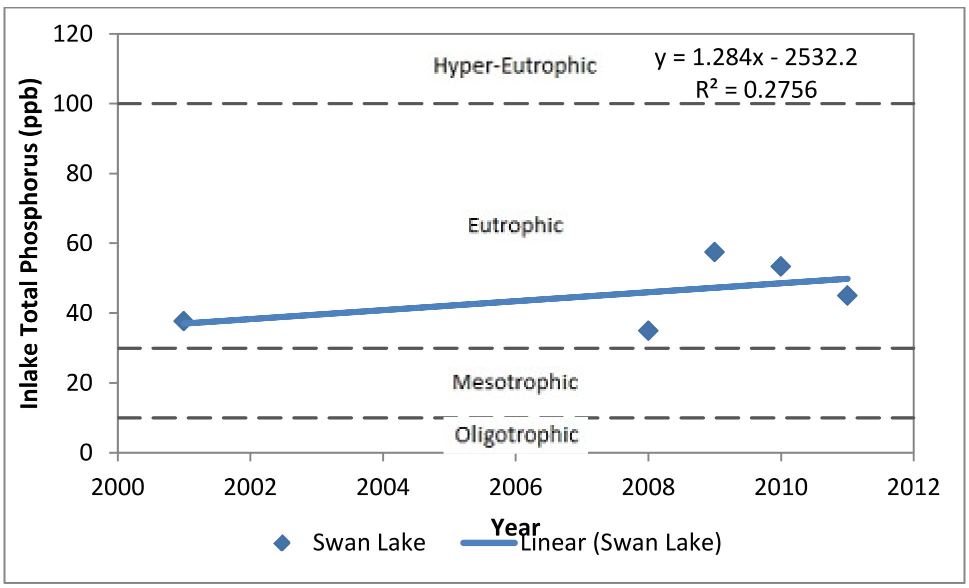

Figure 3.154: Inlake total phosphorus over time for Swan Lake

Figure 3.154 shows the average total inlake phosphorus concentrations over time for Swan Lake. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.2756. The phosphorus concentrations vary in the range of slightly eutrophic to eutrophic.

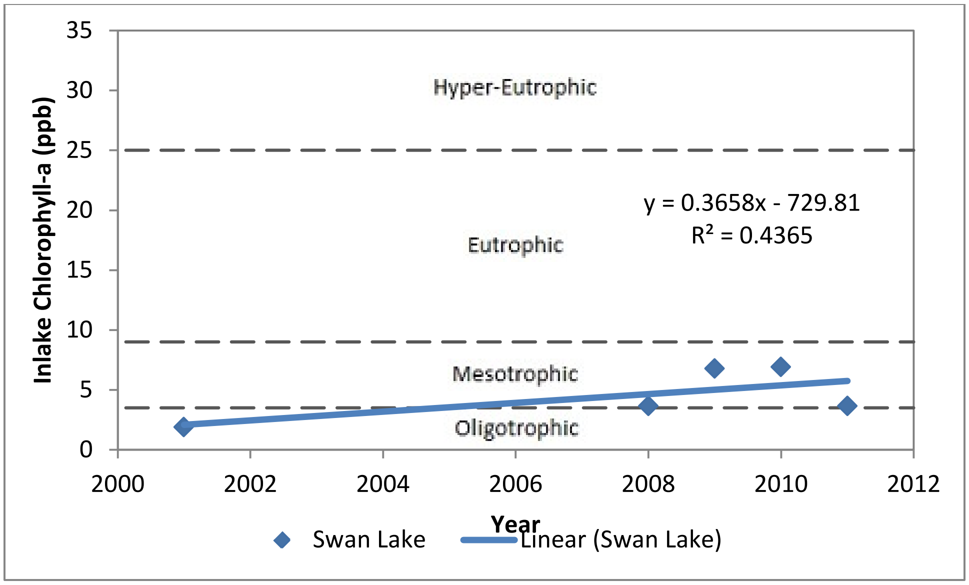

Figure 3.155: Inlake chlorophyll-a over time for Swan Lake

Figure 3.155 shows the average total inlake chlorophyll-a concentrations over time for Swan Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively average in strength correlation coefficient of 0.4365. The chlorophyll-a concentrations vary in the range of slightly oligotrophic to strongly mesotrophic.

3.39 **Sylvan Lake**

Samples for Sylvan Lake were collected in 2004, and 2008-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.156 depicts the Carlson TSI values over time for Sylvan Lake. The figure depicts a slight decrease in TSI values over time with a relatively average correlation coefficient of 0.3425. The TSI values vary in the range of slightly oligotrophic and slightly mesotrophic classification.

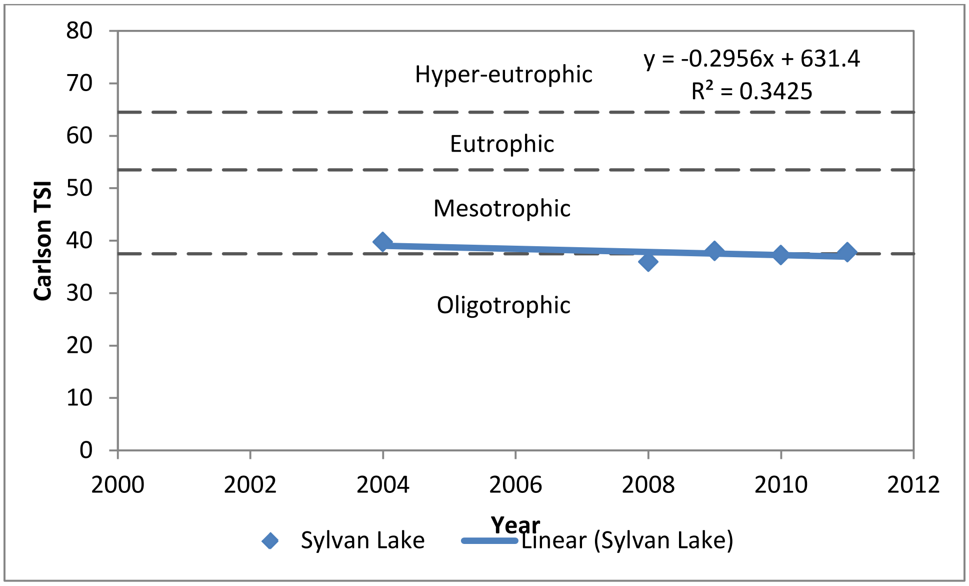

Figure 3.156: Carlson TSI over time for Sylvan Lake

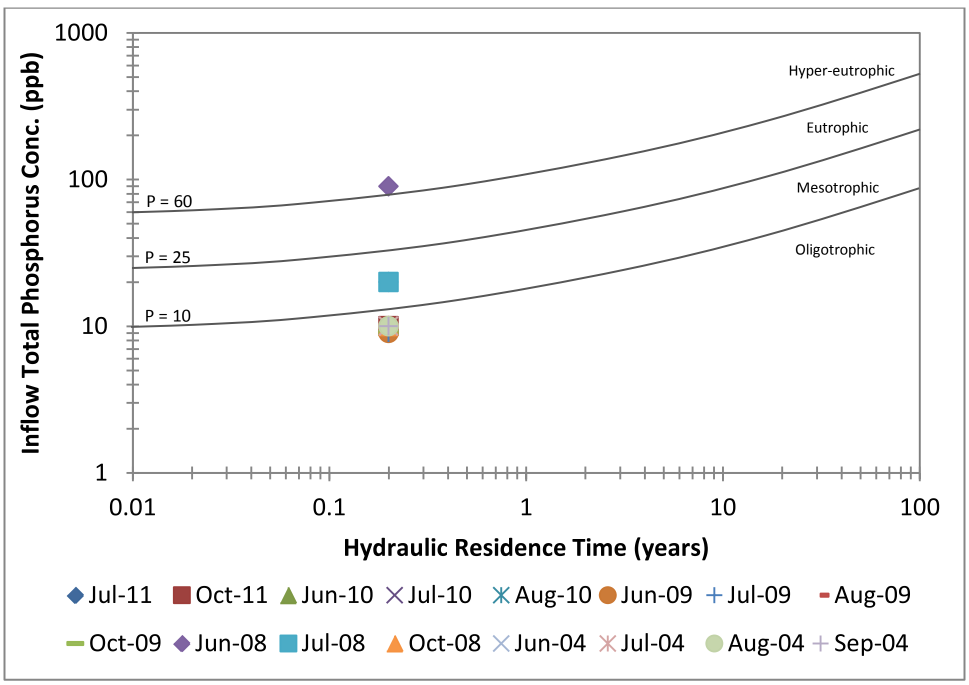

Figure 3.157: Vollenweider Model over time for Sylvan Lake

Figure 3.157 depicts the results of the Vollenweider Model over time for Sylvan Lake. The total phosphorus vs. hydraulic residence time data points range from slightly oligotrophic in June 2009 to slightly hyper-eutrophic in June 2008.

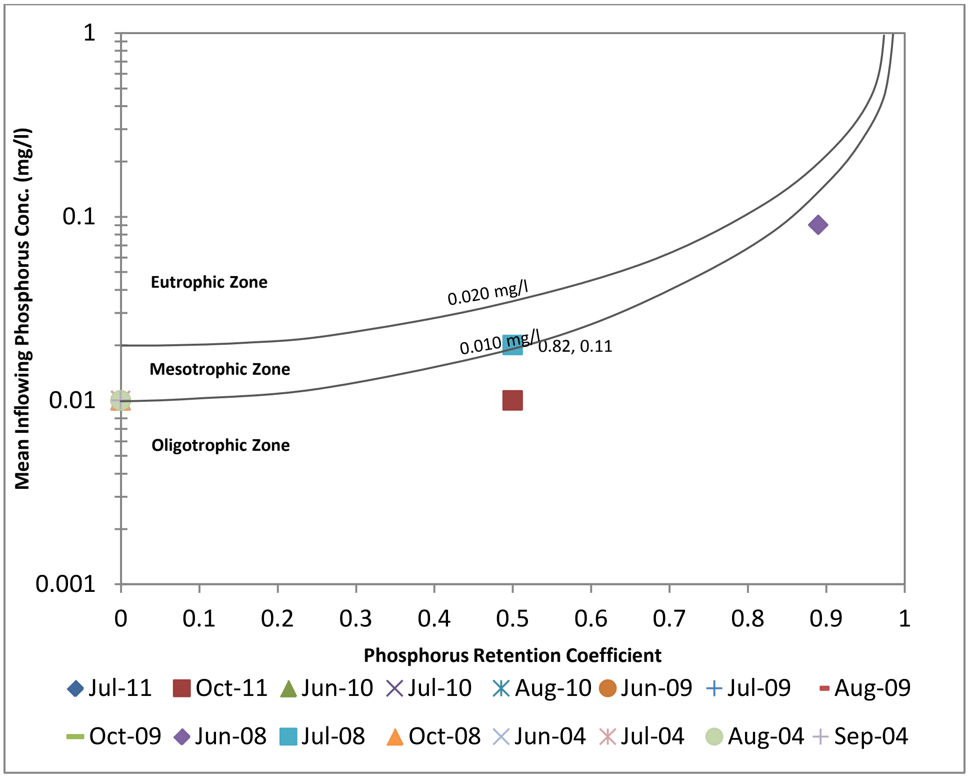

Figure 3.158: Larsen Mercier Model over time for Sylvan Lake

Figure 3.158 shows the results of the Larsen Mercier Model over time for Sylvan Lake. The total inlet phosphorus vs. phosphorus retention coefficient data points range from oligotrophic in October 2011 to slightly mesotrophic in July 2008.

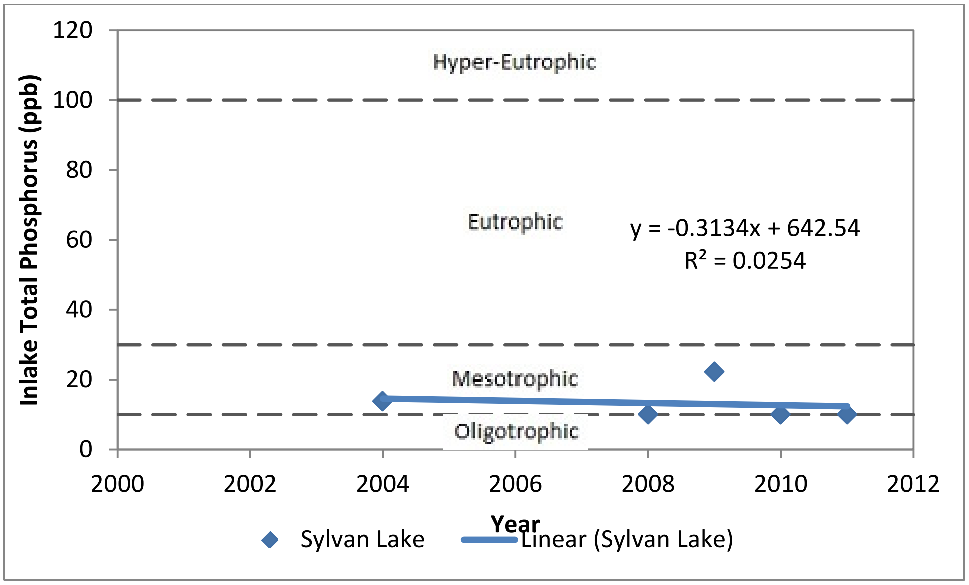

Figure 3.159: Inlake total phosphorus over time for Sylvan Lake

Figure 3.159 shows the average total inlake phosphorus concentrations over time for Sylvan Lake. These values depict a slight decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.0254. The phosphorus concentrations vary in the range of slightly oligotrophic to strongly mesotrophic.

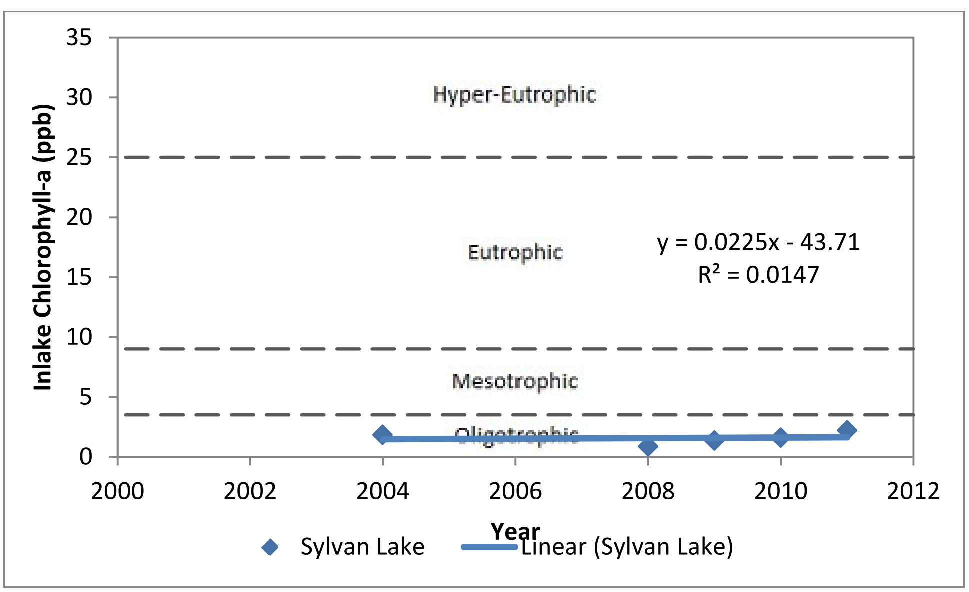

Figure 3.160: Inlake chlorophyll-a over time for Sylvan Lake

Figure 3.160 shows the average total inlake chlorophyll-a concentrations over time for Sylvan Lake. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0147. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly oligotrophic.

3.40 **Tanager Lake**

Samples for Tanager Lake were collected in 2004, and 2009-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

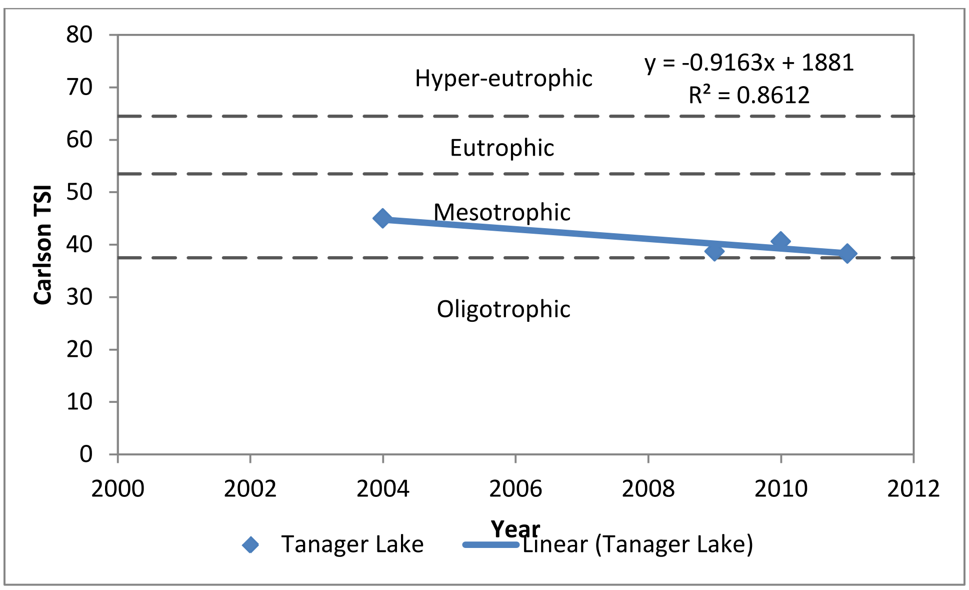

Figure 3.161: Carlson TSI over time for Tanager Lake

Figure 3.161 depicts the Carlson TSI values over time for Tanager Lake. The figure depicts a slight decrease in TSI values over time with a strong correlation coefficient of 0.8612. The TSI values vary in the range of slightly mesotrophic and mesotrophic classification.

Figure 3.162 shows the average total inlake phosphorus concentrations over time for Tanager Lake. These values depict a slight decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.3103. The phosphorus concentrations vary in the range of slightly mesotrophic to mesotrophic.

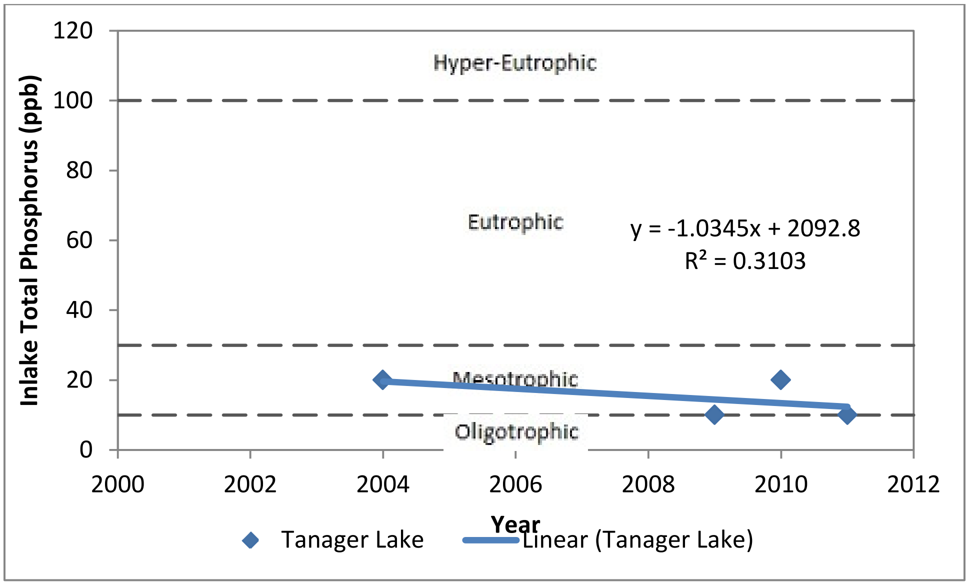

Figure 3.162: Inlake total phosphorus over time for Tanager Lake

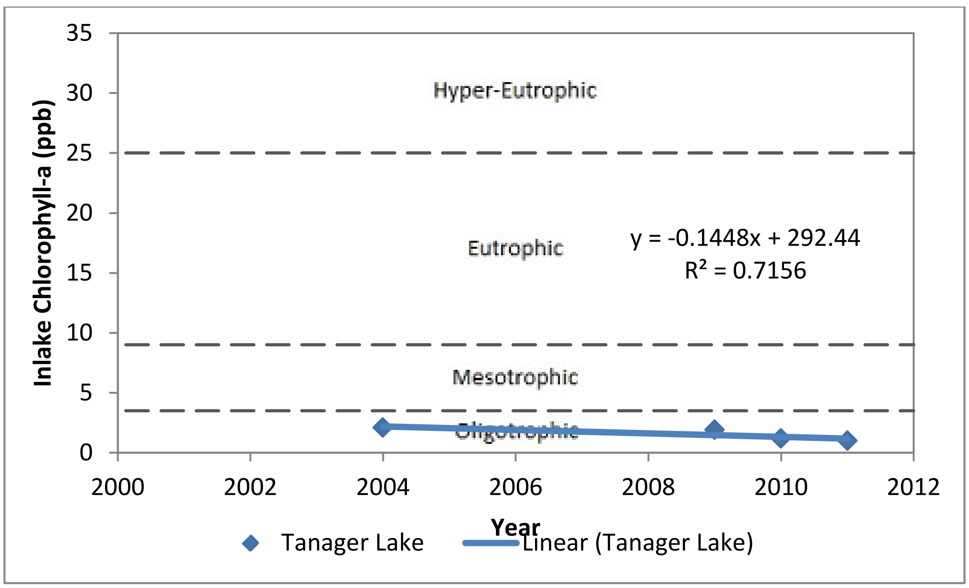

Figure 3.163: Inlake chlorophyll-a over time for Tanager Lake

Figure 3.163 shows the average total inlake chlorophyll-a concentrations over time for Tanager Lake. These values depict a slight decrease in inlake chlorophyll-a with a strong correlation coefficient of 0.7156. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly oligotrophic.

3.41 **Terrace Springs**

Samples for Terrace Springs were collected in 2007, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

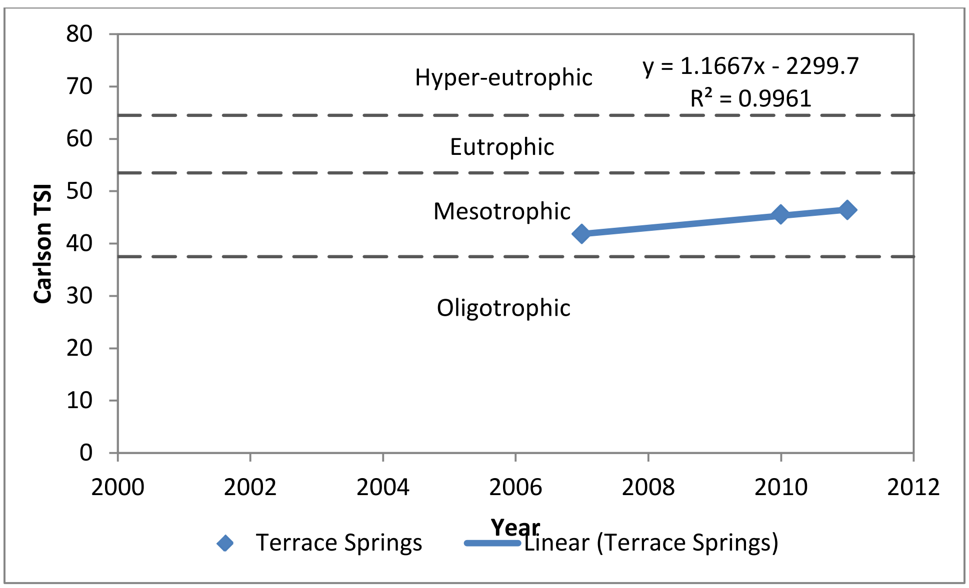

Figure 3.164: Carlson TSI over time for Terrace Springs

Figure 3.164 depicts the Carlson TSI values over time for Terrace Springs. The figure depicts an increase in TSI values over time with a strong correlation coefficient of 0.9961. The strong correlation could be explained by the limited number of data points (three). The TSI values vary in the range of slightly mesotrophic and mesotrophic classification.

Figure 3.165 shows the average total inlake phosphorus concentrations over time for Terrace Springs. These values depict an increase in inlake phosphorus with a relatively average correlation coefficient of 0.5192. The phosphorus concentrations all fall under the eutrophic classification based on the TP Model.

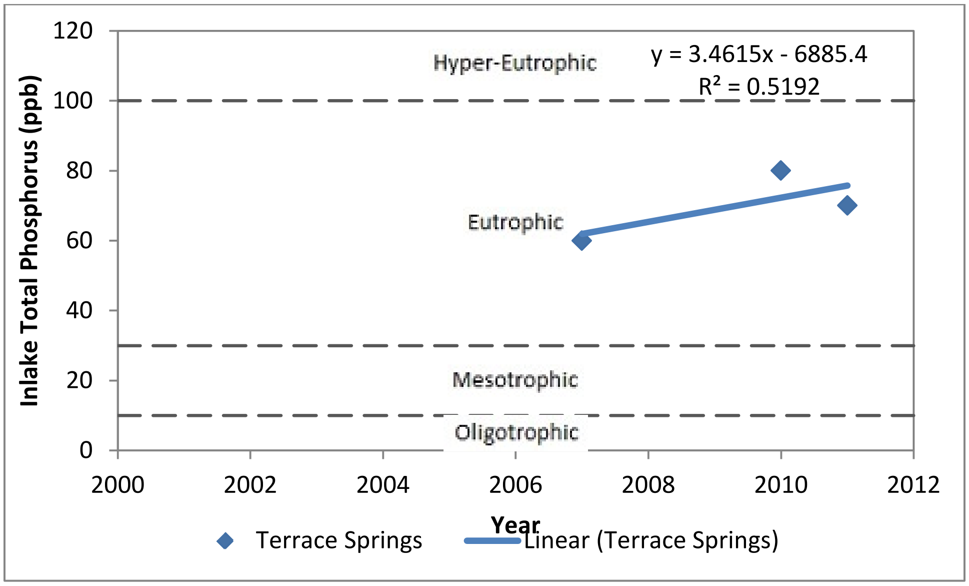

Figure 3.165: Inlake total phosphorus over time for Terrace Springs

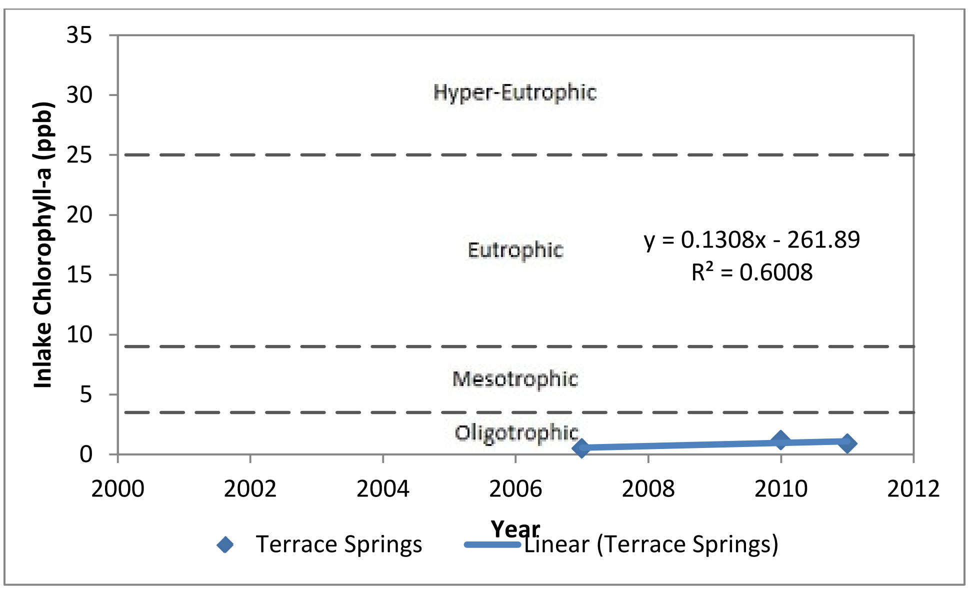

Figure 3.166: Inlake chlorophyll-a over time for Terrace Springs

Figure 3.166 shows the average total inlake chlorophyll-a concentrations over time for Terrace Springs. These values depict a slight increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.6008. The chlorophyll-a concentrations all fall under the oligotrophic classification based on the chlorophyll-a model.

3.42 **Trout Lake East**

Samples for Trout Lake East were collected in 2004-2011. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

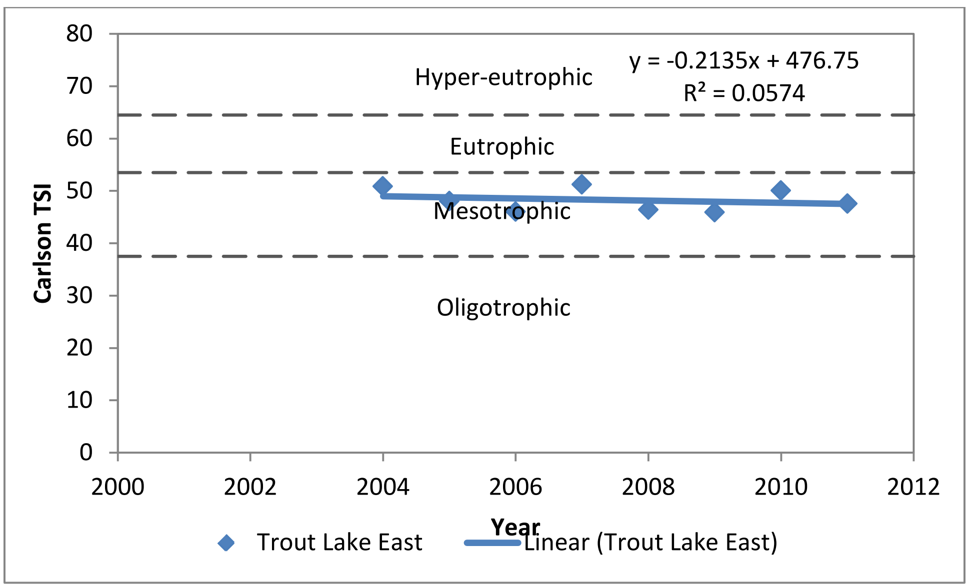

Figure 3.167: Carlson TSI over time for Trout Lake East

Figure 3.167 depicts the Carlson TSI values over time for Trout Lake East. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.0574. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

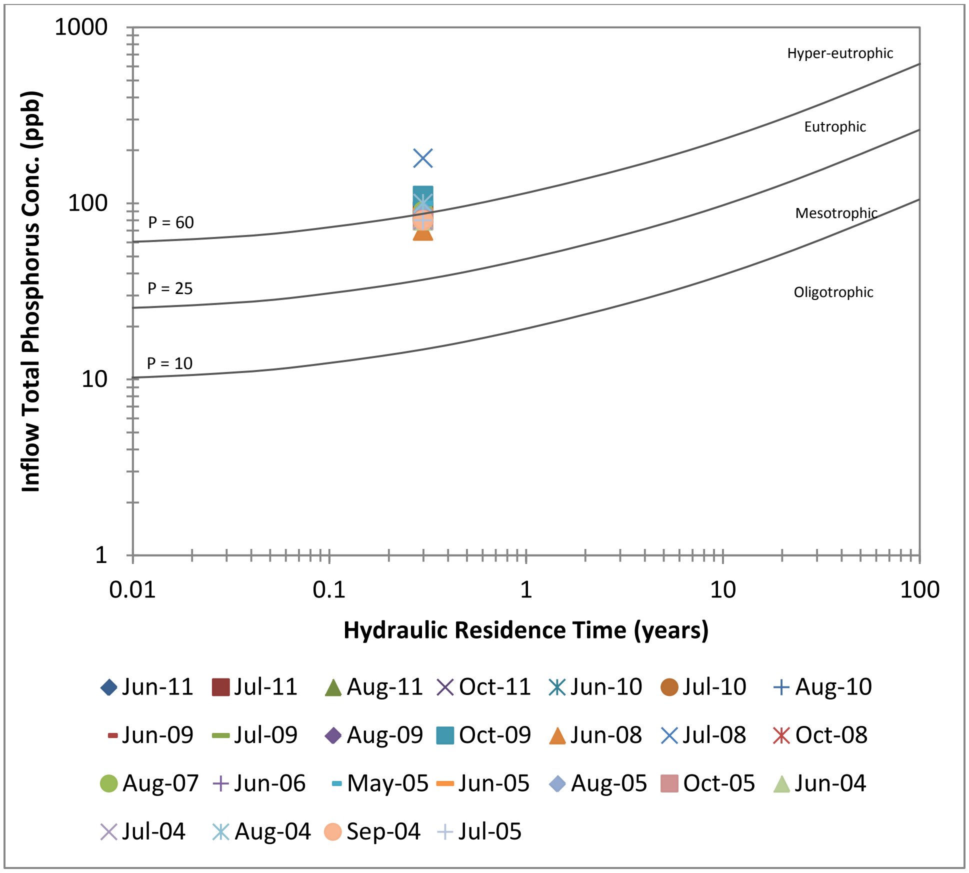

Figure 3.168: Vollenweider Model over time for Trout Lake East

Figure 3.168 depicts the results of the Vollenweider Model over time for Trout Lake East. The total phosphorus vs. hydraulic residence time data points range from eutrophic in June 2008 to hyper-eutrophic in July 2008.

Figure 3.169 shows the results of the Larsen Mercier Model over time for Trout Lake East. The total inlet phosphorus vs. phosphorus retention coefficient data points range from strongly eutrophic in June 2008 to hyper-eutrophic in August 2004.

Figure 3.170 shows the average total inlake phosphorus concentrations over time for Trout Lake East. These values depict an increase in inlake phosphorus with a relatively weak correlation coefficient of 0.0667. The phosphorus concentrations vary in the range of eutrophic to hyper-eutrophic.

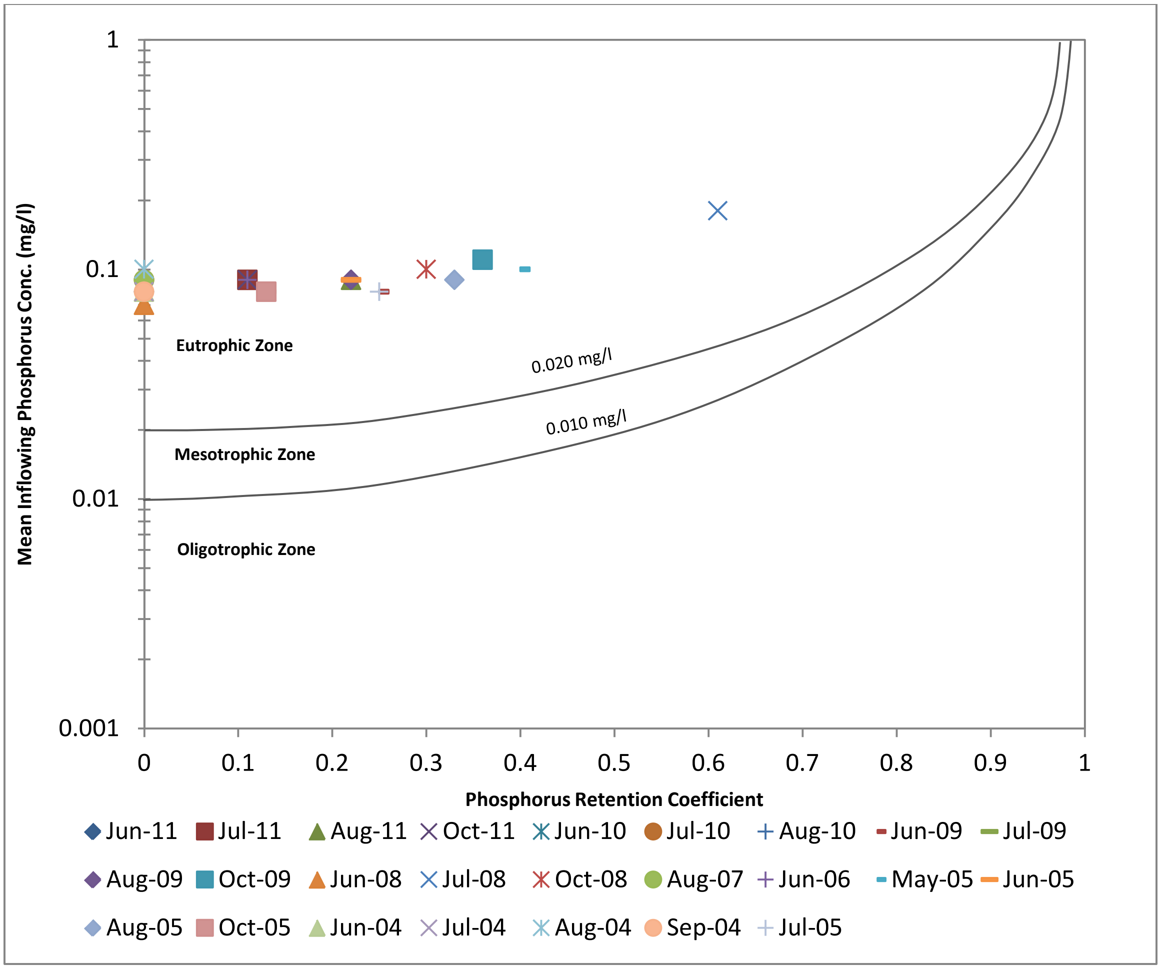

Figure 3.169: Larsen Mercier Model over time for Trout Lake East

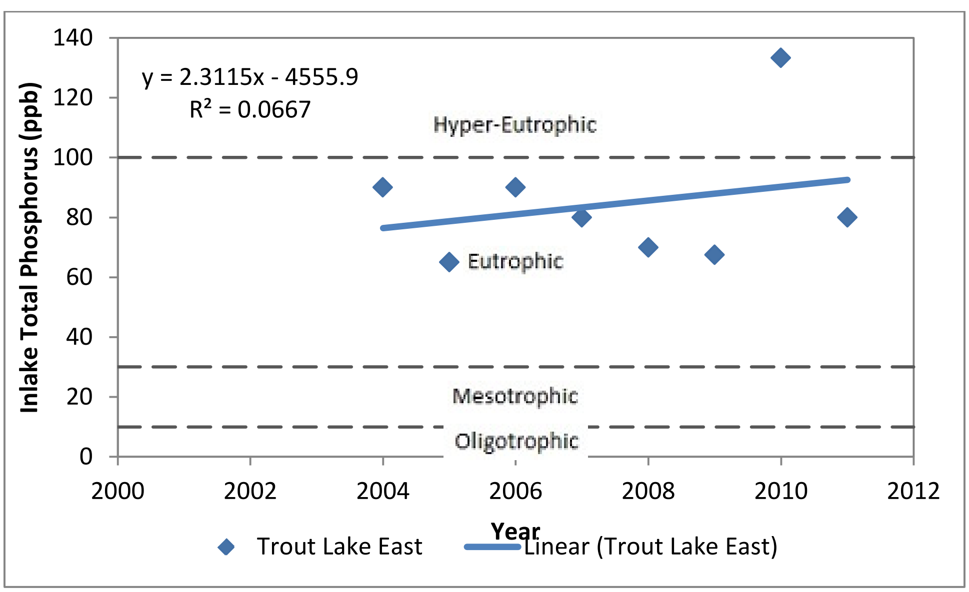

Figure 3.170: Inlake total phosphorus over time for Trout Lake East

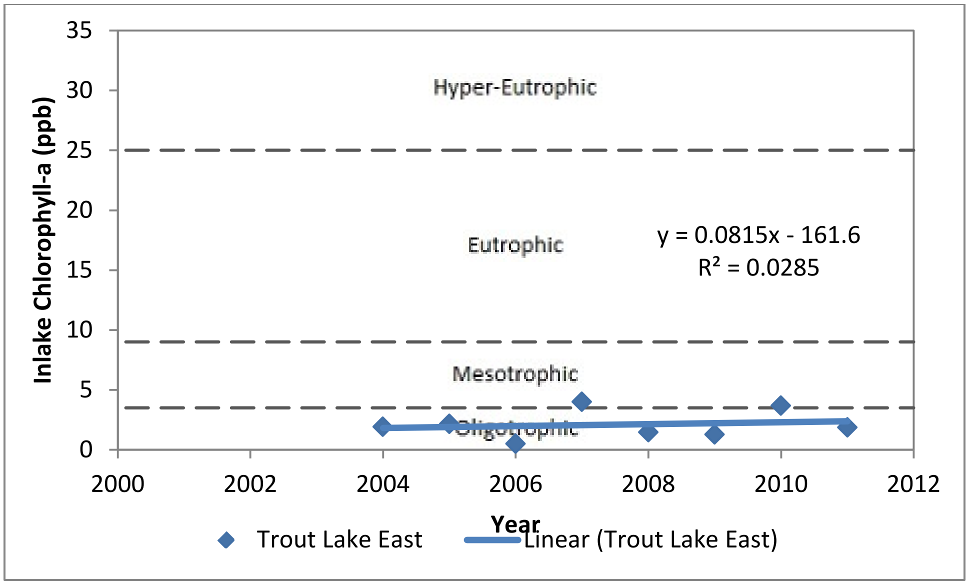

Figure 3.171: Inlake chlorophyll-a over time for Trout Lake East

Figure 3.171 shows the average total inlake chlorophyll-a concentrations over time for Trout Lake East. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.0285. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly mesotrophic.

3.43 **Trout Lake West**

Samples for Trout Lake West were collected in 2005, and 2009-2010. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.172 depicts the Carlson TSI values over time for Trout Lake West. The figure depicts a slight increase in TSI values over time with a relatively average correlation coefficient of 0.4544. The TSI values vary in the range of mesotrophic and strongly mesotrophic classification.

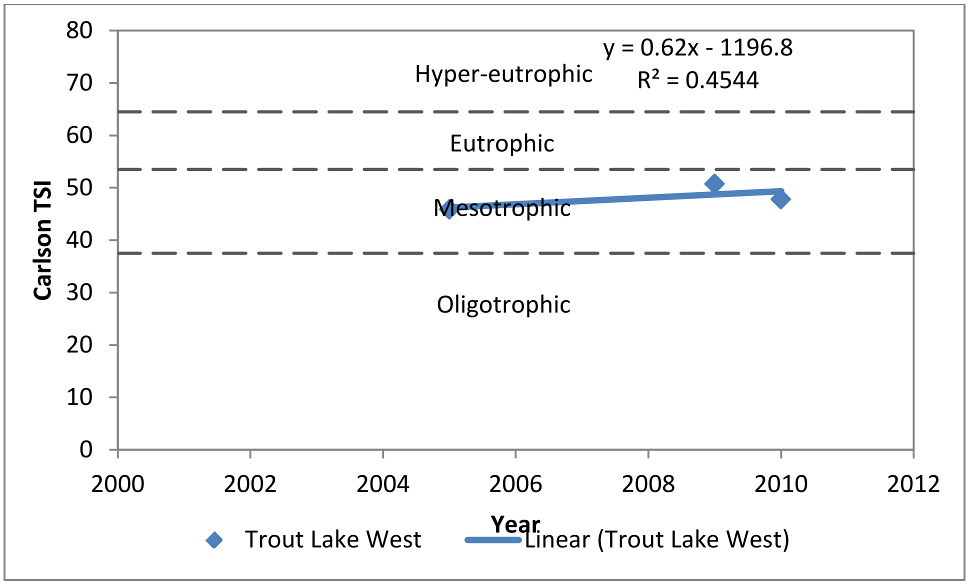

Figure 3.172: Carlson TSI over time for Trout Lake West

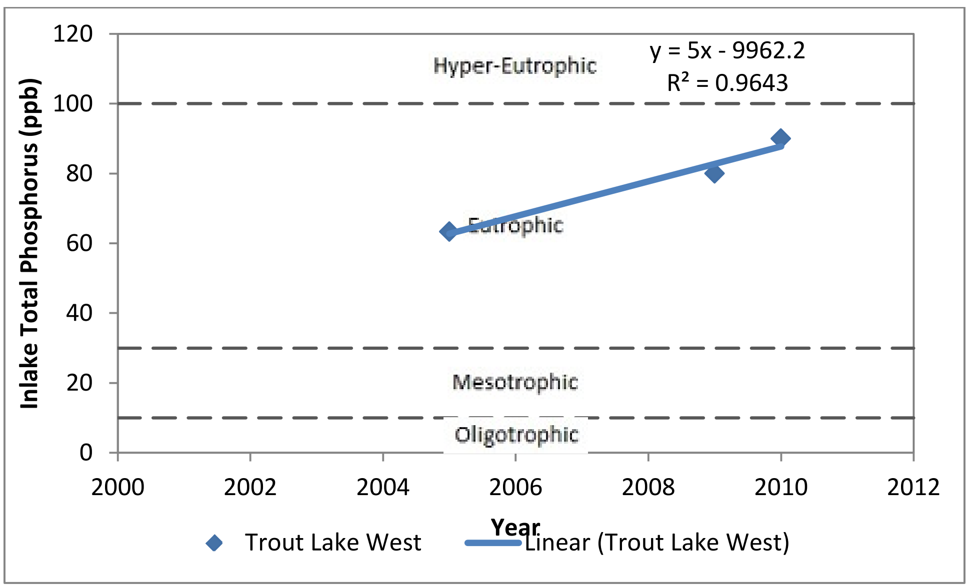

Figure 3.173: Inlake total phosphorus over time for Trout Lake West

Figure 3.175 shows the average total inlake phosphorus concentrations over time for Trout Lake West. These values depict an increase in inlake phosphorus with a strong correlation coefficient of 0.9643. The strong correlation could be explained by the limited number of data points that exist for this data set (three). The phosphorus concentrations vary in the range of eutrophic to strongly eutrophic.

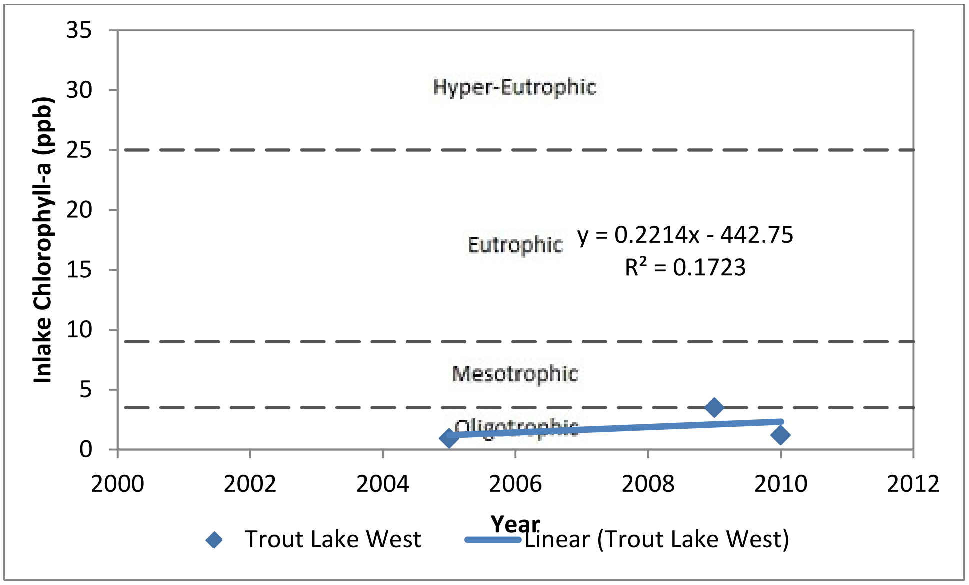

Figure 3.174: Inlake chlorophyll-a over time for Trout Lake West

Figure 3.176 shows the average total inlake chlorophyll-a concentrations over time for Trout Lake West. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.1723. The chlorophyll-a concentrations vary in the range of oligotrophic to slightly mesotrophic.

3.44 **Trumpeter Pond**

Samples for Trumpeter Pond were collected in 2004 and 2010. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.177 depicts the Carlson TSI values over time for Trumpeter Pond. The figure depicts a slight increase in TSI values over time. As only two data points were calculated, a correlation is difficult to determine. The TSI values were classified as slightly hyper-eutrophic and hyper-eutrophic based on the Carlson TSI Model.

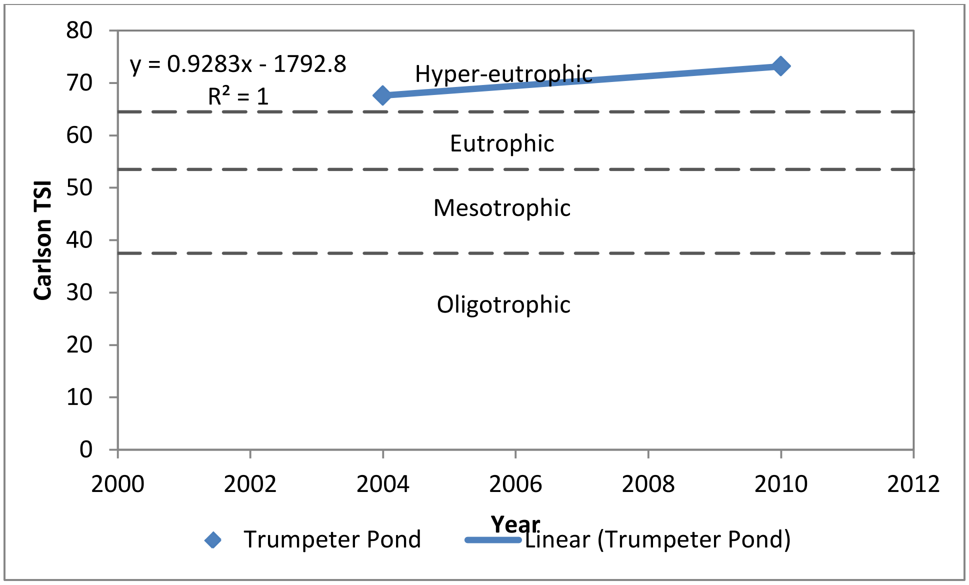

Figure 3.175: Carlson TSI over time for Trumpeter Pond

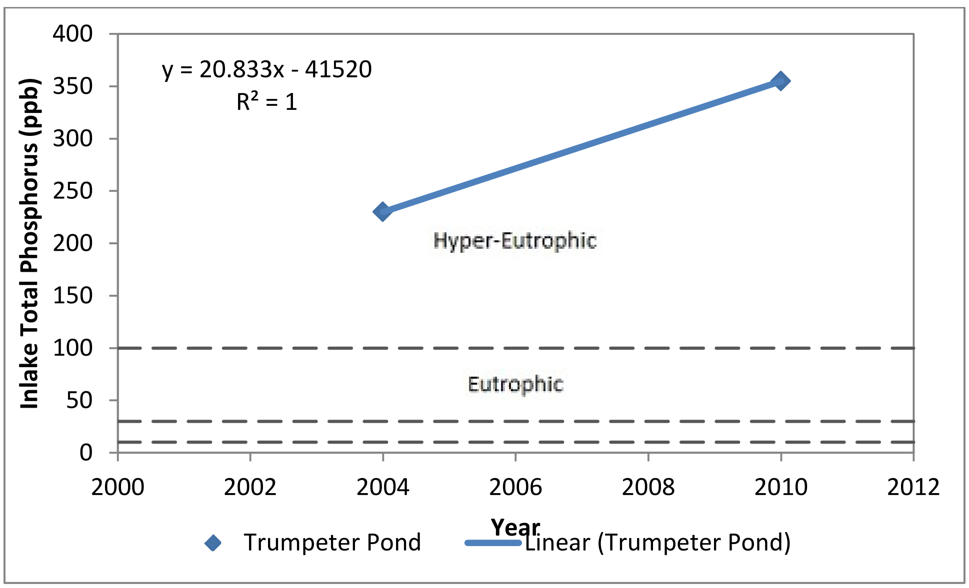

Figure 3.176: Inlake total phosphorus over time for Trumpeter Pond

Figure 3.178 shows the average total inlake phosphorus concentrations over time for Trumpeter Pond. These values depict an increase in inlake phosphorus over time. As only two data points were collected, a correlation is difficult to determine. The TP values were classified as both hyper-eutrophic.

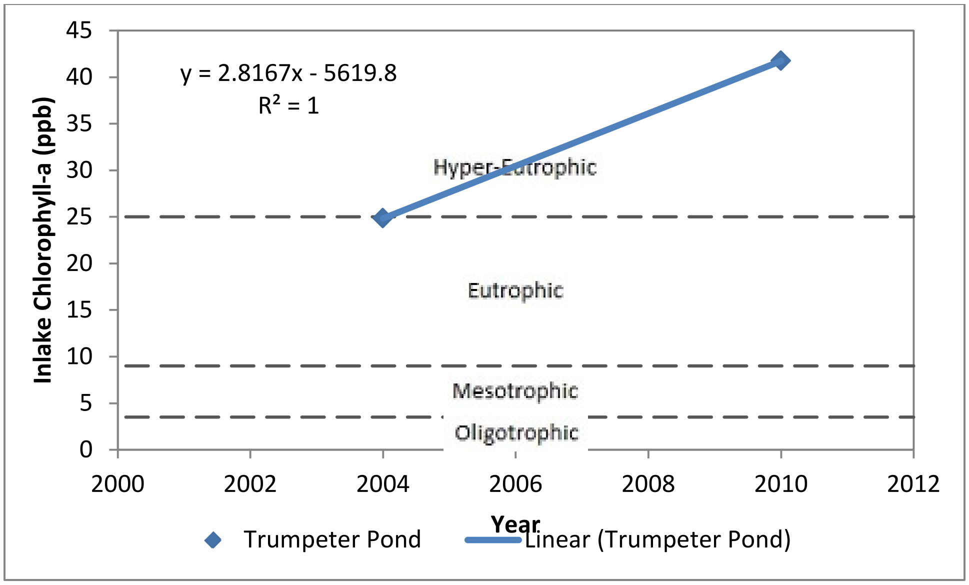

Figure 3.177: Inlake chlorophyll-a over time for Trumpeter Pond

Figure 3.179 shows the average total inlake chlorophyll-a concentrations over time for Trumpeter Pond. These values depict an increase in inlake chlorophyll-a. As only two data points were collected, a correlation is difficult to determine. The chlorophyll-a values were classified as strongly-eutrophic and hyper-eutrophic.

3.45 **Turbid Pond**

Samples for Turbid Pond were collected in 2004. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

Figure 3.180 depicts the Carlson TSI values over time for Turbid Pond. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the hyper-eutrophic classification based on the Carlson TSI Model.

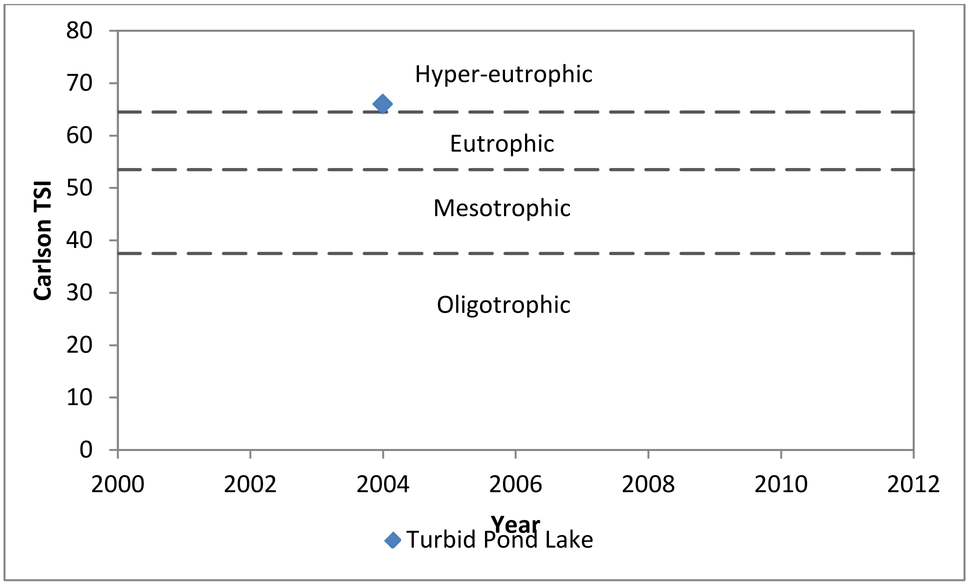

Figure 3.178: Carlson TSI over time for Turbid Pond

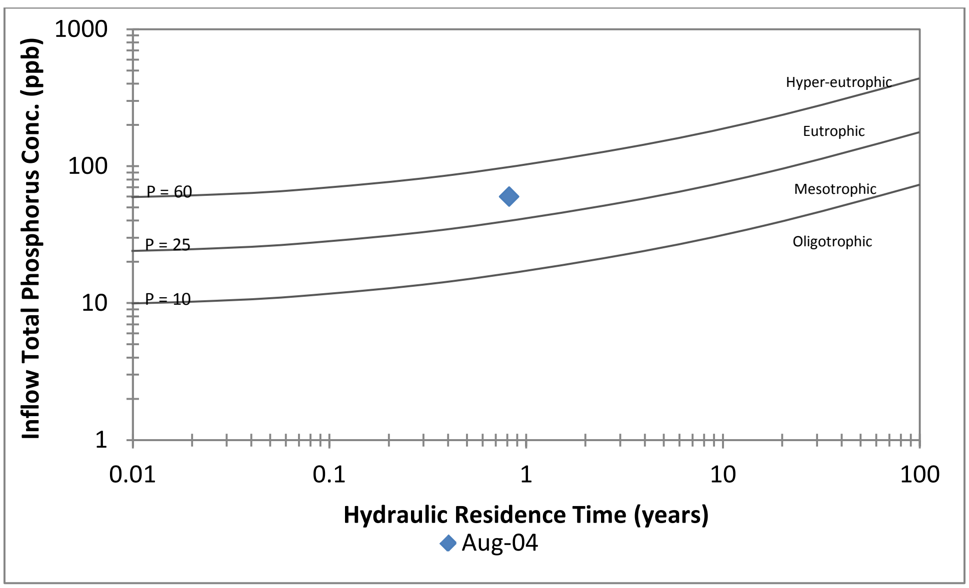

Figure 3.179: Vollenweider Model over time for Turbid Pond

Figure 3.181 depicts the results of the Vollenweider Model over time for Turbid Pond. Only one data point exists for Turbid Pond based on the inflow TP and the hydraulic residence time and it falls under the eutrophic classification according to the Vollenweider Model.

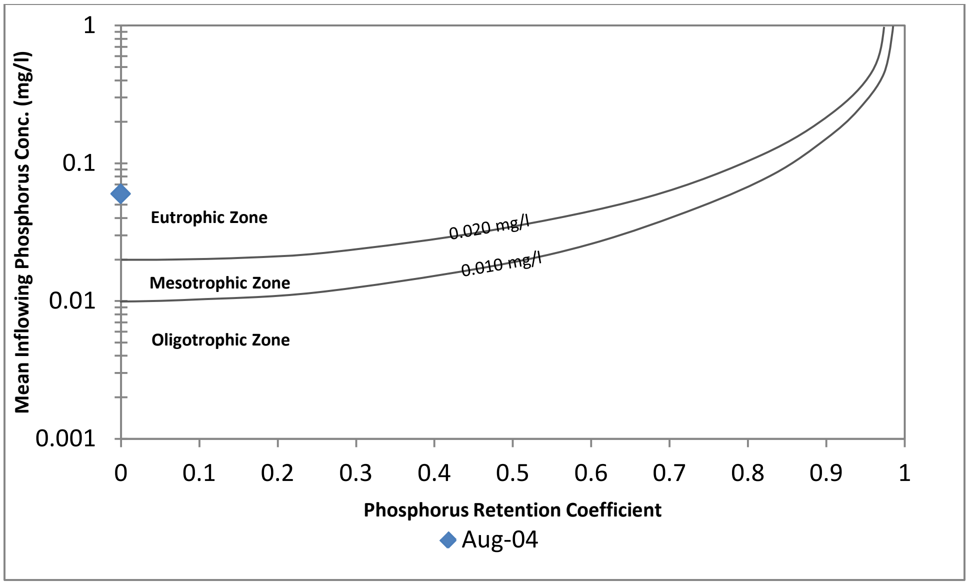

Figure 3.180: Larsen Mercier Model over time for Turbid Pond

Figure 3.182 shows the results of the Larsen Mercier Model over time for Turbid Pond. Only one total inlet phosphorus vs. phosphorus retention coefficient data point exists (August 2004) and it falls under the strongly eutrophic classification based on the Larsen Mercier Model.

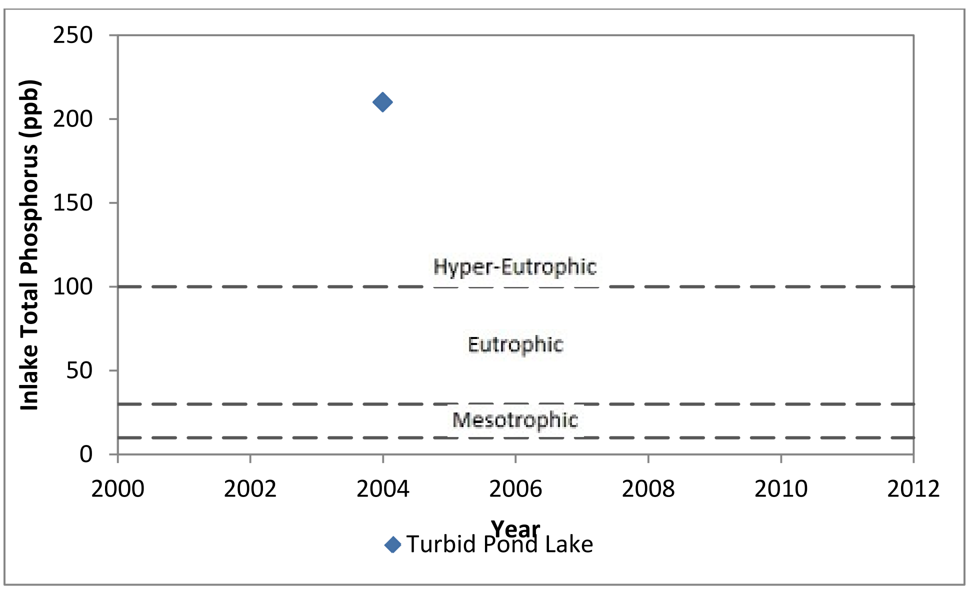

Figure 3.181: Inlake total phosphorus over time for Turbid Pond

Figure 3.183 shows the average total inlake phosphorus concentrations over time for Turbid Pond. As only one year of data exists, the over time data may not be indicative of any sort of trend for TP values. The one TP value falls under the hyper-eutrophic classification.

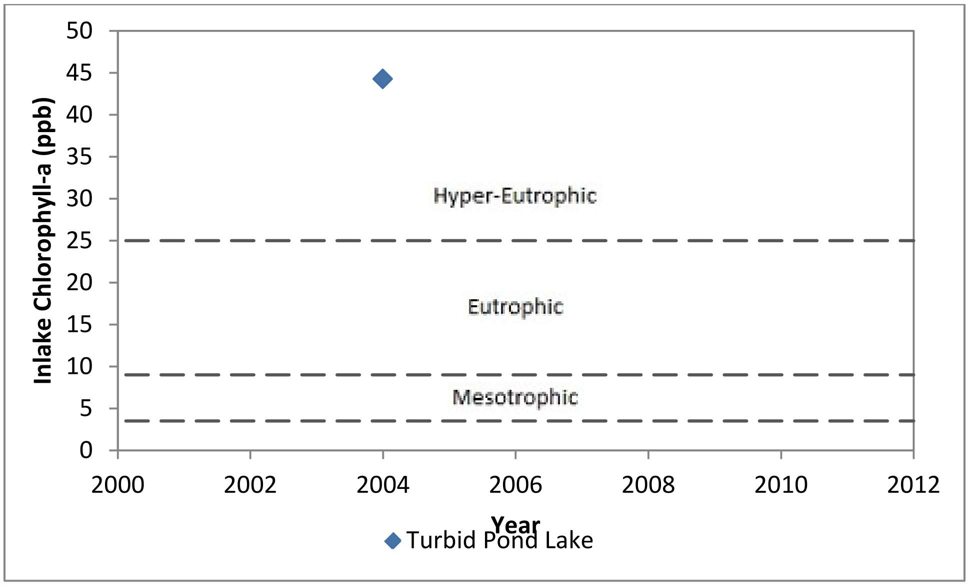

Figure 3.182: Inlake chlorophyll-a over time for Turbid Pond

Figure 3.184 shows the average total inlake chlorophyll-a concentrations over time for Turbid Pond. As only one year of data exists, the over time data may not be indicative of any sort of trend for chlorophyll-a values. The one chlorophyll-a value falls under the hyper-eutrophic classification.

3.46 **Wolf Lake**

Samples for Wolf Lake were collected in the year 2000. Plots of Carlson TSI vs. time, total inlet phosphorus concentration vs. hydraulic residence time (Vollenweider Model), total inlet phosphorus concentration vs. phosphorus retention coefficient (Larsen Mercier Model), total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

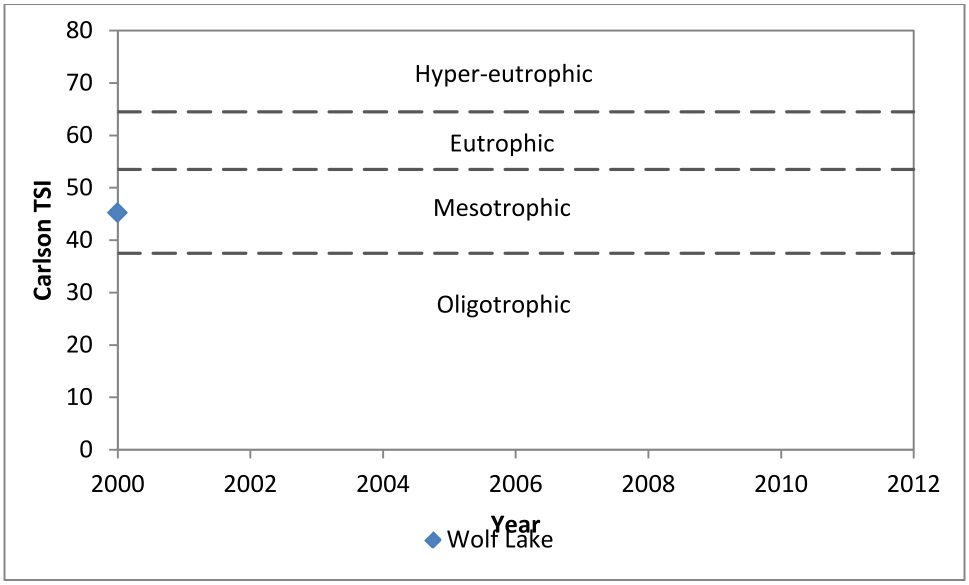

Figure 3.183: Carlson TSI over time for Wolf Lake

Figure 3.185 depicts the Carlson TSI values over time for Wolf Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for Carlson TSI values. The one TSI value falls under the mesotrophic classification based on the Carlson Model.

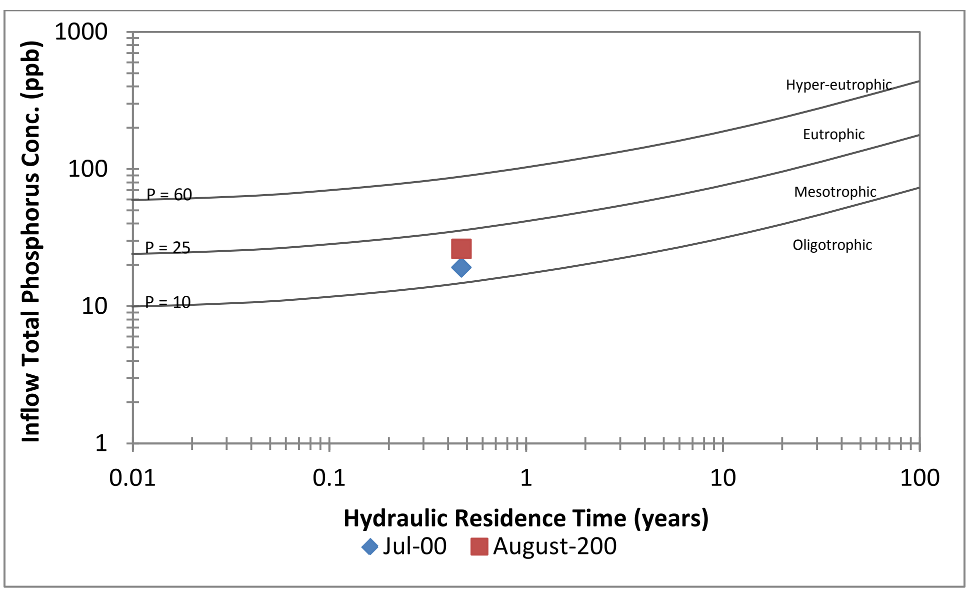

Figure 3.184: Vollenweider Model over time for Wolf Lake

Figure 3.186 depicts the results of the Vollenweider Model over time for Wolf Lake. The two total phosphorus vs. hydraulic residence time data points fall under the mesotrophic classification in July 2000 and strongly mesotrophic in August 2000.

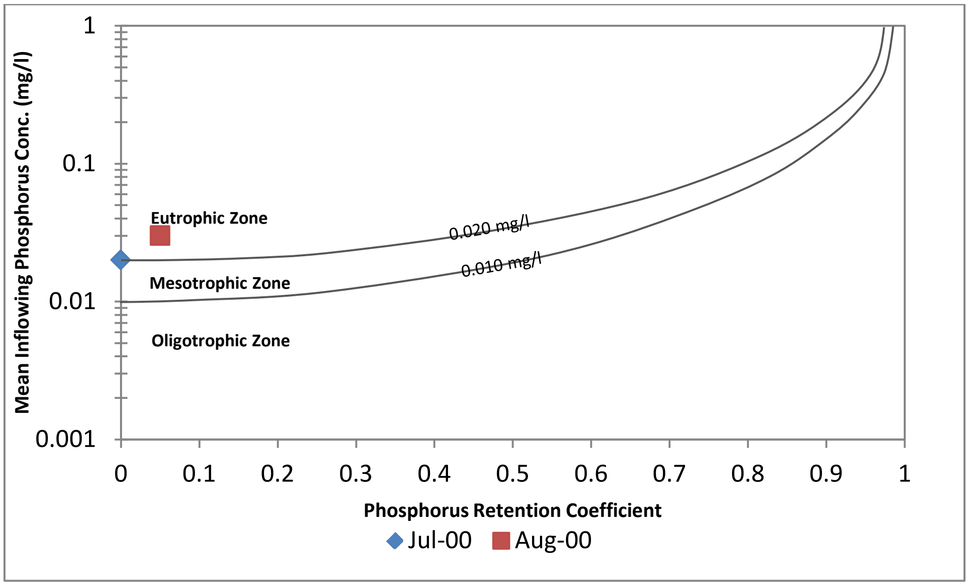

Figure 3.185: Larsen Mercier Model over time for Wolf Lake

Figure 3.187 shows the results of the Larsen Mercier Model over time for Wolf Lake. The two total inlet phosphorus vs. phosphorus retention coefficient data points fall under the slightly eutrophic classification in July 2000 and eutrophic classification in August 2000 based on the Larsen Mercier Model.

Figure 3.188 shows the average total inlake phosphorus concentrations over time for Wolf Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for total inlake phosphorus values. The one TP value falls under the slightly eutrophic classification based on the TP Model.

Figure 3.189 shows the average total inlake chlorophyll-a concentrations over time for Wolf Lake. As only one year of data exists, the over time data may not be indicative of any sort of trend for chlorophyll-a values. The one chlorophyll-a value falls under the mesotrophic classification.

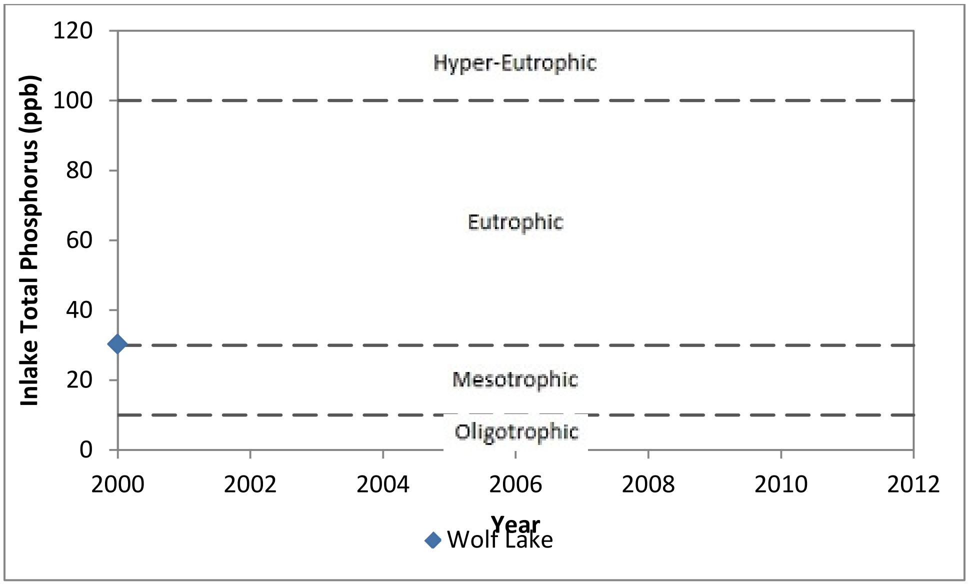

Figure 3.186: Inlake total phosphorus over time for Wolf Lake

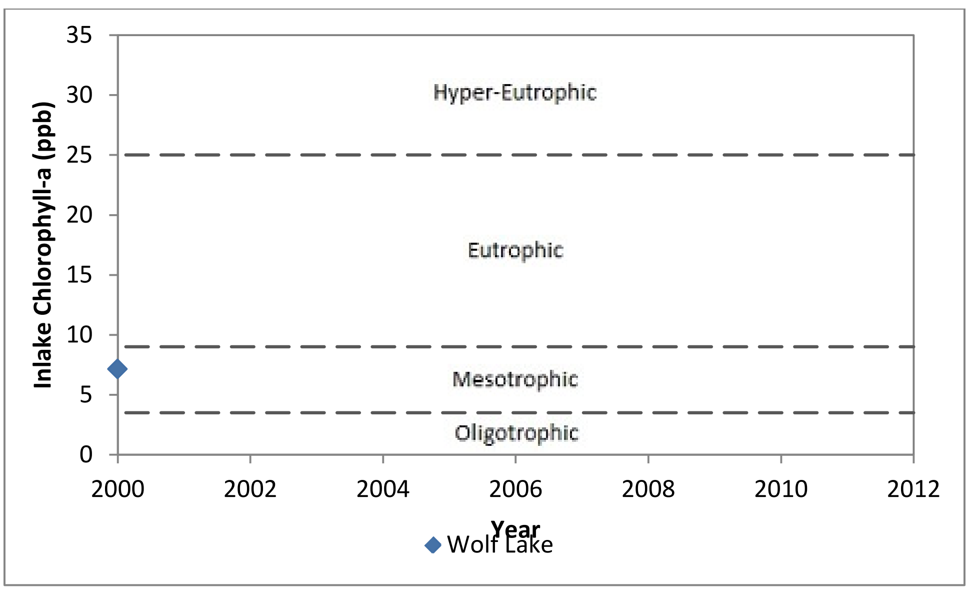

Figure 3.187: Inlake chlorophyll-a over time for Wolf Lake

3.47 Yellowstone Lake at Bridge Bay

Samples for Yellowstone Lake at Bridge Bay were collected in 2004, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

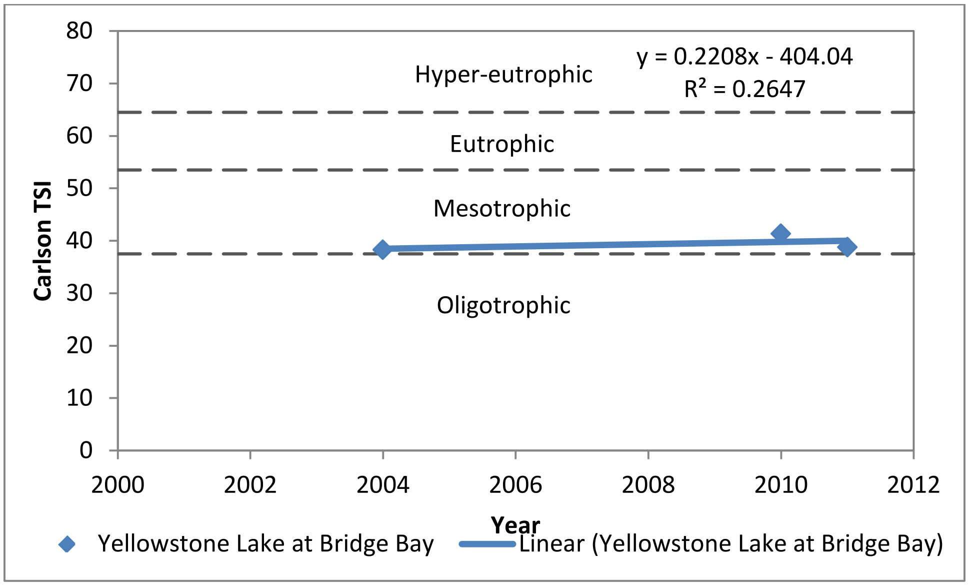

Figure 3.188: Carlson TSI over time for Yellowstone Lake at Bridge Bay

Figure 3.190 depicts the Carlson TSI values over time for Yellowstone Lake at Bridge Bay. The figure depicts a slight increase in TSI values over time with a relatively weak correlation coefficient of 0.2647. The TSI values all fall in the mesotrophic classification range.

Figure 3.191 shows the average total inlake phosphorus concentrations over time for Yellowstone Lake at Bridge Bay. These values depict a slight decrease in inlake phosphorus with a relatively weak correlation coefficient of 0.0174. The phosphorus concentrations vary in the range of mesotrophic to slightly eutrophic.

Figure 3.192 shows the average total inlake chlorophyll-a concentrations over time for Yellowstone Lake at Bridge Bay. These values depict a slight increase in inlake chlorophyll-a with a relatively strong correlation coefficient of 0.7536. The chlorophyll-a concentrations were all classified as oligotrophic.

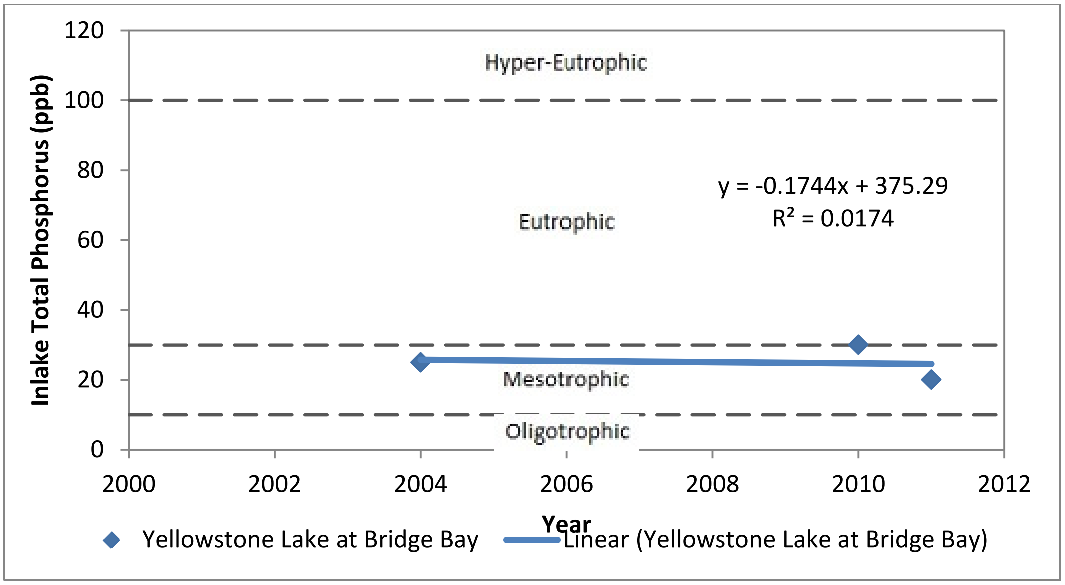

Figure 3.189: Inlake total phosphorus over time for Yellowstone Lake at Bridge Bay

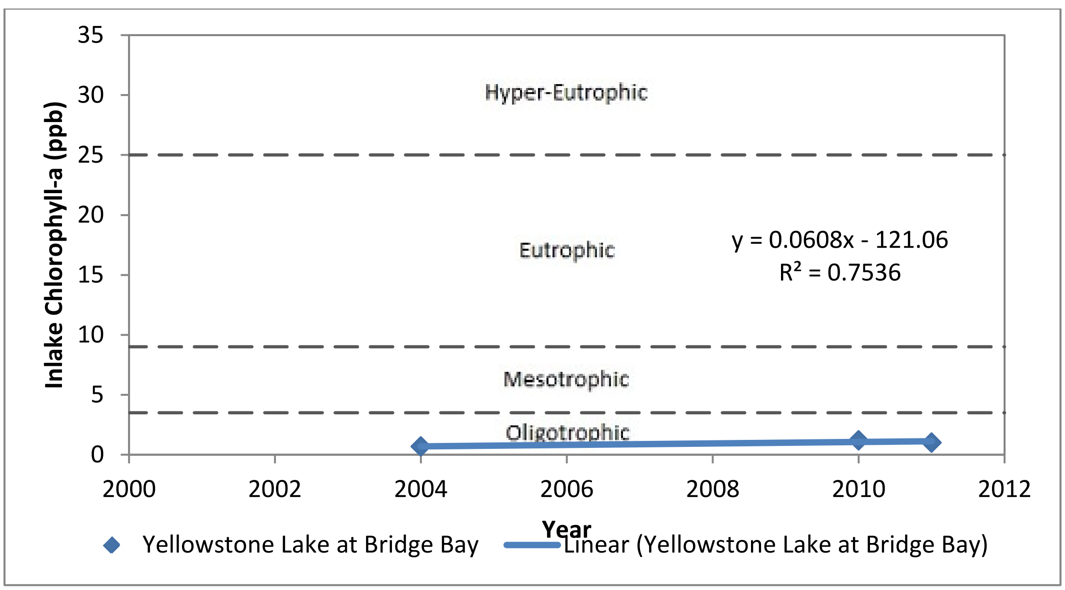

Figure 3.190: Inlake chlorophyll-a over time for Yellowstone Lake at Bridge Bay

3.48 **Yellowstone Lake at West Thumb**

Samples for Yellowstone Lake at West Thumb were collected in 2004, and 2010-2011. Plots of Carlson TSI vs. time, total inlake phosphorus concentration vs. time, and total inlake chlorophyll-a concentration vs. time are included below.

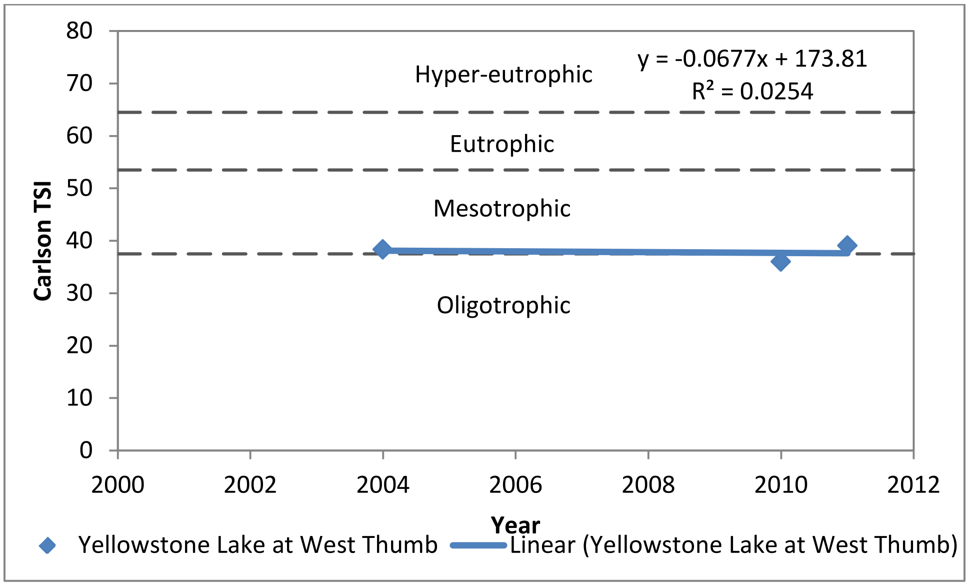

Figure 3.191: Carlson TSI over time for Yellowstone Lake at West Thumb

Figure 3.193 depicts the Carlson TSI values over time for Yellowstone Lake at West Thumb. The figure depicts a slight decrease in TSI values over time with a relatively weak correlation coefficient of 0.0254. The TSI values vary in the range of slightly oligotrophic and slightly mesotrophic classifications.

Figure 3.194 shows the average total inlake phosphorus concentrations over time for Yellowstone Lake at West Thumb. These values depict a decrease in inlake phosphorus with a strong correlation coefficient of 0.9826. The strong correlation could be explained by the limited number of data points that exist in this data set (three). The phosphorus concentrations vary in the range of mesotrophic to strongly mesotrophic.

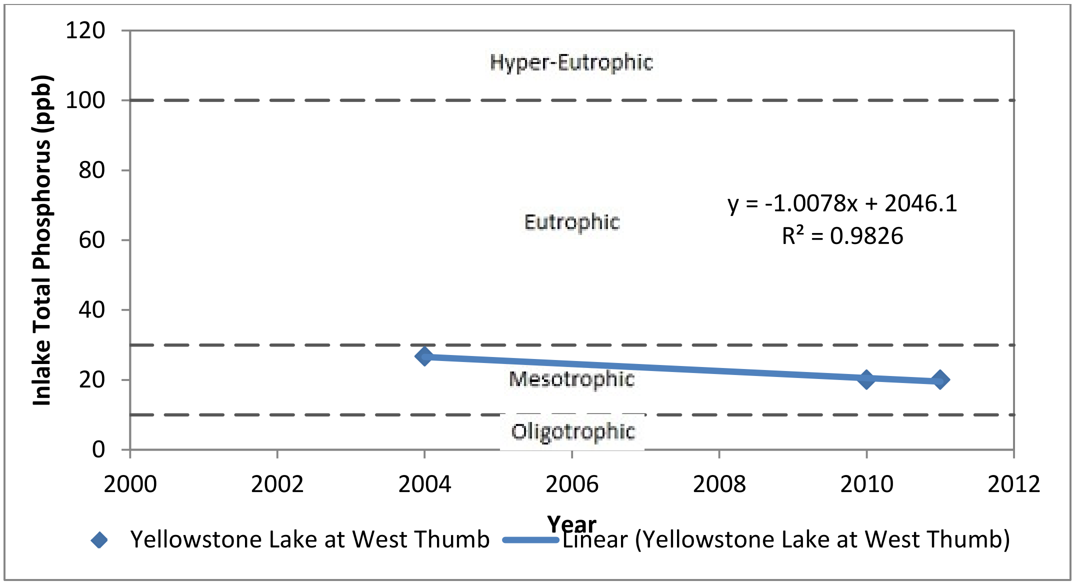

Figure 3.192: Inlake total phosphorus over time for Yellowstone Lake at West Thumb

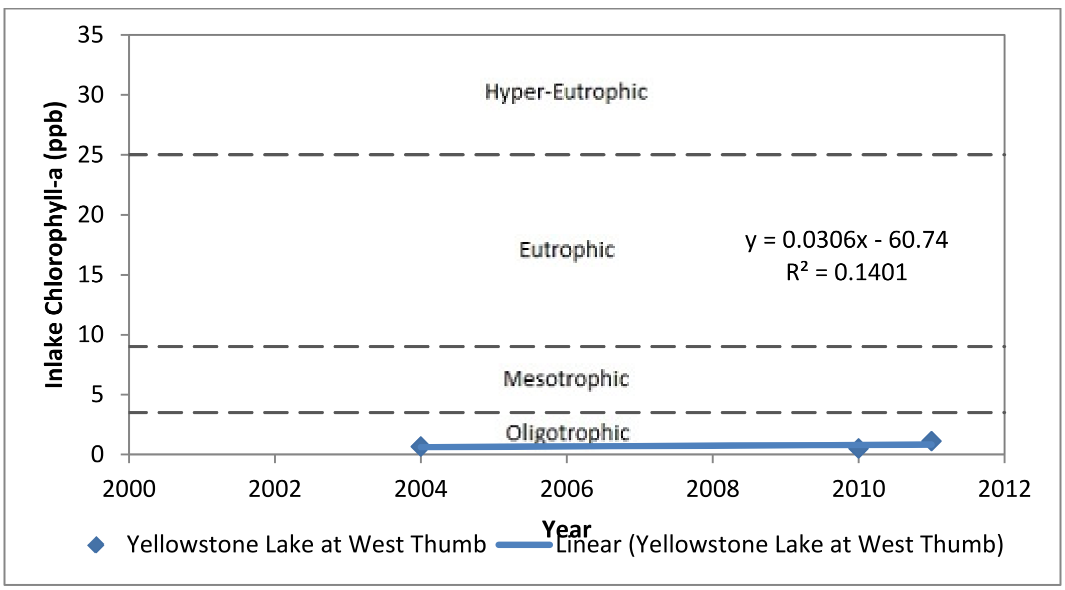

Figure 3.193: Inlake chlorophyll-a over time for Yellowstone Lake at West Thumb

Figure 3.195 shows the average total inlake chlorophyll-a concentrations over time for Yellowstone Lake at West Thumb. These values depict a slight increase in inlake chlorophyll-a with a relatively weak correlation coefficient of 0.1401. The chlorophyll-a concentrations all represented a classification of oligotrophic.

4 STATISTICAL ANALYSIS

4.1 **Principle Components Analysis**

Further analysis was performed in order to describe this particular set of data. The majority of the work was completed with the JMP Pro 10 software developed by SAS Institute Inc. in 2012. This software is useful for performing principal component analyses (PCAs), multivariate cluster analyses, and graphing high-dimensional data.

The idea behind a principal component analysis is to simplify or take multidimensional sets of data and reduce them to fewer dimensions, or the most prominent components. This process is completed by determining the eigenvectors and eigenvalues of the covariance matrix of the data. The eigenvalues are then ranked based on significance; the higher eigenvalues are determined more significant than the lower. Discretion is then used to determine how many of the eigenvectors and eigenvalues are used, thus reducing the dimensionality of the set of data. The highest eigenvector is determined to be the primary or first principal component. It is beyond the scope of this document to provide an in depth description of the process. Additional information on the subject can be found in Lindsay I. Smith's document entitled "A Tutorial on Principal Component Analysis."

Table 4.1 shows the covariance matrix that was used in order to determine the principal components of the data set. The data used for this statistical analysis were the inlake Secchi depth (m), the inlake chlorophyll-a concentrations (mg/m^3), and the inlake phosphorus concentrations (mg/L) for each lake sampled. One can see that this is a symmetric matrix with the main diagonal being the variance values.

Table 4.1: Covariance matrix of Secchi depth, chlorophyll-a, and phosphorus

	Depth (m)	*Chla (mg/m3)*	*Phosphorus (mg/L)*
Depth (m)	1.874765	-5.57665	-0.02828
Chla (mg/m3)	-5.57665	436.5898	1.146233
Phosphorus (mg/L)	-0.02828	1.146233	0.015014

The loading matrix provides a good representation of each principal component. Table 4.2 provides a description of each component and its loading factors based on each variable. For example, principal component one shows a loading factor of -0.67517 for Secchi depth, 0.774284 for chlorophyll-a, and 0.665406 for phosphorus concentration. The loading factors are nearly equal. This implies that as a data points increase along the principal component one axis, the chlorophyll-a and phosphorus increase at a similar rate. The depth, however, decreases at that same rate. This is due to the negative loading factor. Principal component two is loaded primarily by Secchi depth and phosphorus. Principal component three is loaded primarily by chlorophyll-a.

Table 4.2: Loading matrix

Parameter	*Prin1*	*Prin2*	*Prin3*
Depth (m)	-0.67517	0.63155	0.381172
Chla (mg/m3)	0.774284	-0.0162	0.632631
Phosphorus (mg/L)	0.665406	0.659672	-0.34938

4.2 K-Means Cluster Analysis

K-means clustering is a method of partitioning data into a specified number of groups (k) or clusters. The clusters are obtained by determining "k" number of means or centroids and then minimizing the sum of squared errors. Those clusters are then plotted in the PCA subspace (Ding and He n.d.).

In this particular analysis, four clusters were determined to be the most significant. This was determined by the separation and distinction of clusters when plotted in PCA subspace. Figure 4.1 shows the k-means 2D biplot for the data set. Each cluster is colored and numbered accordingly. The centroids of each cluster are depicted by the circle located in the center of the cluster itself. The size of the circle is based on the number of data points assigned to each cluster. From Figure 4.1 one can see that the majority of the data points are assigned to cluster 2, while the fewest data points are assigned to cluster 4. Clusters 1 and 3 have a similar number of data points assigned.

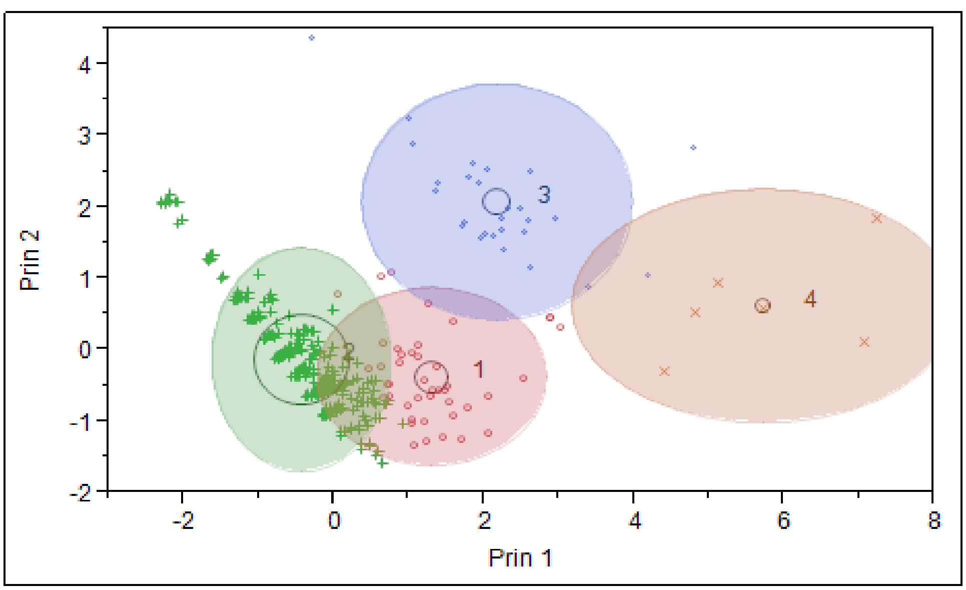

Figure 4.1: 2D k-means cluster biplot

Figure 4.2 depicts the same biplot in 3D, thus facilitating the visualization of all three principal components. When Figure 4.1 is used in conjunction with Figure 4.2, distinctions between the different clusters can be made. This allows the assigning of certain attributes to each cluster. Cluster 4 is obviously most positive along the principal component 1 and 3 axes. Referring to Table 4.2 the loading for these two axes are with chlorophyll-a and phosphorus concentrations. There is an inverse relationship to Secchi depth, which is to be expected due to the fact that an increase in nutrient loading, brings an increase in chlorophyll-a concentrations, which ultimately reduces the transparency of the lake.

Cluster 3 seems to be most positive along the principal component 2 axis. This indicates that the cluster could be dominant in phosphorus concentrations, Secchi depth, or both. This implies that though the phosphorus concentrations are high, the Secchi depth had not yet begun to reflect the added nutrient loading.

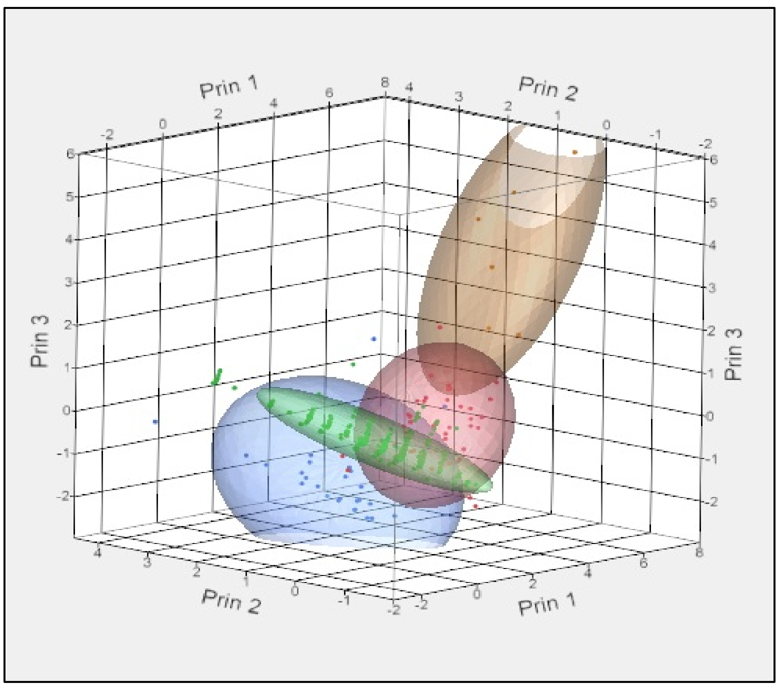

Figure 4.2: 3D k-means cluster biplot

4.3 **Graph Builder**

JMP Pro 10.0 has a very useful graph building tool. This tool allows for the visualization of many sets of data on the same graph by using primary and secondary x and y axes. One can also color or size the plotted points by additional data sets.

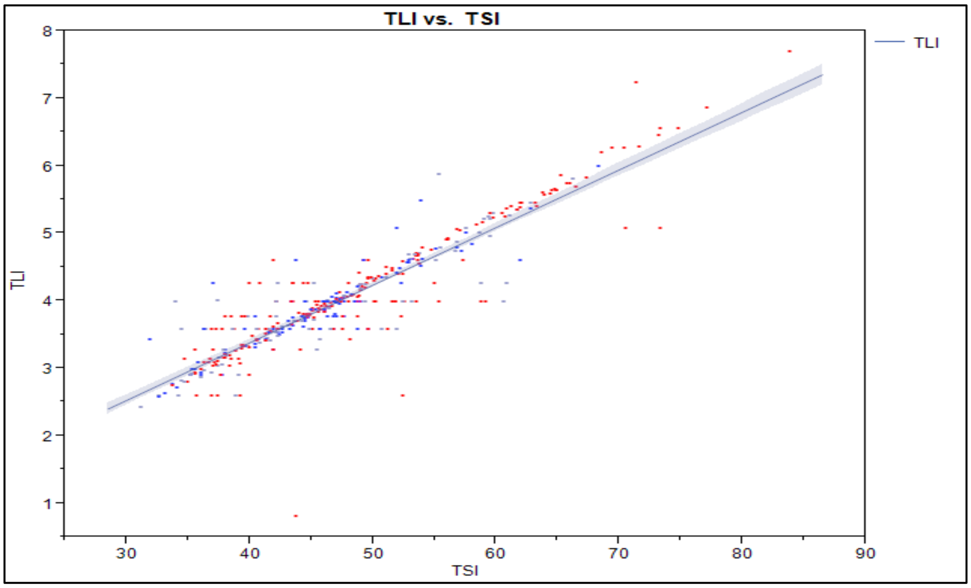

Figure 4.3: TLI vs. TSI relational plot

Figure 4.3 shows a linear plot of Burns TLI values vs. Carlson TSI values. This plot is of interest in that it shows the linear correlation that one would expect. This is due to the fact that both the Burns TLI values and the Carlson TSI values are functions of the same parameters (namely phosphorus concentrations, chlorophyll-a concentrations, and Secchi depth). This plot also shows a linear trendline with a varying width based on confidence intervals. The plot shows some of the variance that is built into the Burns and Carlson Models themselves. The strongest linear correlation seems to be between the values of 50 and 70 for Carlson TSI and 4.5 and 6.0 for Burns TLI. When either of the values fall below or above these ranges, their seems to be a weaker correlation. This fact is shown by the spread of values away from the trendline.

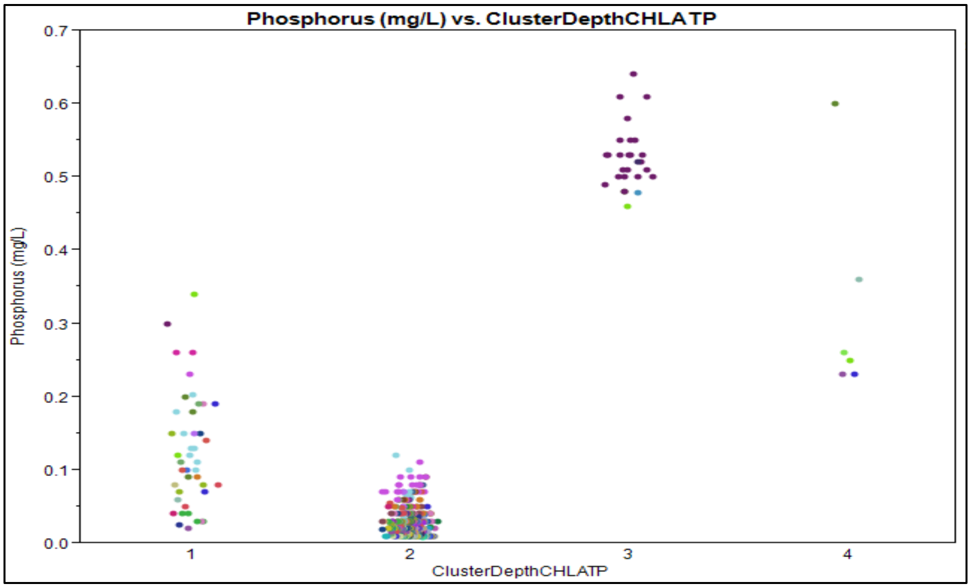

Figure 4.4: Phosphorus concentrations (mg/L) vs. k-means clusters (colored by lake name) using Graph Builder

Figure 4.4 shows a plot of phosphorus concentrations, grouped by their assigned clusters along the x-axis. The data points are colored by lake name. The majority of the data points were assigned to cluster 2, which seem to have the common attribute of a lower phosphorus concentration. Cluster 3 seems to have the highest phosphorus readings. This was to be expected based on the biplots and the loading matrix. One unexpected result obtained is that cluster 3 is comprised of readings that are primarily from the same lake, Indian Pond. Further discussion on this fact will be included later in section 4.4 of this document.

Contrary to the assumption made previously for cluster 3, the recorded Secchi depths shown in Figure 4.5 denote average Secchi depth values for the cluster. These results make more sense. This plot also depicts a color scheme based on MonthID (eg. April = 4; May = 5; June = 6; etc.). There seems to be an even spread among the spring, summer, and autumn months.

Figure 4.6 depicts the plot of Carlson TSI values vs. the k-means clusters. The plot is colored based on Lake Name. Based on the plot results, cluster 2 seems to have the lowest average Carlson TSI value. This is to be expected as cluster 2 also had the lowest average phosphorus and chlorophyll-a concentrations (see Figure 4.4 and Figure 4.7). Cluster 3 seems to have above average TSI values. The data points assigned to cluster 4 were those that were most eutrophic based on the Carlson TSI Model.

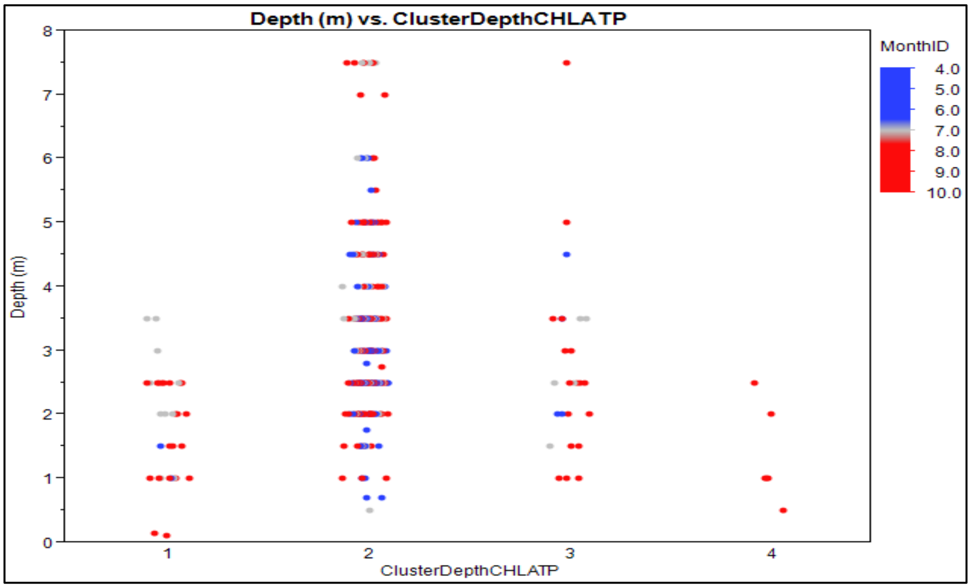

Figure 4.5: Secchi depth (m) vs. k-means clusters (colored by MonthID)

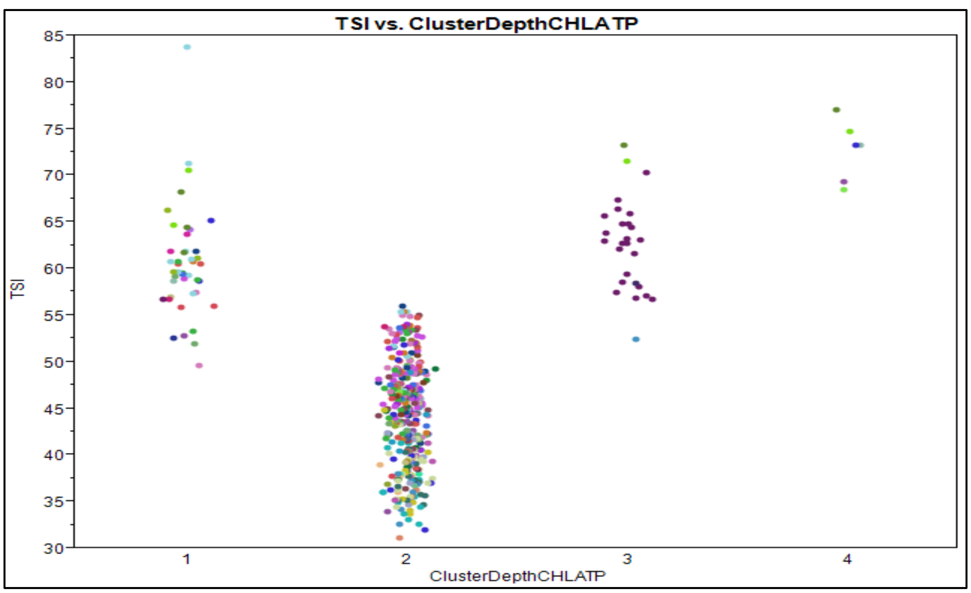

Figure 4.6: Carlson TSI values vs. k-means clusters (colored by lake name) using Graph Builder

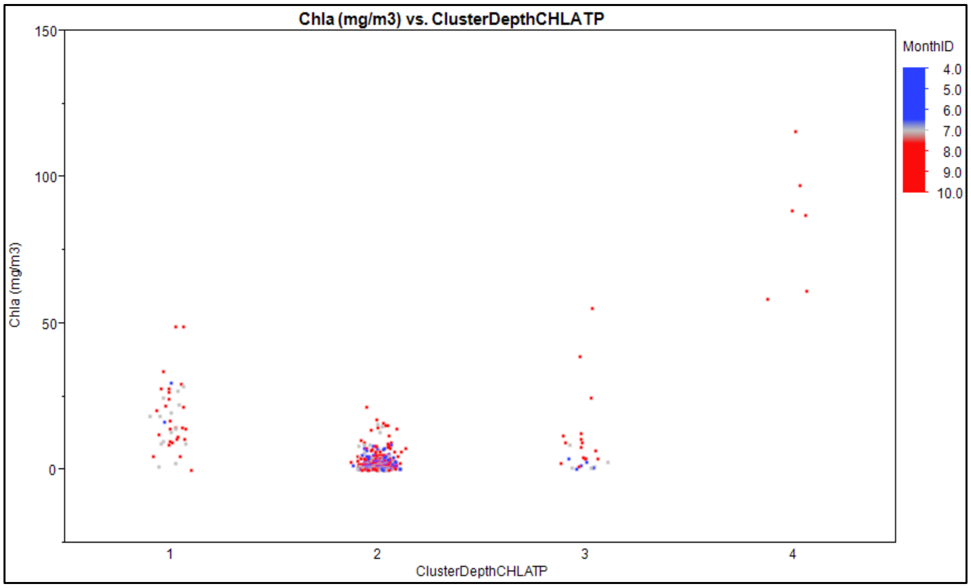

Figure 4.7: Chlorophyll-a concentrations (ppb) vs. k-means clusters (colored by MonthID)

Figure 4.7 shows a plot of chlorophyll-a concentrations vs. k-means clusters. The plot was colored based on the MonthID. This plot is of interest in that it shows that cluster 4 contains the highest chlorophyll-a readings. The fact that the majority of high chlorophyll-a readings occurred during the autumn months is also noteworthy. This implies that greater plant growth occurs during the autumn months, while the nutrient loading occurs during spring runoff.

4.4 Discussion on Indian Pond

As was mentioned previously, one of the unexpected results of the cluster analysis is that almost all of the readings assigned to cluster 3 were taken from one lake, Indian Pond. Cluster 3 showed characteristics of high phosphorus readings as well as high Carlson TSI values. This section serves as a discussion on the potential sources of excess phosphorus for Indian Pond. Further analysis would be required in order to provide verification of the source.

Figure 4.8: Location of Indian Pond

Figure 4.8 shows that Indian Pond is located along the East Entrance Rd at the northeast side of Yellowstone Lake. The lake is relatively small and stagnant and, based on the five trophic state models used in this document shown in Table 2.16, the overall average trophic state is strongly eutrophic.

Table 4.3 gives an overall summary of Indian Pond based on the five trophic state models described in this document. The table also gives the average phosphorus and chlorophyll-a readings for the seven years that samples were collected from Indian Pond. The trophic states range from slightly eutrophic based on the Carlson TSI Model in 2006 to hyper-eutrophic based on the Vollenweider, Larsen Mercier, and Naumann models in 2011.

As was mentioned previously, samples from Indian Pond have shown high phosphorus concentrations. It is difficult to declare causation for these high readings, but it is important to note that this small lake has little dynamic activity. The lake is relatively stagnant without much inflow. Sources come primarily from small seeps. The higher residence time may allow for nutrient buildup. It is also worth noting the high animal activity in the vicinity, primarily birds. According to the EPA, animals and animal waste can be a significant source of nutrient pollution (EPA, Sources and Solutions 2012).

Table 4.3: Summary of Indian Pond over time

Year	*Carlson*	*Burns*	*Vollenweider*	*Larsen Mercier*	*Naumann*	*TP (mg/L)*	*Chla (ppb)*
2011	Eutrophic	Strongly Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	Hyper-Eutrophic	0.46	3.77
2010	Strongly Eutrophic	Strongly Eutrophic	Hyper-Eutrophic	Strongly Eutrophic	-	0.55	3.92
2009	Eutrophic	Strongly Eutrophic	Slightly Hyper-Eutrophic	Strongly Eutrophic	-	0.4	8.5
2008	Eutrophic	Strongly Eutrophic	Slightly Hyper-Eutrophic	Strongly Eutrophic	-	0.51	6.7
2006	Slightly Eutrophic	Eutrophic	Slightly Hyper-Eutrophic	Eutrophic	-	0.52	0.9
2005	Strongly Eutrophic	Strongly Eutrophic	Slightly Hyper-Eutrophic	Eutrophic	-	0.54	16.6
2004	Strongly Eutrophic	Strongly Eutrophic	-	-	-	0.55	4.28

5 CONCLUSION

5.1 Summary

The results from the 2011 classifications are summarized in Table 5.1. The most recent trophic state classification is included in this table. This classification could pertain to the 2011 samples, or, in the case where samples were not collected in 2011, the most recent year of sampling.

Of the 47 total lakes and ponds that have been tested over the past 14 years, five lakes are classified as slightly oligotrophic, implying that the waters are relatively clear and free from nutrient pollution. Of the 46 lakes, 19 are classified as slightly mesotrophic, mesotrophic, or strongly mesotrophic. These classifications imply that the waters are moderately clear and contain some nutrient pollution. Of the 46 lakes, 14 are classified as slightly eutrophic, eutrophic, or strongly eutrophic. This implies that the waters have high turbidity and nutrient content. Of the 46 lakes, 8 are classified as slightly hyper-eutrophic or hyper-eutrophic. These lakes are noticeable for their high algae content with very high nutrient content.

These classifications are based on a qualitative average of the 4 or 5 (Naumann Trophic Scale used only for 2011 data) trophic state models used in this document. The average was determined for the most recent year for which water samples were taken. This was determined to be the method that would show the results closest to the current conditions.

Table 5.1: Overall summary of Yellowstone lakes

Lake/Pond	Years Sampled	Rate of Change	Most Recent Classification
Beaver Lake	2001, 2008-2011	Slight Increase	Strongly Mesotrophic
Blacktail Pond	2001, 2008-2011	Increase	Strongly Eutrophic
Buck Lake	2004-2011	Slight Decrease	Strongly Eutrophic
Cascade Lake	2000, 2010-2011	Slight Increase	Eutrophic
Clear Lake	2004, 2008-2011	Decrease	Slightly Eutrophic
Crevice Lake	2005	N/A	Mesotrophic
Druid Lake	2010-2011	Decrease	Strongly Mesotrophic
Duck Lake	1999, 2003, 2008-2011	Slight Decrease	Slightly Mesotrophic
Eleanor Lake	2004, 2008-2011	Slight Decrease	Slightly Oligotrophic
Feather Lake	2010-2011	Slight Increase	Slightly Hyper-Eutrophic
Floating Island Lake	2004, 2010-2011	Decrease	Slightly Hyper-Eutrophic
Goose Lake	2001, 2009-2011	Slight Increase	Mesotrophic
Grebe Lake	2000	N/A	Mesotrophic

Table 5.1 continued: Overall summary of Yellowstone lakes

Lake/Pond	Years Sampled	Rate of Change	Most Recent Classification
Grizzly Lake	2010	N/A	Slightly Oligotrophic
Harlequin Lake	2001-2003, 2007-2011	Slight Increase	Slightly Eutrophic
Hazle Lake	2001, 2010-2011	Slight Increase	Slightly Eutrophic
Heart Lake	1999	N/A	Slightly Oligotrophic
Hot Beach Pond	2004, 2010-2011	Increase	Hyper-Eutrophic
Hot Lake	2001, 2010	Slight Decrease	Slightly Mesotrophic
Ice Lake	2000, 2009-2011	Slight Decrease	Slightly Mesotrophic
Indian Pond	2004-2006, 2008-2011	Slight Decrease	Strongly Eutrophic
Isa Lake	1999, 2010-2011	Slight Increase	Eutrophic
Lake of the Woods	2001, 2010	Increase	Hyper-Eutrophic
Lewis Lake	1998-1999, 2009-2011	Slight Decrease	Slightly Oligotrophic
Lily Pad Lake	2004-2006, 2008-2011	Increase	Slightly Hyper-Eutrophic
Lost Lake	2004-2011	Slight Decrease	Strongly Mesotrophic
Mallard Lake	2010	N/A	Slightly Mesotrophic

Table 5.1 continued: Overall summary of Yellowstone lakes

Lake/Pond	Years Sampled	Rate of Change	Most Recent Classification
North Twin Lake	2001, 2008-2011	Slight Increase	Slightly Eutrophic
Nymph Lake	2001, 2008-2011	Slight Decrease	Slightly Hyper-Eutrophic
Pool by Morning Glory Pool	2001, 2010	Increase	Eutrophic
Ribbon lake	2006, 2010	Slight Increase	Eutrophic
Riddle Lake	1999, 2008, 2010	Increase	Eutrophic
Scaup Lake	2002, 2010-2011	Slight Increase	Strongly Mesotrophic
Shoshone Lake	1998-1999, 2010	Slight Decrease	Slightly Mesotrophic
Shrimp Lake	2004-2005, 2011	Decrease	Slightly Eutrophic
South Twin Lake	2001, 2008-2011	Slight Increase	Strongly Mesotrophic
Swan Lake	2001, 2008-2011	Slight Increase	Strongly Mesotrophic
Sylvan Lake	2004, 2008-2011	Slight Decrease	Slightly Mesotrophic
Tanager Lake	2004, 2009-2011	Slight Decrease	Slightly Oligotrophic
Terrace Springs	2007, 2010-2011	Increase	Strongly Mesotrophic
Trout Lake	2004-2011	Slight Decrease	Strongly Eutrophic

Table 5.1 continued: Overall summary of Yellowstone lakes

Lake/Pond	Years Sampled	Rate of Change	Most Recent Classification
Trumpeter Pond	2004, 2010	Slight Increase	Hyper-Eutrophic
Turbid Pond	2004	N/A	Slightly Hyper-Eutrophic
Wolf Lake	2000	N/A	Mesotrophic
Yellowstone Lake Bridge Bay	2004, 2010-2011	Slight Increase	Slightly Mesotrophic
Yellowstone Lake West Thumb	2004, 2010-2011	Slight Decrease	Slightly Mesotrophic

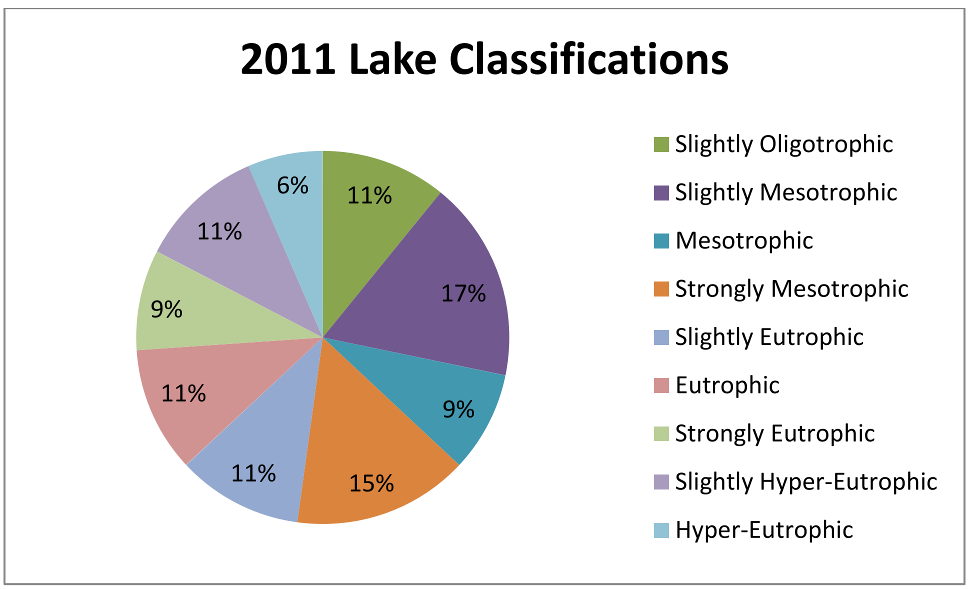

Figure 5.1: Lakes of Yellowstone classifications shown as percentages

Figure 5.1 and Figure 5.2 show the results for each lake categorized by trophic state. Figure 5.1 shows the results as a percentage and Figure 5.2 reports the lake count.

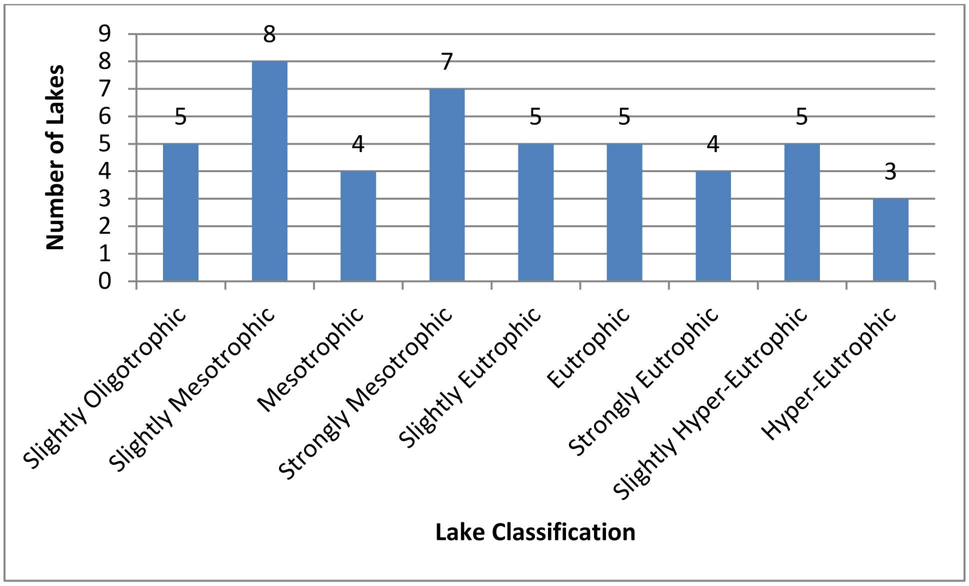

Figure 5.2: Bar graph of the classifications for the lakes of Yellowstone

5.2 Naumann Trophic Scale Results

As was mentioned previously, the Naumann Trophic Scale Model was used for the first time to analyze the 2011 data. It is essential now to determine whether or not this analysis was a wise decision and should be continued in the future.

The original study performed by Chapra and Dobson stated that the purpose of the study was to relate surface water quality, hypolimnetic dissolved oxygen depletion, and the overall trophic state of the lake. In order to relate the two indices "There are three possibilities for classifying lakes using indices: (1) average them, (2) classify the lake in terms of maximum index, or (3) use both. We prefer the last since it retains the most information. For management purposes, however, we feel that the maximum index should form the basis of determining remedial measures (Chapra and Dobson 1981)." This quote shows that the maximum index can be used as an indicator of the overall classification of the lake. The assumption made in this document is that the majority of lakes and ponds sampled in Yellowstone National Park act as surface water, as they are shallow enough to experience limited stratification, or, in other words, the surface water quality index would be the maximum index. The surface water quality method was provided by Einar Niemann.

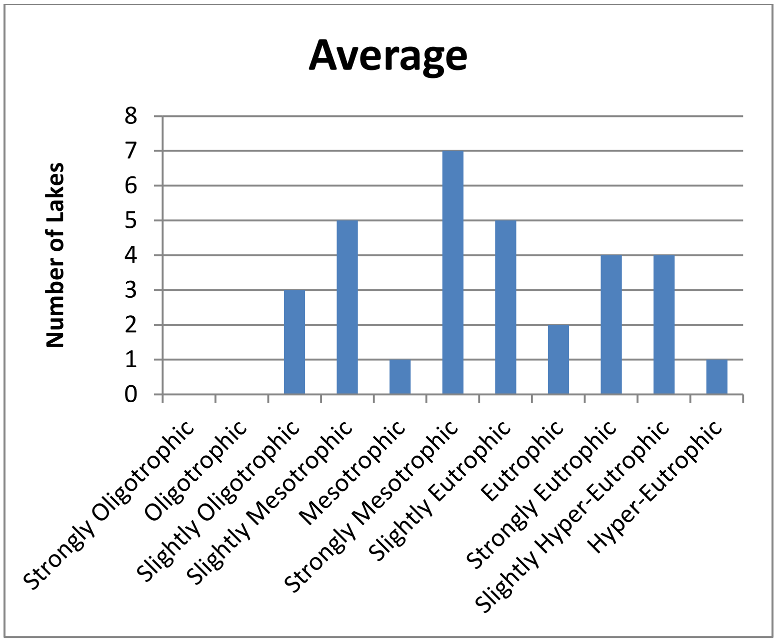

Figure 5.3: 2011 average trophic state classification distribution

Figure 5.3 shows a distribution of the trophic state classifications based on all five models considered in this document. There is a noticeable normal/Gaussian distribution with the median occurring at the strongly mesotrophic level. Figure 5.4 shows the distribution of trophic state classifications based on the Naumann Trophic Scale Model. This distribution seems to be slightly skewed left with a high number of lakes receiving the hyper-eutrophic classification. This may give reason to believe that the Naumann Trophic Scale errs on the side of overestimating the trophic scale, assuming average classification to be the actual health of the lake. Figure 5.5 and Table 5.2 seem to emphasize that fact. Table 5.2 shows that 27 of the 32 lakes sampled in 2011 were classified as equal to or above the average by the Naumann Trophic Scale Model. This information may be essential in determining the accuracy of the model and whether or not it should be used to analyze future years' data.

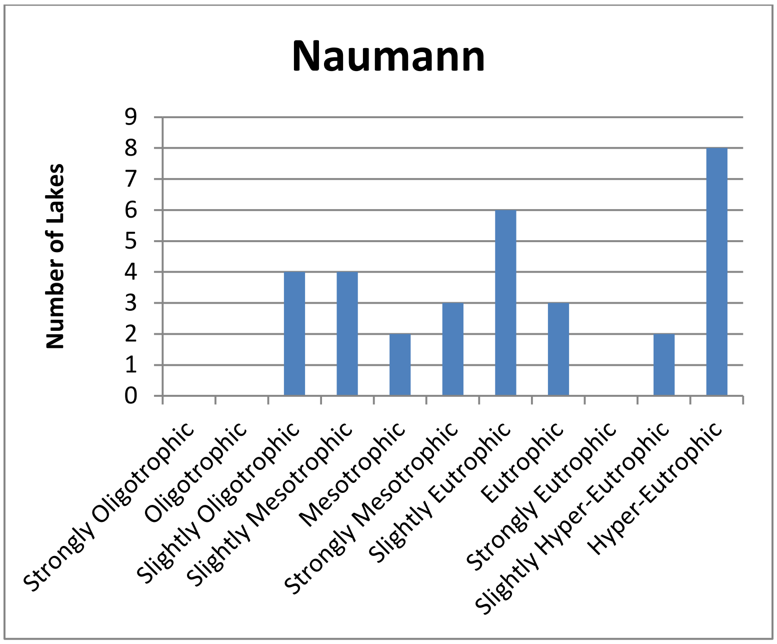

Figure 5.4: 2011 Naumann Trophic Scale classification distribution

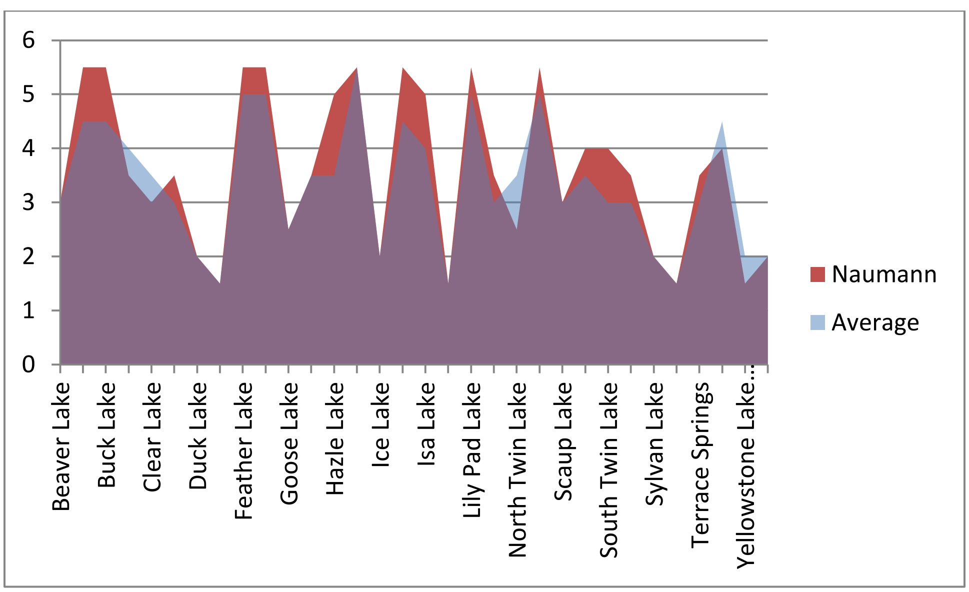

Figure 5.5: Naumann TS vs. the average 2011 classification

Table 5.2: Overall comparison of Naumann TS vs. average 2011 classification

Trophic Index	# lakes above average	# lakes below average	# lakes equal to average
Naumann Trophic Scale	15	5	12

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APPENDIX A. DATA TABLES

The following tables show the data collected as well as the results from the entire study.

Table A. 1 Beaver Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake NE	2	2.7	30				48.85	4.07	9.89
2011	Aug	Inlet			20	0.2	0.06	0			
2010	Aug	Inlake NE	2.5	22	100				59.43	5.29	
2010	Oct	Inlake NE	3.5	2.3	40				46.02	3.96	
2009	Aug	Inlet			200	0.1	0.06	0.85			
2009	Aug	Inlake NE	2.5	3.4	30				47.5	4.03	
2008	Jun	Inlet			40	2.0	0.06	0			
2008	Jun	Outlet			100	1.0					
2008	Jun	Inlake NE	3	5.8	10				43.1	3.69	
2001	Apr	Inlet			50	3.0	0.04	0.4			
2001	Apr	Inlake E	2.5	3.4	30				47.5	4.03	
2001	Jun	Inlet			43	0.3	0.04	0.09			
2001	Jun	Inlake E	1	0.5	39				46.9	3.8	
2001	Jul	Inlet			75	0.3	0.04	0.63			
2001	Jul	Inlake NE	3.5	1.2	28				42.2	3.48	
2001	Aug	Inlet			10	2.0	0.04	0			
2001	Aug	Inlake NE	2	0.2	29				39.2	3.06	
2001	Oct	Inlet			12	1.0	0.04	0			
2001	Oct	Inlake NE	1	2	20				53.7	4.54	

Table A. 2 Blacktail Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake SE	2	14.8	50				55.87	4.91	22.95
2010	Sep	Inlake SE	2.5	10.7	80				56	4.93	
2009	Aug	Inlake SE	2.5	4.9	40				50.1	4.29	
2008	Jun	Inlake SE	2	8.2	40				52.9	4.57	

Table A. 2 continued Blacktail Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Jul	Inlake SE	2.5	14.9	40				53.7	4.7	
2008	Aug	Inlake SE	2.5	17.5	15				49.5	4.34	
2008	Oct	Inlake SE	2.5	4	20				46.1	3.92	
2001	Apr	Inlake SE	3.5	2.8	20				43.3	3.65	
2001	Jul	Inlet			26	0.5	0.13	0.38			
2001	Jul	Inlake SE	3.5	0.7	16				37.7	3.05	
2001	Aug	Inlake W	2	0	13				45.6	3.87	
2001	Oct	Inlake W	2.5		14				44.5	3.78	

Table A. 3 Buck Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake W	3	5	20				45.97	3.98	9.25
2011	Jun	Inlet			110	2.0	0.25	0.82			
2011	Jul	Inlake W	1	22.3	40				59.47	5.21	33.07
2011	Jul	Inlet			80	1.0	0.25	0.50			
2011	Aug	Inlake W	2	14.8	30				53.41	4.70	20.65
2011	Aug	Inlet			90	2.0	0.25	0.67			
2011	Oct	Inlake W	2	9.7	40				53.41	4.66	17.27
2011	Oct	Inlet			90	2.0	0.25	0.56			
2010	Jun	Inlake W	3.5	4.2	30				46.61	4.06	
2010	Jun	Inlet			90	1.0	0.25	0.67			
2010	Jul	Inlake W	3.5	1.7	20				41.70	3.55	
2010	Jul	Inlet			100	1.0	0.25	0.8			
2010	Aug	Inlake W	3.5	3.4	20				43.97	3.81	
2010	Aug	Inlet			80	1.0	0.25	0.75			
2009	Jun	Inlet			80	1.0	0.25	0.75			
2009	Jun	Inlake W	3	3.5	20				44.80	3.80	
2009	Jul	Inlet			80	1.0	0.25	0.63			
2009	Jul	Inlake W	3.5	8.2	30				48.80	4.22	
2009	Aug	Inlet			70	1.0	0.25	0.86			
2009	Aug	Inlake W	2.5	3.4	10				42.20	3.57	
2009	Oct	Inlet			60	2.5	0.25	0.17			
2009	Oct	Inlake W	2.5	10.4	50				53.60	4.66	
2008	Jun	Inlet			70	0.5	0.25	0.57			

Table A. 3 continued Buck Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Jun	Inlake W	2.5	2.4	30				46.40	3.90	
2008	Jul	Inlet			100	0.5	0.25	0.7			
2008	Jul	Inlake W	2.5	19.8	30				53.30	4.68	
2008	Oct	Inlet			100	2.0	0.25	0.8			
2008	Oct	Outlet			20	2.0					
2008	Oct	Inlake W	2	15.6	30				53.60	4.68	
2007	Aug	Inlet			100	0.5	0.25	0.7			
2007	Aug	Inlake W	4.5	4.7	30				45.80	3.91	
2006	Jun	Inlet			80	0.5	0.25	0.75			
2006	Jun	Inlake w	2.5	1.8	20				43.50	3.63	
2005	May	Inlet			100	1.0	0.25	0.7			
2005	May	Inlake W	3	1.7	30				44.40	3.70	
2005	Jun	Inlet			90	1.0	0.25	67			
2005	Jun	Inlake W	3	1.9	30				44.70	3.74	
2005	Jul	Inlet			70	1.0	0.25	0.57			
2005	Jul	Inlake W	2.5	2.9	30				47.00	3.97	
2005	Aug	Inlet			70	1.0	0.25	0.43			
2005	Aug	Inlake W	1	33.9	40				60.80	5.36	
2005	Oct	Inlet			100	1.0	0.25	0.7			
2005	Oct	Inlake W	2.5	5.5	30				49.10	4.21	
2004	Jun	Inlet			70	1.0	0.25	0.57			
2004	Jun	Inlake W	2	2.2	30				47.20	3.96	
2004	Jul	Inlet			70	1.0	0.25	0.57			
2004	Jul	Inlake W	2	13.1	30				53.00	4.62	
2004	Aug	Inlet			110	1.0	0.25	0.73			
2004	Aug	Inlake W	1	27.9	30				58.80	5.16	
2004	Sep	Inlet			80	1.5	0.25	0.63			
2004	Sep	Inlake W	2	3	30				48.20	4.07	

Table A. 4 Cascade Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake N	2	8.2	30				51.48	4.48	14.78
2011	Aug	Inlet			50	2.0	0.33	0.4			
2010	Aug	Inlake N	2.5	16.1	40				54.00	4.78	

Table A. 4 continued Cascade Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Aug	Inlet			40	1.0	0.33	0			
2010	Sep	Inlake N	3.5	5.1	30				47.24	4.13	
2010	Sep	Inlet			30	0.5	0.33	0			
2000	Jun	Inlet			22.6	2.0	0.33	0			
2000	Jun	Outlet NE			40	2.0					
2000	Jun	Inlake NE	1.5	7.2	28				52.1	4.48	
2000	Aug	Inlet			30.1	1.0	0.33	0.48			
2000	Aug	Inlake NE	2.5	3.8	15.7				44.8	3.8	
2000	Oct	Inlet			14.6	2.0	0.33	0			
2000	Oct	Outlet			29.1	2.0					
2000	Oct	Inlake NE	5	9.3	19.5				45.4	3.93	
2000	Jun	Inlake NW	2.5	4.1	24.6				47.2	4.02	
2000	Aug	Inlake NW	2.5	3.2	28.4				47.1	3.99	
2000	Oct	Inlake NW	5	3.1	14.9				40.5	3.41	

Table A. 5 Clear Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake S	3	0.6	40				42.37	3.5	7.64
2011	Jun	Inlet			110	0.2	0.1	0.64			
2011	Oct	Inlake S	2	2.5	40				48.98	4.16	10.87
2010	Jun	Inlake S	3.5	2.9	60				48.73	4.21	
2010	Jul	Inlake S	2.5	1.9	60				48.96	4.17	
2010	Aug	Inlake S	2.5	3.9	50				50.44	4.36	
2009	Jun	Inlake S	2.5	0.6	50				44.3	3.61	
2009	Aug	Inlake S	2.5	5.3	20				47	4.02	
2009	Oct	Inlake S	2.5	2.4	30				46.4	3.9	
2008	Jul	Inlake S	3.5	0.9	30				41.6	3.41	
2008	Aug	Inlake S	3	2.4	30				45.5	3.83	
2008	Oct	Inlake S	2.5	6.5	40				51	4.39	
2004	Jun	Inlet			80	0.2	0.1	0.13			
2004	Jun	Inlake S	2	5	70				53.9	4.62	
2004	Jul	Inlake S	1.5	8.5	50				55.4	4.79	

Table A. 5 continued Clear Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2004	Aug	Inlake S	1	9.8	90				60.7	5.24	
2004	Sep	Inlake S	1	3.5	30				52	4.4	

Table A. 6 Crevice Lake

Year	Month	Location	SD (m)	Chl-a (ppb	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2005	Aug	Inlake	3	1.4	40				45.1	3.75	

Table A. 7 Druid Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake SE	3	1.6	20				42.24	3.57	6.23
2011	Oct	Inlake SE	2	6.5	50				53.18	4.61	15.57
2010	Oct	Inlake SE	3.5	7.6	50				51	4.49	

Table A. 8 Duck Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake SW	4	3.5	20				43.42	3.75	7.15
2011	Aug	Inlake SW	4	0.5	10				33.73	2.74	3.33
2010	Jun	Inlake SW	5	1.1	10				35.23	2.98	
2010	Jul	Inlake SW	4.5	0.8	20				38.03	3.19	
2009	Aug	Inlake SW	3.5	0.7	9				34.9	2.8	
2009	Oct	Inlake SW	4.5	2.1	10				37.8	3.15	
2008	Jun	Inlake SW	2.5	1.9	10				40.3	3.35	
2003	Aug	Inlake E	2.5	2.7	20				44.8	3.78	
1999	Jun	Inlake E	5.5	0.5	15				34.1	2.71	
1999	Aug	Inlake E	5	1.9	13				38.3	3.18	

Table A. 9 Eleanor Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake E	4	1.5	10				37.32	3.03	4.22
2010	Jun	Inlake E	4	0.5	10				33.73	2.77	
2010	Jul	Inlake E	3.5	0.5	10				34.37	2.81	
2010	Aug	Inlake E	3.5	0.7	10				35.47	2.93	
2009	Jun	Inlake E	4.5	0.5	10				33.1	2.62	
2009	Aug	Inlake E	3.5	0.7	9				34.9	2.8	
2008	Jun	Inlet			30	1.0	0.02	0.33			
2008	Jun	Outlet			20	1.0					
2008	Jun	Inlake E	3.5	0.5	20				41.3	3.42	
2008	Jul	Inlet			10	5.0	0.02	0			
2008	Jul	Inlake E	2.5	0.5	10				36	2.86	
2008	Oct	Inlet			20	0.1	0.02	0			
2008	Oct	Inlake E	2.5	2.6	20				44.7	3.76	
2004	Jun	Inlet			10	1.0	0.02	0			
2004	Jun	Inlake E	5	0.5	10				32.6	2.58	
2004	Jul	Inlet			10	3.0	0.02	0			
2004	Jul	Inlake E	3.5	1.3	20				40.8	3.37	
2004	Aug	Inlake E	3	1.2	20				41.3	3.4	

Table A. 10 Feather Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Oct	Inlake S	2	14.5	260				63.73	5.6	46.88
2010	Oct	Inlake S	2.5	11.5	260				61.9	5.45	

Table A. 11 Floating Island Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake W	2	28.6	70				59.64	5.3	37.53
2010	Aug	Inlake W	1.5	24.5	80				61.16	5.4	
2004	Jul	Inlake W	1	25	150				66.2	5.8	

Table A. 12 Goose Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake W	3	0.9	20				40.36	3.35	5.6
2011	Jun	Inlet			20	2.5	0.21	0			
2011	Oct	Inlake W	3	3	20				44.3	3.8	7.47
2011	Oct	Inlet			10	1.0	0.21	0			
2010	Oct	Inlake W	4.5	21.7	20				48.82	4.41	
2010	Oct	Inlet			20	1.0	0.21	0			
2009	Jun	Inlet			10	3.0	0.21	0			
2009	Jun	Inlake W	4.5	1.2	10				36	2.94	
2009	Jul	Inlet			50	1.5	0.21	0.6			
2009	Jul	Inlake W	4	1.9	20				41.4	3.45	
2009	Aug	Inlet			20	2.0	0.21	0.5			
2009	Aug	Inlake W	3.5	1.2	10				37.2	3.05	
2001	Jul	Inlet			24	2.0	0.21	0.38			
2001	Jul	Inlake W	3.5	0	15				42.6	3.62	

Table A. 13 Grebe Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2000	Jul	Inlet			15.6	5.0	1.7	0			
2000	Jul	Outlet			19.2	6.0					
2000	Jul	Inlake E	3	3.6	18				43.1	3.63	
2000	Aug	Inlet			42.2	4.0	1.7	0.38			
2000	Aug	Outlet			26.1	5.0					
2000	Aug	Inlake E	2.5	4.7	22.8				47.3	4.03	
2000	Jul	Inlake W	3	1.9	25				36.9	2.93	
2000	Aug	Inlake W	2.5	6.7	32.8				50.2	4.32	

Table A. 14 Grizzly Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Aug	North	4.5	1.5	10				36.75	3.13	

Table A. 15 Harlequin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake S	2	4.3	30				49.37	4.24	11.31

Table A. 15 continued Harlequin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Jun	Inlake S	2.5	5.3	30				48.98	4.25	
2009	Jul	Inlake S	2.5	2.2	20				44.2	3.7	
2009	Oct	Inlake S	2.5	7.6	40				51.5	4.45	
2008	Jun	Inlake S	1.5	3.6	20				48.2	4.08	
2008	Jul	Inlake S	1.5	4.6	30				51	4.34	
2008	Oct	Inlake S	2	11.7	40				56	4.91	
2007	Oct	Inlake S	1.5	12.1	150				61.9	5.38	
2003	Jun	Inlake S	3.5	2	20				42.2	3.53	
2003	Aug	Inlake S	2.5	2.5	20				44.6	3.75	
2002	Jul	Inlake S	4	8.8	19				46.2	4	
2001	Jun	Inlake S	2.5	7.3	19				47.8	4.12	
2001	Jul	Inlake S	2.5	1.4	15				41.3	3.41	
2001	Aug	Inlake S	2	0.4	15				38.3	3.04	

Table A. 16 Hazle Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake E	2	1	20				42.65	3.53	7.23
2011	Jun	Inlet			30	5.0	0.019	0.33			
2011	Jul	Inlake E	2	22.4	20				52.82	4.68	26.25
2011	Jul	Inlet			40	1.0	0.019	0.5			
2010	Aug	Inlake E	2	97.6	230				69.37	6.26	
2010	Oct	Inlake E	3.5	1.7	30				43.65	0.81	
2010	Oct	Inlet			140	5.0	0.019	0.79			
2001	Apr	Inlet			26	5.0	0.019	0			
2001	Apr	Inlake E	2.5	2	26				49	3.99	
2001	Jun	Inlet			28	1.0	0.019	0.14			
2001	Jun	Inlake E	2.5	1.8	24				44.4	3.99	
2001	Jul	Inlet			42	1.0	0.019	0.71			
2001	Jul	Inlake E	2.5	0.2	15				33.9	3.99	
2001	Aug	Inlet			17	0.5	0.019	0.12			
2001	Aug	Inlake E	2	1.9	15				43.4	4.26	
2001	Oct	Inlet			22	0.3	0.019	0.27			
2001	Oct	Inlake E	1.5	2	16				49.2	4.6	

Table A. 17 Heart Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
1999	Jul	Inlet			13	40	2				
1999	Jul	Inlake NW	7.5	0.5	11			0.15	31.1	2.43	
1999	Jul	Inlake SW	7.5	1.5	15			0	36.2	2.97	
1999	Aug	Inlet			24	25	2				
1999	Aug	Inlake NW	7.5	1.5	13			0.46	35.5	2.91	
1999	Aug	Inlake SW	7.5	4.4	14			0.42	39.4	3.34	

Table A. 18 Hot Beach Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Oct	Inlake S	1	10.9	180				64.36	5.58	39.07
2010	Sep	Inlake S	1.5	372	1300				83.45	7.58	
2010	Oct	Inlake S	1	88.9	600				77.01	6.86	
2004	Jun	Inlake S	1	30	200				68.2	5.99	
2004	Jul	Inlake S	1	13.2	90				61.7	5.35	
2004	Aug	Inlake S	1	39	480				73.2	6.46	
2004	Sep	Inlake S	2	3.1	30				48.3	4.09	

Table A. 19 Hot Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Oct	Inlake NW	5	0	30				37.93	3.16	
2001	Jun	Inlet			10	2.0	0.003	0.2			
2001	Jun	Inlake NW	3.5	0	8				38	3.22	

Table A. 20 Ice Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake SW	4	2	20				41.59	3.54	5.82
2010	Sep	Inlake SW	4.5	2.9	20				42.24	3.67	

Table A. 20 continued Ice Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2009	Jul	inlet			60	0.1	2.28	0.83			
2009	Jul	Inlake NW	4.5	0.8	10				34.7	2.79	
2009	Aug	Inlake SW	3.5	1.3	9				37	3.03	
2009	Oct	Inlake SW	4.5	3.4	10				39.4	3.32	
2000	Jun	Inlet			25	0.1	2.28	0.16			
2000	Jun	Outlet			21	0.1					
2000	Jun	Inlake NW	2.5	1.7	35				46	3.84	
2000	Aug	Inlet			34.8	0.1	2.28	0.09			
2000	Aug	Inlake NW	5	2.4	31.8				43.3	3.64	
2000	Oct	Inlet			22.6	0.1	2.28	0.28			
2000	Oct	Outlet			16.2	0.1					
2000	Oct	Inlake NW	5	2.4	12.5				38.8	3.25	
2000	Jun	Inlake SW	2.5	1.2	21				42.4	3.5	
2000	Aug	Inlake SW	5	1.8	18.8				39.9	3.31	
2000	Oct	Inlake SW	5	2.2	16.2				39.8	3.32	

Table A. 21 Indian Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake W	3	2.5	300				56.72	4.87	39.3
2011	Aug	Inlake W	3	4.6	550				61.63	5.35	69.98
2011	Aug	Inlet			110	0.2	0.2	0			
2011	Oct	Inlake W	2	4.2	530				63.1	5.45	68.85
2010	Jun	Inlake W	4.5	2.7	500				57.48	5	
2010	Jun	Inlet			200	0.2	0.2	0			
2010	Jul	Inlake W	2.5	1.2	490				62.93		

Table A. 21 continued Indian Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Jul	Inlet			220	0.1	0.2	0			
2010	Aug	Inlake W	1.5	2.5	580				63.22	5.4	
2010	Sep	Inlake W	2.5	6.6	640				64.41	5.63	
2010	Oct	Inlake W	3.5	6.6	550				62.07	5.45	
2010	Oct	Inlet			130	0.1	0.2	0			
2009	Jun	Inlet			500	0.2	0.2	0.88			
2009	Jun	Inlake W	4.5	2.5	60				47	3.97	
2009	Jul	Inlet			50	0.5	0.2	0			
2009	Jul	Inlake W	3.5	8.9	510				62.7	5.45	
2009	Aug	Inlet			100	0.1	0.2	0			
2009	Aug	Inlake W	2.5	10.7	500				64.8	5.64	
2009	Oct	Inlet			190	0.1	0.2	0			
2009	Oct	Inlake W	3.5	11.9	530				63.8	5.57	
2008	Jun	Inlet			140	0.5	0.2	0			
2008	Jun	Inlake W	3.5	1.5	500				56.8	4.78	
2008	Jul	Inlet			60	0.2	0.2	0			
2008	Jul	Inlake W	3.5	2.8	480				58.6	5	
2008	Aug	Inlet			100	0.2	0.2	0			
2008	Aug	Inlake W	2.5	9.7	530				64.8	5.63	
2008	Oct	Inlet			90	0.5	0.2	0			
2008	Oct	Inlake W	2.5	12.8	530				65.7	5.73	
2006	Jun	Inlet			110	0.5	0.2	0			
2006	Jun	Outlet			550	0.5	0.2				
2006	Jun	Inlake S	2	0.9	520				58	4.84	
2005	Jun	Inlet			60	0.4	0.2	0			
2005	Jun	Inlake W	2	0.7	510				57.1	4.74	
2005	Jul	Inlet			140	0.4	0.2	0			

Table A. 21 continued Indian Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2005	Jul	Inlake W	2.5	0.9	500				56.7	4.73	
2005	Aug	Inlake W	2	9.5	550				65.9	5.73	
2005	Oct	Inlake W	3	55.3	610				70.3	6.26	
2004	Jun	Inlake W	2	3.9	510				62.7	5.37	
2004	Jul	Inlake W	1.5	0.9	530				59.4	4.96	
2004	Aug	Inlake W	1.5	8.1	610				67.3	5.83	
2004	Sep	Inlake W	1	4.2	530				66.4	5.68	

Table A. 22 Isa Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Oct	Inlake	1	2.5	40				52.31	4.4	15.47
2010	Jul	Inlake	2.5	2.3	40				47.64	4.07	
2010	Oct	Inlake	2.5	5.3	30				48.98	4.25	
1999	Aug	Inlake	2.5	4.2	30				44.6	3.8	

Table A. 23 Lake of the Woods

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Sep	Inlake S	2.5	87.1	260				68.52	6.2	
2010	Sep	Inlet			60	1.0	1	0			
2001	Jun	Inlake S	3.5	5.2	27				46.8	3.58	

Table A. 24 Lewis Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake SE	5	1.2	10				35.52	2.98	3.49
2011	Aug	Inlake SE	5	0.7	20				37.09	3.08	4.2
2010	Jun	Inlake SE	6	1.7	10				35.78	3.08	
2010	Aug	Inlake SE	5.5	0.7	20				36.63	3.08	

Table A. 24 continued Lewis Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2009	Aug	Inlake NE	5	1.3	20				39.1	3.13	
2009	Jun	Inlake SE	4	1.5	20				40.6	3.42	
2009	Oct	Inlake SE	5	0.9	10				34.6	3.13	
1999	Jun	Inlet N			16	5.0	0.8	0.73			
1999	Jun	Inlake N	6	0.7	16				35.1	2.89	
1999	Jun	Inlake SE	6	1.9	14				37.7	2.89	
1999	Jul	Inlet NW			10	250	0.8	0			
1999	Jul	Inlake N	7.5	0.9	36				38.8	2.59	
1999	Aug	Inlet N			41	1.0	0.8	0.13			
1999	Aug	Inlet NW			16.7	200	0.8	0.93			
1999	Aug	Inlake N	7.5	2.9	12				37.3	2.59	
1999	Aug	Inlake N	7.5	1.7	12				35.6	2.59	
1999	Aug	Inlake SE	7	1.1	11				35.1		
1998	Sep	Inlake SE	7	1.3	20				40.3		

Table A. 25 Lily Pad Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake S	2	1.7	20				44.39	3.73	7.85
2011	Oct	Inlake S	1	116	230				73.27	6.55	138.26
2010	Jun	Inlake S	2.5	1.5	10				39.58	3.33	
2010	Jul	Inlake S	2.5	4.1	20				46.2	3.99	
2010	Aug	Inlake S	2.5	2.4	20				44.44	3.79	
2010	Sep	Inlake S	2.5	49.1	190				65.14	5.85	
2009	Jun	Inlake S	1.5	0.9	20				43.7	4.6	
2009	Aug	Inlake S	3.5	1.1	10				36.9	3.58	
2009	Oct	Inlake S	2.5	8.3	40				51.8	3.99	
2008	Jul	Inlake S	3.5	0.9	10				36.3	3.58	
2008	Aug	Inlake S	2.5	14.2	20				50.2	3.99	
2008	Oct	Inlake S	2.5	29.5	70				58.7	3.99	
2006	Jun	Inlake S	4	0.5	50				31.9	3.42	
2004	Jun	Inlake S	2	0.5	10				37	4.26	
2004	Jul	Inlake S	2	2.4	10				42.2	4.26	
2004	Aug	Inlake S	1.5	1.4	10				41.8	4.6	
2004	Oct	Inlake S	2	1.2	10				39.9	4.26	

Table A. 26 Lost Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake N	2	8.7	40				53.06	4.62	16.38
2011	Jul	Inlake N	3	3.1	30				46.35	3.98	8.71
2011	Aug	Inlake N	3	4	10				41.91	3.61	7.21
2011	Aug	Inlet			30	0.0	0.51	0.67			
2010	Jun	Inlake N	2.5	1.5	10				47	4.11	
2010	Jul	Inlake N	2.5	4.1	20				48.9	4.25	
2010	Aug	Inlake N	2.5	2.4	20				49.8	4.35	
2010	Sep	Inlake NE	2.5	49.1	190				49.6	4.32	
2009	Jun	Inlake N	2.5	4.2	20				46.3	3.99	
2009	Jul	Inlet			90	0.0	0.51	0.667			
2009	Jul	Inlake N	2.5	5.9	30				49.3	3.99	
2009	Aug	Inlet			30	0.5	0.51	0.333			
2009	Aug	Inlake NW	2.5	8.9	20				48.7	3.99	
2009	Oct	Inlake NW	2.5	13.7	40				53.5	3.99	
2008	Jun	Inlet			50	1.0	0.51	0.4			
2008	Jun	Inlake N	2.5	4.8	30				48.7	3.99	
2008	Aug	Inlet			60	0.0	0.51	0.67			
2008	Aug	Inlake N	1.5	5.4	20				49.5	4.6	
2008	Oct	Inlet			60	0.0	0.51	0.67			
2008	Oct	Inlake N	2	7.9	20				49.4	4.26	
2007	Aug	Inlet			50	0.1	0.51	0.2			
2007	Aug	Inlake N	2.5	4.9	40				50.1	3.99	
2006	Jun	Inlet			60	0.5	0.51	0.33			
2006	Jun	Inlake N	2.5	3.1	40				48.6	3.99	
2005	May	Inlet			50	0.5	0.51	0.4			
2005	May	Inlake N	2.5	2.7	30				46.8	3.99	
2005	Jun	Inlet			60	0.5	0.51	0.5			
2005	Jun	Inlake N	3	1.6	30				44.2	3.77	
2005	Jul	Inlet			60	0.5	0.51	0.5			
2005	Jul	Inlake N	1	18.5	30				57.5	5.07	
2005	Aug	Inlet			70	0.5	0.51	0.71			
2005	Aug	Inlake N	2.75	3.3	20				45	3.88	
2005	Oct	Inlake N	2	15.3	40				54.9	4.26	
2004	Jun	Inlet			100	0.5	0.55	0.7			
2004	Jun	Inlake N	1.75	7.6	30				51.9	4.42	

Table A. 26 continued Lost Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2004	Jul	Inlet			30	0.5	0.55	0.33			
2004	Jul	Outlet			20	0.5					
2004	Jul	Inlake N	1.5	15.8	30				55	4.6	
2004	Aug	Inlet			90	0.5	0.55	0.67			
2004	Aug	Inlake N	3	4.4	30				47.5	3.77	
2004	Sep	Inlet			50	0.5	0.55	0.4			
2004	Sep	Inlake N	2	0.9	30				44.3	4.26	

Table A. 27 Mallard Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Aug	Inlake SE	4.5	1.2	20				39.35	3.34	
2010	Aug	Inlet			30	1.0	1	0.33			

Table A. 28 North Twin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake E	3	0.5	30				40.39	3.31	6.4
2011	Jun	Inlet			60	2.0	0.49	0.5			
2011	Oct	Inlake E	3	1.4	30				43.76	3.69	7.2
2011	Oct	Inlet			130	0.3	0.49	0.77			
2010	Jun	Inlake E	2.5	2.9	30				47.01	4.03	
2010	Jun	inlet			100	2.0	0.49	0.7			
2010	Jul	Inlake E	3.5	0.7	40				42.13	3.52	
2010	Jul	inlet			170	0.5	0.49	0.76			
2010	Aug	Inlake E	2.5	1.2	50				46.58	3.92	
2010	Aug	inlet			190	0.5	0.49	0.74			
2009	Jun	inlet			200	2.0	0.49	0.8			
2009	Jun	Inlake E	3.5	6.8	40				49.6	3.58	
2009	Jul	inlet			40	0.5	0.49	0			
2009	Jul	Inlake E	3.5	1.4	190				51.9	3.58	
2009	Aug	inlet			200	0.1	0.49	0.85			
2009	Aug	Inlake E	3.5	0.8	30				41.25	3.58	
2009	Oct	inlet			150	0.1	0.49	0.6			
2009	Oct	Inlake E	3.5	2	60				47.5	3.58	
2008	Jun	inlet			140	2.0	0.49	0.86			

Table A. 28 continued North Twin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Jun	Inlake E	2.5	3.8	20				45.9	3.99	
2008	Jul	inlet			200	0.5	0.49	0.85			
2008	Jul	Inlake E	3.5	4.1	30				46.5	3.58	
2008	Aug	inlet			170	0.3	0.49	0.35			
2008	Aug	Inlake E	2.5	17.1	110				59.1	3.99	
2008	Oct	inlet			160	0.3	0.49	0.88			
2008	Oct	Inlake E	3	1.3	20				41.6	3.77	
2001	Apr	inlet			71	2.0	0.49	0.77			
2001	Apr	Inlake E	3.5	3.1	16				42.6	3.58	
2001	Jun	inlet			113	0.5	0.49	0.76			
2001	Jun	Inlake E	2.5	1.1	27				43.3	3.99	
2001	Jul	inlet			103	0.5	0.49	0.88			
2001	Jul	Inlake E	3	0	12				42.1	3.77	
2001	Aug	inlet			70	0.5	0.49	0.86			
2001	Aug	Inlake E	2.5	0	10				42.1	3.99	
2001	Oct	inlet			70	0.3	0.49	0.77			
2001	Oct	Inlake E	2.5		16				45.5	3.99	

Table A. 29 Nymph Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake E	1	9.3	100				61.011	5.27	28.43
2011	Aug	Inlet N			130	4.0	0.055	0.44			
2011	Aug	Inlet E			50	1.0	0.055	0.44			
2010	Jun	Inlake E	2.5	2.5	70				50.6	4.34	
2010	Jun	inlet N			50	6.0	0.055	0			
2010	Jul	Inlake E	2.5	14.4	130				59.3	5.24	
2010	Jul	Inlet N			120	3.0	0.055	0			
2010	Aug	Inlake E	2	9.5	150				59.7	5.22	
2010	Aug	Inlet N			120	3.0	0.055	0			
2009	Jul	Inlet			110	2.0	0.055	0			
2009	Jul	Inlake E	2	10.1	180				60.8	4.26	
2009	Aug	Inlet			100	1.5	0.055	0			
2009	Aug	Inlake E	2.5	6.3	100				55.3	3.99	
2009	Oct	Inlet			110	2.0	0.055	0			
2009	Oct	Inlake E	2.5	1.6	120				51.7	3.99	

Table A. 29 continued Nymph Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Jun	Inlet			30	1.0	0.055	0			
2008	Jun	Inlake E	1.5	16.7	120				61.9	4.6	
2008	Oct	Inlet			90	0.5	0.055	0			
2008	Oct	Inlake E	1.5	4.7	110				57.3	4.6	
2001	Apr	Inlet			20	5.0	0.055	0			
2001	Apr	Inlake E	3	1.2	62				46.7	3.77	
2001	Jun	Inlet			16	3.0	0.055	0			
2001	Jun	Inlake E	2.5	0.9	65				46.9	3.99	
2001	Jul	Inlet			22	2.0	0.055	0			
2001	Jul	Inlake E	0.5	2.4	38				55.3	5.87	
2001	Aug	Inlet			10	1.5	0.055	0			
2001	Aug	Inlake E	0.15	4.7	203				71.3	7.24	
2001	Oct	Inlet			16	1.0	0.055	0			
2001	Oct	Inlake E	0.1	0	130				83.8	7.7	

Table A. 30 Pool By Morning Glory Pool

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Oct	Inlake	5	3.9	520				58.36	5.12	
2001	Aug	Inlake	5	4	12				38.4	3.13	

Table A. 31 Ribbon Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Sep	Inlake N	2	26.8	40				56.74	5.05	
2006	Jun	Outlet			50	2.0	0.01	0			
2006	Jun	Inlake NE	0.7	2.3	40				53.8	4.51	
2006	Jun	Inlake NW	0.7	1.7	50				53.8	5.48	

Table A. 32 Riddle Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Oct	Inlake NW	2.5	14.4	80				56.97	5.04	
2008	Jul	Inlet			134	1.0	2	0.85			

Table A. 32 continued Riddle Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Jul	Inlake NW	4	6.9	20				45.6	3.42	
1999	Aug	Inlake NW	7.5	4.1	14				39.2	2.59	

Table A. 33 Scaup Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Oct	Inlake S	2	3.3	20				46.56	3.97	9.27
2010	Aug	Inlake S	2.5	7.1	50				52.4	4.58	
2002	Aug	Inlake S	2	4.5	22				48	4.26	

Table A. 34 Shoshone Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Aug	Inlake NE	5	0.9	20				37.91	3.2	
2010	Aug	Inlet			40	3.0	3.6	0.5			
1999	Jun	Inlet			26	200	3.6	0.61			
1999	Jun	Inlake NE	6	1	15				36	2.89	
1999	Jul	Inlet			13	65	3.6	0.42			
1999	Jul	Inlake W	7.5	0.5	15				32.6	2.59	
1999	Jul	Outlet			11	200	3.6	0			
1999	Jul	Inlake NW	7.5	1.7	9				34.2	2.59	
1999	Aug	Inlet			74	8.0	3.6	0			
1999	Aug	Inlake SW	7.5	1.3	478				52.4	2.59	
1999	Aug	Inlake SE	7.5	1.4	18				36.9	2.59	
1998	Sep	Inlake NE		1.1	36				43.7		

Table A. 35 Shrimp Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Oct	Inlake SW	2	1	70				48.68	4.06	12.99
2005	Jul	Inlake SW	2.5	8.9	50				53.1	3.99	
2005	Aug	Inlake SW	3	8	30				48.7	3.77	
2004	Sep	Inlake SW	2.5	8.9	150				64.2		

Table A. 36 South Twin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake E	3	3.6	20				44.89	3.86	8
2011	Jun	Inlet			30	1.0	0.8	0			
2011	Oct	Inlake E	2	9.7	40				53.41	4.66	17.27
2011	Oct	Inlet			30	1.0	0.8	0			
2010	Jun	Inlake E	1.5	7.5	50				55.03	4.77	
2010	Jun	Inlet			30	1.0	0.8	0			
2010	Jul	Inlake E	3.5	1.1	40				43.61	3.69	
2010	Jul	Inlet			40	1.0	0.8	0			
2010	Aug	Inlake E	3.5	1.7	40				45.03	3.85	
2010	Aug	Inlet			50	1.0	0.8	0			
2009	Jun	Inlake E	2.5	4.4	30				48.4	3.99	
2009	Jun	Inlet			40	1.0	0.8	0			
2009	Jul	Inlet			190	1.0	0.8	0	51.9	3.58	
2009	Jul	Inlake E	3.5	1.6	40				44.8	3.58	
2009	Aug	Inlet			30	1.0	0.8	0	41.2	3.58	
2009	Aug	Inlake E	3.5	1.7	40				45	3.58	
2009	Oct	Inlet			60	1.0	0.8	0			
2009	Oct	Inlake E	3.5	2	50				46.6	3.58	
2008	Jun	Inlake E	1	3.4	30				51.9	5.07	
2008	Jun	Inlet			20	1.0	0.8	0			
2008	Jul	Inlake E	3.5	1.6	20				41.5	3.58	
2008	Jul	Inlet			30	1.0	0.8	0			
2008	Aug	Inlet			110	1.0	0.8	0			
2008	Aug	Inlake E	3.5	1.2	20				40.6	3.58	
2008	Oct	Inlet			20	1.0	0.8	0			

Table A. 36 continued South Twin Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2008	Oct	Inlake E	3.5	4.5	30				46.8	3.58	
2001	Apr	Inlet			16	1.0	0.8	0			
2001	Apr	Inlake E	3	2	30				44.2	3.77	
2001	Jun	Inlet			27	1.0	0.8	0			
2001	Jun	Inlake E	2.5	2.5	28				46.2	3.99	
2001	Jul	Inlet			12	1.0	0.8	0			
2001	Jul	Inlake E	3.5	0.8	11				36.4	3.58	
2001	Aug	Inlet			10	1.0	0.8	0			
2001	Aug	Inlake E	2.5	0	12				43.4	3.99	
2001	Oct	Inlet			16	1.0	0.8	0			
2001	Oct	Inlake E	2.5	2	16				45.5	3.99	

Table A. 37 Swan Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake S	3	0.9	20				40.36	3.35	5.6
2011	Oct	Inlake S	2	6.4	70				54.75	4.75	17.79
2010	Jun	Inlake S	3.5	1.6	20				41.5	3.53	
2010	Jul	Inlake S	2.5	4.7	40				49.97	4.33	
2010	Aug	Inlake S	1.5	14.4	100				60.49	5.3	
2009	Jun	Inlake S	3.5	1.8	20				41.9	3.58	
2009	Jul	Inlake S	2.5	18.7	140				60.5	3.99	
2009	Aug	Inlake S	2.5	1.7	20				43.3	3.99	
2009	Oct	Inlake S	1.5	4.9	50				53.6	4.6	
2008	Jun	Inlake S	2.5	2.3	40				47.6	3.99	
2008	Jul	Inlake S	2.5	1.4	30				44.6	3.99	
2008	Aug	Inlake S	2.5	7.6	40				51.5	3.99	
2008	Oct	Inlake S	2.5	3.3	30				47.4	3.99	
2001	Apr	Inlake S	2	4.3	54				52.2	4.26	
2001	Jun	Inlake S	2.5	2.4	49				48.7	3.99	
2001	Jul	Inlake S	3.5	0.5	24				38.6	3.58	
2001	Aug	Inlake S	2	0.3	24				43.5	4.26	

Table A. 38 Sylvan Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake N	4	0.8	10				35.26	2.91	3.6
2011	Jul	Inlet N			20	2.0	0.2	0.5			
2011	Oct	Inlake N	4	3.6	10				40.18	3.47	6.09
2011	Oct	Inlet N			10	1.0	0.2	0.5			
2010	Jun	Inlake N	4.5	2.2	10				38	3.27	
2010	Jun	Inlet N			10	3.0	0.2	0			
2010	Jul	Inlake N	3.5	1.3	10				37.49	3.16	
2010	Jul	Inlet N			10	2.0	0.2	0			
2010	Aug	Inlake N	4.5	1.3	10				36.28	3.08	
2010	Aug	Inlet N			20	1.0	0.2	0.5			
2009	Jun	Inlet N			9	3.0	0.2	0			
2009	Jun	Inlet E			10	20	0.2				
2009	Jun	Inlake N	4.5	0.5	60				41.8	3.27	
2009	Jul	Inlet N			9	1.0	0.2	0			
2009	Jul	Inlake N	4.5	2.1	10				37.8	3.27	
2009	Aug	Inlet E			9	5.0	0.2	0			
2009	Aug	Inlake N	4.5	1.2	9				35.5	3.27	
2009	Oct	Inlet N			9	0.5	0.2	0			
2009	Oct	Inlake N	4.5	1.6	10				37	3.27	
2008	Jun	Inlet E			90	20	0.2	0.89			
2008	Jun	Inlake N	3.5	0.9	10				36.3	3.58	
2008	Jul	Inlet N			20	1.0	0.2	0.5			
2008	Jul	Inlake N	3.5	0.5	10				34.4	3.58	
2008	Oct	Inlet N			10	0.5	0.2	0			
2008	Oct	Inlake N	3.5	1.2	10				37.2	3.58	
2004	Jun	Inlet N			10	1.0	0.2	0			
2004	Jun	Inlake NE	3.5	2.7	20				43.2	3.58	
2004	Jul	Inlet N			10	1.0	0.2	0			
2004	Jul	Inlake NE	3.5	3.3	10				40.5	3.58	
2004	Aug	Inlet N			10	5.0	0.2	0			
2004	Aug	Inlake NE	3	1.8	10				39.3	3.77	
2004	Sep	Inlet N			10	5.0	0.2	0			
2004	Sep	Inlake NE	3	1.9	10				39.5	3.77	
2004	Jun	Inlake N	3.5	0.5	30			0	39.6	3.58	
2004	Jul	Inlake N	3	2.1	10			0	39.8	3.77	
2004	Aug	Inlake NW	3	1.2	10			0	38	3.77	
2004	Sep	Inlake N	3	1.2	10			0	38	3.77	

Table A. 39 Tanager Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake SE	3	1	10				37.37	3.1	4.54
2010	Sep	Inlake SE	3.5	1.2	20				40.56	3.43	
2009	Aug	Inlake SE	3.5	1.9	10				38.7	3.58	
2004	Jun	Outlet			20	1.0					
2004	Jun	Inlake SE	1.5	2.7	30				49.2	4.6	
2004	Jul	Inlake SE	2	2.2	20				45.2	4.26	
2004	Aug	Inlake SE	2	1.9	20				44.7	4.26	
2004	Sep	Inlake SE	2	1.6	10				40.8	4.26	

Table A. 40 Terrace Springs

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake S	3	0.9	70				46.38	3.88	11.37
2010	Oct	Inlake S	5	1.2	80				45.51	3.89	
2007	Oct	Inlake S	4.5	0.5	60				41.8	3.27	

Table A. 41 Trout Lake East

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jun	Inlake E	3	4.3	90				52.71	4.56	16.69
2011	Jun	Inlet			80	10	0.3	0			
2011	Jul	Inlake E	3	0.5	80				45.1	3.72	12.16
2011	Jul	Inlet			90	15	0.3	0.11			
2011	Aug	Inlake E	3	0.8	70				46	3.84	11.28
2011	Aug	Inlet			90	10	0.3	0.22			
2011	Oct	Inlake E	3	1.8	80				49.29	4.19	13.32
2011	Oct	Inlet			90	6.0	0.3	0.11			
2010	Jun	Inlake E	5	1.1	80				45.23	3.86	
2010	Jun	Inlet			80	10	0.3	0			
2010	Jul	Inlake E	3.5	9.2	230				58.96	5.21	
2010	Jul	Inlet			90	4.0	0.3	0			
2010	Aug	Inlake E	3.5	0.7	90				46.03	3.86	
2010	Aug	Inlet			90	6.0	0.3	0			
2009	Jun	Inlet			80	10	0.3	0.25			
2009	Jun	Inlake E	3.5	2.9	60				48.7	3.58	

Table A. 41 continued Trout Lake East

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2009	Jul	Inlet			80	5.0	0.3	0.13			
2009	Jul	Inlake E	3.5	0.9	70				45.6	3.58	
2009	Aug	Inlet			90	5.0	0.3	0.22			
2009	Aug	Inlake E	2.5	0.5	70				45.3	3.99	
2009	Oct	Inlet			110	4.5	0.3	0.36			
2009	Oct	Inlake E	4.5	0.8	70				44	3.27	
2008	Jun	Inlet			70	5.0	0.3	0			
2008	Jun	Inlake E	3.5	0.9	70				45.6	3.58	
2008	Jul	Inlet			180	6.0	0.3	0.61			
2008	Jul	Inlake E	4.5	1.2	70				45.4	3.27	
2008	Oct	Inlet			100	5.0	0.3	0.3			
2008	Oct	Inlake E	4	2.3	70				48.1	3.42	
2007	Aug	Inlet			90	3.5	0.3	0			
2007	Aug	Outlet			90	4.5					
2007	Aug	Inlake E	3.5	4	80				51.2	3.58	
2006	Jun	Inlet			90	5.0	0.3	0.11			
2006	Jun	Outlet			80	6.0					
2006	Jun	Inlake E	2.8	0.5	90				46	3.86	
2005	May	Inlet			100	7.0	0.3	0.4			
2005	May	Inlake E	3	0.6	60				44.3	3.77	
2005	Jun	Inlet			90	6.0	0.3	0.22			
2005	Jun	Inlake E	3	1.3	70				47.6	3.77	
2005	Jul	Inlet			80	5.0	0.3	0.25			
2005	Aug	Inlet			90	4.0	0.3	0.33			
2005	Aug	Inlake E	2.5	1.4	60				48	3.99	
2005	Oct	Inlet			80	4.0	0.3	0.13			
2005	Oct	Inlake E	3	5.3	70				52.2	3.77	
2004	Jun	Inlet			80	6.0	0.3	0			
2004	Jun	Inlake E	1.5	1.2	110				52.8	4.6	
2004	Jul	Inlet			80	5.0	0.3	0			
2004	Jul	Inlake E	2.5	3	90				52.4	3.99	
2004	Aug	Inlet			100	4.0	0.3	0			
2004	Aug	Outlet			100	5.0					
2004	Aug	Inlake E	3.5	2.4	80				49.5	3.58	
2004	Sep	Inlet			80	4.0	0.3	0			
2004	Sep	Inlake E	2.5	1.1	80				48.6	3.99	

Table A. 42 Trout Lake West

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Aug	Inlake W	3.5	1.2	90				47.79	4.06	
2009	Jul	Inlake W	3.5	3.5	80				50.7	3.58	
2005	May	Inlake W	3	1.1	60				46.3	3.77	
2005	Jun	Inlake W	3	1.1	70				47	3.77	
2005	Jul	Inlake W	3	0.6	60				44.3	3.77	

Table A. 43 Trumpeter Pond

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2010	Sep	Inlake W	0.5	58.5	250				74.76	6.56	
2010	Oct	Inlake W	1	25	460				71.58	6.28	
2004	Sep	Inlake W	1	27.9	340				70.5	5.07	
2004	Sep	Inlake E	1	21.8	120				64.7	5.66	

Table A. 44 Turbid Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2004	Jul	Outlet			50	8.0					
2004	Jul	Inlake NW	2	27.1	60				58.7	4.26	
2004	Aug	Inlet			60	4.0	0.82	0			
2004	Aug	Outlet			120	6.0					
2004	Aug	Inlake SW	1	61.4	360				73.3	5.07	

Table A. 45 Wolf Lake

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2000	Jul	Inlet			19.2	10	0.47	0			
2000	Jul	Outlet			24.7	10					
2000	Jul	Inlake N	2.5	2	18				42.1	3.99	
2000	Aug	Inlet			26.1	3.0	0.47	0.05			
2000	Aug	Inlake N	2.5	20.7	24.7				52.5	3.99	
2000	Jul	Inlake S		2	26				37.4	4	
2000	Aug	Inlake S	2.5	3.9	35.8				48.8	3.99	

Table A. 46 Yellowstone Lake at Bridge Bay

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Aug	Inlake	4	1	20				39.32	3.29	4.93
2010	Aug	Inlake	4.5	1.2	30				41.3	3.51	
2004	Jun	Inlake	3	0.5	30				40.4	3.77	
2004	Jul	Inlake	6	0.5	20				35.1	2.89	
2004	Aug	Inlake	6	1.2	30				39.9	2.89	
2004	Sep	Inlake	3.5	0.5	20				37.7	3.58	

Table A. 47 Yellowstone Lake at West Thumb

Year	Month	Location	SD (m)	Chl-a (ppb)	TP (ppb)	Flow (cfs)	HRT (yrs)	PRC	Carlson TSI	Burns TLI	Namnn TI
2011	Jul	Inlake	4	1.1	20				39.64	3.32	5.02
2010	Aug	Inlake	5	0	20				35.99	2.99	
2004	Jul	Inlake	6	0.9	30				39	2.89	
2004	Aug	Inlake	6	0.6	30				37.6	2.89	
2004	Sep	Inlake	3	0.5	20				38.4	3.77	