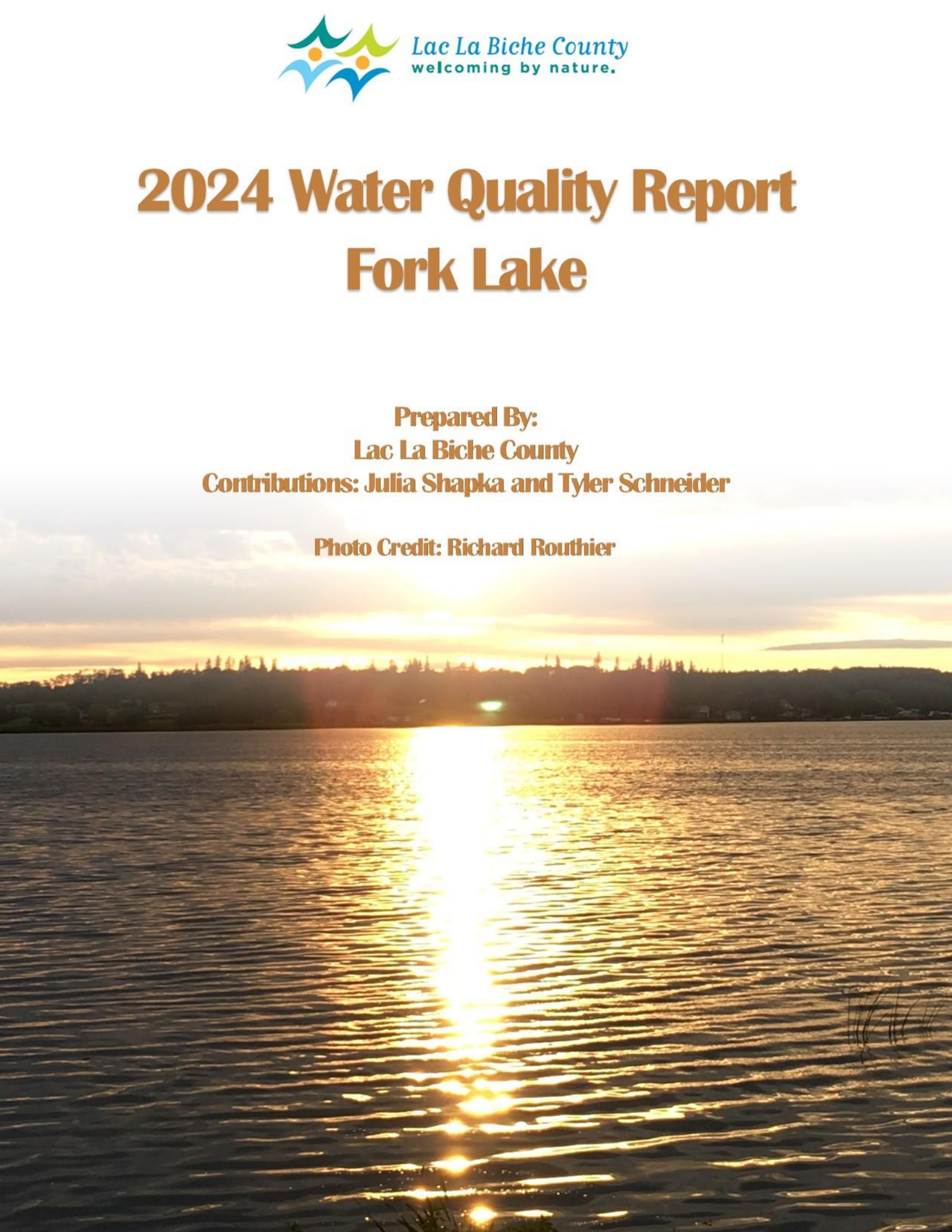
Lac La Biche County
welcoming by nature.

2024 Water Quality Report
Fork Lake

Prepared By:
Lac La Biche County
Contributions: Julia Shapka and Tyler Schneider

Photo Credit: Richard Routhier



Executive Summary

Fork Lake is relatively small, but a scenic fork-shaped lake located within Lac La Biche County, Alberta ("County"), and is known for the opportunities for recreational activities such as swimming and boating. However, there is a concern that declining water quality in the lake is limiting the opportunities of recreational activities. Therefore, it is important that the lake water quality be monitored.

The County follows a regular program to monitor water quality of lakes located within its jurisdiction. The water sampling events were conducted during the early spring and summer of 2024. The data collected includes water temperature, pH, specific conductivity, and dissolved oxygen which was collected in-situ through a multi-probe and Kemmerer sampling device. Analytical data of nitrogenous compounds, heavy metals, and other inorganic parameters were provided by ALS laboratory.

Collected water samples were analyzed by ALS Laboratory. The laboratory results obtained were compared to the CCME Canadian Environmental Quality Guidelines for Protection of Aquatic Life and Protection of Agricultural Water; and Alberta Environment and Protected Areas Environmental Quality Guidelines for Alberta Surface Waters 2018.

Trophic State Index (TSI) is a classification system designed to rate lakes based on the amount of biological activity they sustain. The concentrations of nutrients (nitrogen and phosphorus) are the primary determinants of TSI. Increased concentrations of nutrients tend to result in increased plant growth, followed by an increase in subsequent trophic level. Nurnberg (1996) used parameters including Secchi depth, chlorophyll, total nitrogen, and total phosphorus concentrations in lake waters to determine the trophic state of the lakes, which is provided as Table 1 in Appendix A. TSI is a useful tool for evaluation and management of lake health and setting objectives including sports and recreational activities related to the lake. The trophic classification of Fork Lake based on Secchi depth and nutrients is presented in Table 2.

There are four classes of trophic states which include: Oligotrophic which would be the highest quality of water with low productivity, nutrients, and algae; Mesotrophic which is fair quality water with some productivity, nutrients and algae; Eutrophic which is relatively poor-quality water with high productivity, nutrients and algae; and Hypereutrophic which is the poorest quality water with excessive productivity, nutrients, and algae.

Fork Lake would be considered Eutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen, Eutrophic based on total phosphorus, and Eutrophic based on chlorophyll-a.

Results and Discussion

In 2024, Secchi depths in Fork Lake were measured on June 20, July 18, and August 29, 2024. The average seasonal Secchi depth was observed to be 1.7 m, which is lower than historical results. The low average Secchi depth means that Fork Lake water has poor transparency due to suspended materials. Based on the Secchi depths and in accordance with the classification provided in Table 1 (Appendix A), Fork Lake is classified as Eutrophic (high productivity, nutrients, and algae growth).

Sampling events in 2024 showed an average summer water temperature of 17.36 ˚C. Uniform temperature profiles were observed during the June and August sampling events as there was no significant variation in temperatures with depth. However, signs of stratification were observed on July 18, 2024, with significant variations in temperature. Based on the data provided, thermal stratification was only observed on July 18, 2024.

Dissolved oxygen data collected in 2024 shows that the average dissolved oxygen levels were 5.70 mg/L. These concentrations were slightly lower than the regulatory criteria for dissolved oxygen in cold water lakes for early life stages (9.5 mg/L) and for all other life stages (6.5 mg/L). However, dissolved oxygen was significantly higher near the surface on June 20 and July 18. Dissolved oxygen levels were considerably low on August 29.

In 2024, two types of lake water samples for analyses of nutrients were collected from Fork Lake; composite samples and Kemmerer samples (obtained from different depths using a Kemmerer device). These samples were analyzed for total nitrogen and total phosphorus.

Total nitrogen concentrations in the composite samples collected from the lake in 2024 had an average of 2.05 mg/L of total nitrogen, while the Kemmerer samples collected had an average of 2.49 mg/L of total nitrogen; both of which exceeded the applicable regulatory guidelines and were consistent with historical results. Total nitrogen concentrations from both sampling methods classify Fork Lake as Hypereutrophic (excessive productivity, nutrients, and algae growth).

Total phosphorus concentrations in the composite samples collected during the summer of 2024 had an average of 0.064 mg/L of total phosphorus, while the Kemmerer samples collected had an average of 0.099 mg/L. The average of both sampling methods is 0.082 mg/L of total phosphorus which does exceed the applicable regulatory guidelines of 0.05 mg/L and is similar to historical results. Total phosphorus concentrations from both sampling methods classify Fork Lake as Eutrophic (high productivity, nutrients, and algae growth).

The average N:P ratios for composite and Kemmerer sampling events were 32:1 and 25:1, which is higher than the Redfield Ratio of 16:1. Therefore, the total phosphorus concentrations are considered low enough for phosphorus to be considered the main nutrient limiting growth in Fork Lake.

Total chlorophyll-a concentrations in the composite samples collected during the summer of 2024 had an average of 22.33 µg/L of total chlorophyll-a, exceeding the standard of 3.5 µg/L for Oligotrophic lakes (low productivity, nutrients, and algae growth). This concentration classifies Fork Lake as Eutrophic (high productivity, nutrients, and algae growth).

Routine water chemistry showed that Fork Lake has an average pH of 8.39 in 2024 which is similar to historical results.

Concentrations of metals analyzed from the composite and Kemmerer samples were generally below detection limits and/or below the applicable regulatory guidelines.

Fork Lake would be considered Eutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen, Eutrophic based on total phosphorus, and Eutrophic based on chlorophyll-a.

Recommendations:

It is recommended that Lac La Biche County continues to monitor the water quality of Fork Lake on a regular basis. Continuous monitoring will help the County to determine how the lake management strategies and policies such as the Watershed Management Plan and Riparian Setback Matrix Model are impacting the lake water quality, and what the net effect on human and environmental health is.

Monitoring and sampling should continue to be conducted under a strategic plan and in a uniform manner to ensure that results produced are meaningful and are useful for establishing a correlation with the past results. This may include sampling at the same period of the year each time, recording the same parameters critical to lake health, obtaining samples from the same depths, and implementing a quality assurance program for reliability of analytical results.

Nutrient loading is the main source of eutrophication in Fork Lake which is degrading the water quality, leading to algae growth, foul smells, and a reduction in water recreation. Therefore, action must be taken to slow down the eutrophication process and improve water quality. Best management practices would include education of the public on appropriate land use including restoration and protection of riparian areas (water buffers); and strengthening laws and regulations governing land use such as municipal sewer hookups and protection of environmental reserves.

Lac La Biche County updated the Lac La Biche Watershed Management Plan, which was adopted by Council in May 2021. This plan includes specific action items based on the recommendations that were formulated while drafting the plan. Although Fork Lake is not within the Lac La Biche watershed, the recommended action items may still apply.

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List of Abbreviations Used

CCME: Canadian Council of Ministers of the Environment
County: Lac La Biche County
EQGASW-AGW: Environmental Quality Guidelines for Alberta Surface Waters 2018 for protection of Agricultural Water
EQGASW-FAL: Environmental Quality Guidelines for Alberta Surface Waters 2018 for protection of Fresh Water Aquatic Life
EQGASW-RA: Environmental Quality Guidelines for Alberta Surface Waters 2018 for Recreation and Aesthetics
QA/QC: Quality Assurance and Quality Control
Total N: Total Nitrogen
Total P: Total Phosphorus
TSI: Trophic State Index

1. INTRODUCTION

Fork Lake is located in east central Alberta, approximately 185 km northeast of Edmonton and approximately 40 km southeast of the hamlet of Lac La Biche. It covers a surface area of 12 km^2 within the Beaver River Basin. Popular game fish of this lake include Yellow Perch (*Perca flavescens*), Northern Pike (*Esox lucius*), and Lake Whitefish (*Coregonus clupeaformis*).

Figure 1: Location map of Fork Lake

2. FORK LAKE WATER QUALITY SAMPLING PROGRAM

Fork Lake has been sampled since 2005 first by the Alberta Lake Management Society, and then by Lac La Biche County. Fork Lake is sampled for various parameters using different techniques. Vertical profiles were taken using a multi-probe testing different depths (zones) of the lake for dissolved oxygen, pH, conductivity, and temperature. Composite samples are taken from 10 different locations throughout the lake, while Kemmerer sampling is used for discrete depth sampling; both the composite and Kemmerer samples are tested for nutrients such as phosphorus, nitrogen, ammonia, nitrates, nitrites, and metals. Fork Lake sampling program for 2024 was completed as follows:

a) Secchi depths were measured on June 20, July 18, and August 29, 2024, using a Secchi Disk.
b) Composite samples from the lake were collected on June 20, July 18, and August 29, 2024. Lake water samples were analyzed for nutrients, metals, and basic water chemistry parameters by ALS Laboratories. Lake water samples were also analyzed for chlorophyll-a by InnoTech Alberta Laboratories.
c) Kemmerer water samples using a Kemmerer device were collected on March 12, 2024, from 0 m, 3 m, 6 m, and 9 m, and on August 29, 2024, from depths of 3 m, 6 m, and 9 m. These samples were analyzed for nutrients, metals, and basic water chemistry parameters by ALS laboratories.
d) Fork Lake profiles were recorded for various parameters (pH, temperature, dissolved oxygen) to a maximum depth of 12.0 m using a multi-probe on June 20, July 18, and August 29, 2024.

2.1 Water Quality Parameters

Water samples collected during the 2024 sampling events of Fork Lake were analyzed for a variety of parameters to characterize the lake water and identify potential issues associated with lake water quality. The water quality parameters measured/analyzed during 2024 are provided in the table below with a brief description.

Parameters affecting lake water quality

Water Quality Parameter	Description and Reason for Measuring
Secchi Depth	Secchi depth is a measure of the transparency of water and trophic state of a lake. A Secchi disk is generally a disk of 20 cm diameter with alternating black and white quadrants. It is lowered into the lake water until it can no longer be seen. This depth of disappearance is called the Secchi depth. A low Secchi depth (<4 m) is characteristic of a mesotrophic to hypereutrophic lake with turbid water. Whereas a high Secchi depth (>4 m) is characteristic of an oligotrophic lake with clear water.
Dissolved Oxygen	Dissolved oxygen is required by aquatic plants and animals for respiration. Survival of aquatic life such as fish, generally depends on an adequate amount of dissolved oxygen for respiration. As dissolved oxygen levels in the water drop below 5.0 mg/L, aquatic life is subjected to stress. Oxygen levels that consistently remain below 1-2 mg/L can result in the loss of large populations of fish.
Temperature	Temperature of water affects different physical, biological and chemical characteristics of a lake and determines the behavior of many parameters responsible for water quality. The solubility of oxygen and other gases decrease as temperature increases. An increase in water temperature decreases the concentration of dissolved oxygen required for the survival of aquatic organisms.
Nutrients	Total nitrogen (N) and phosphorus (P) are principal nutrients in lake water and are representative of all forms of N and P present in the water. There are various sources of N and P both natural and anthropogenic. These nutrients are a major cause of eutrophication, decreasing dissolved oxygen concentrations and are detrimental to lake water quality.
Chlorophyll-a	Chlorophyll-a is a green pigment present in all green plants and is responsible for the absorption of light to provide energy for photosynthesis. It is associated with algae growth in a waterbody and affects the trophic status of a lake.
Metals	Metals enter the lake waters through natural (geological) and anthropogenic point and non-point sources. Certain metals such as lead and mercury, are toxic to aquatic life and can bio-accumulate in the tissues and organs of aquatic organisms, becoming a part of the food chain. This may lead to loss of aquatic life and further affect human health.

3. REGULATORY FRAMEWORK

The protection of water quality in Canadian lakes is a federal, provincial, and territorial responsibility. Therefore, lake waters in Alberta are regulated by federal and provincial guidelines and fall under the jurisdiction of Canadian Council of Ministers of the Environment (CCME), Alberta Environment and Protected Areas, and Health Canada.

The regulatory criteria selection for lake waters in Alberta is subjected to CCME's Canadian Environmental Quality Guidelines (CEQG) and AEP's Environmental Quality Guidelines for Alberta Surface Waters 2018 (EQGASW). Protection of lake water is covered under CCME's CEQG and AEP's EQGASW chapters of water quality guidelines for Protection of Aquatic Life, Protection of Agricultural Water, and protection of Recreation and Aesthetics. In addition, Health Canada's Guidelines for Canadian Recreational Water Quality for protection of lake waters have also been considered.

The analytical and monitoring results obtained for this report were compared to the above-mentioned regulations and are hereinafter referred to as regulatory guidelines or regulatory criteria.

4. SAMPLING ANALYSIS AND MONITORING RESULTS

4.1 Secchi Depths

The Secchi disk is a common method used to measure water clarity. Water clarity of a lake can be influenced by the amount of suspended materials such as phytoplankton, zooplankton, pollen, sediments, and dissolved compounds. The Secchi depth multiplied by 2 provides us with the euphotic depth of the lake. The euphotic depth is the maximum depth to which light can penetrate within a lake to facilitate growth.

In 2024, Secchi depths in Fork Lake were measured on June 20, July 18, and August 29, 2024. The average seasonal Secchi depth was observed to be 1.7 m, which is consistent with historical results. The low average Secchi depth means that Fork Lake water has poor transparency due to suspended materials. Based on the Secchi depths and in accordance with the classification provided in Table 1 (Appendix A), Fork Lake is classified as Eutrophic (high productivity, nutrients, and algae growth).

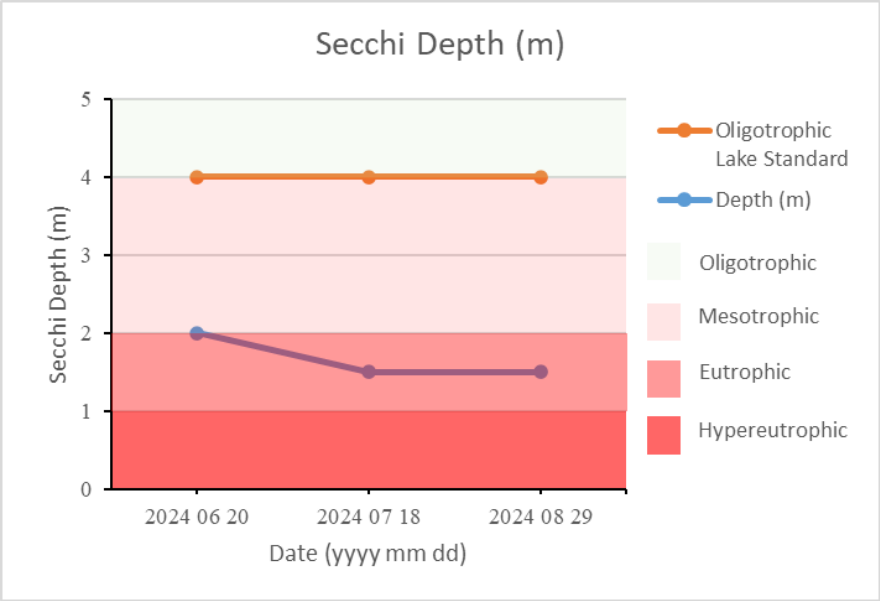

Figure 2: Secchi depths measured in Fork Lake – 2024

4.2 Dissolved Oxygen

Dissolved oxygen is the amount of gaseous oxygen dissolved in the water and is necessary for the respiration and survival of aquatic life (e.g., fish, invertebrates, bacteria, and underwater plants). Dissolved oxygen is also needed for the decomposition of organic matter in lakes. Oxygen enters the lake water by direct absorption from the atmosphere through the rapid movement of water or as a product of plant photosynthesis. Therefore, the epilimnion zone (shallow layer of water) is relatively richer in oxygen than the hypolimnion zone (deeper layer of water) which is low in oxygen due to consumption by respiration.

There are several conditions necessary for fish survival in a lake including adequate water temperatures and available dissolved oxygen for respiration. The regulatory guidelines for dissolved oxygen in cold water lakes are 9.5 mg/L for early life stages and 6.5 mg/L for all other life stages (CCME, 1999). If dissolved oxygen levels are too low, fish will move to other depths in the water column, often where temperatures are conducive to sustain aquatic life.

The amount of dissolved oxygen in lakes usually decreases under winter ice cover primarily due to respiration by organisms (particularly bacteria) and decomposition of organic matter. In shallow lakes, oxygen depletion can proceed rapidly under ice during the winter. If dissolved oxygen drops below 3.0 mg/L during the winter, many fish and invertebrate species will not survive.

In 2024, dissolved oxygen levels in Fork Lake were recorded to a maximum depth of 12.0 m using a multi-probe on June 20, July 18, and August 29, 2024. Maximum dissolved oxygen (13.38 mg/L) was observed on June 20, 2024, at a 1 m depth which declined minimally to 10.85 mg/L at a 10 m depth (Figure 3).

A gradual decreasing temporal trend was observed in all dissolved oxygen measurements, except for June 20, 2024, where dissolved oxygen began to increase slightly closer to the lakebed. The average dissolved oxygen level was 5.70 mg/L and is slightly lower than the range of applicable regulatory guidelines for dissolved oxygen in cold water lakes (9.5 mg/L for early life stages and 6.5 mg/L for all other life stages).

However, dissolved oxygen is generally higher near the surface. Dissolved oxygen was consistently low throughout the water column on August 29, 2024, with a maximum concentration of 5.57 mg/L.

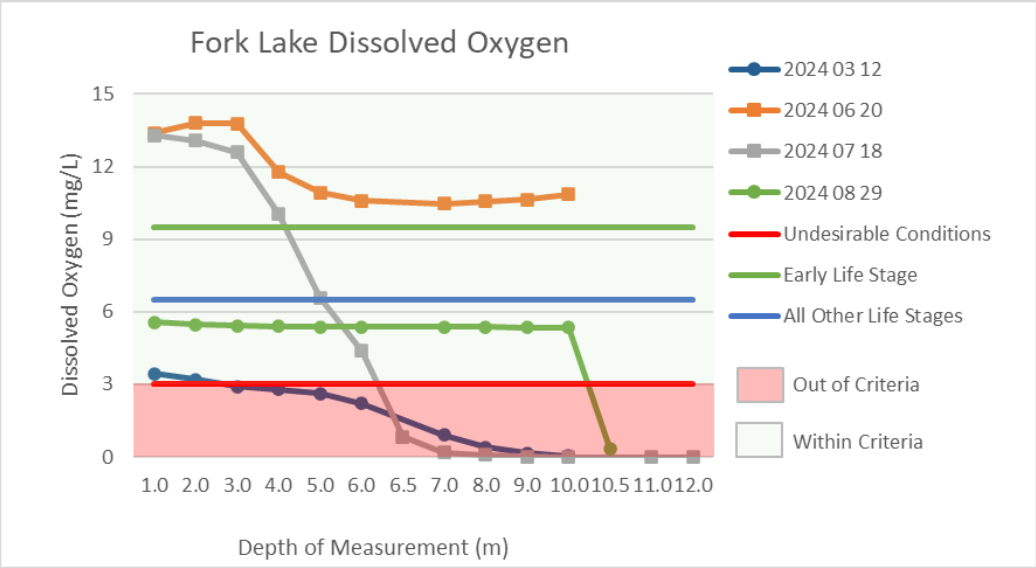

Figure 3: Dissolved oxygen in Fork Lake – 2024

4.3 Temperature

Water temperature in a lake determines the behavior of many parameters responsible for water quality. Thermal stratification occurs within a lake with a distinct difference in temperature between the surface water (epilimnion layer) and the deeper water (hypolimnion layer) separated by a thermocline. The thermocline is identified when the water changes by more than one degree Celsius per meter. Under winter conditions, ice covers the surface water, and a thermocline is formed with the colder water at the surface and the warmer water at the bottom of the lake. Lakes without thermal stratification mix from top to bottom and this mixing allows oxygen to distribute throughout the water column preventing hypolimnetic anoxia (lack of oxygen). In summertime, warmer surface water can facilitate cyanobacteria blooms at the lake surface (Wetzel, R. 2001).

Fork Lake temperatures were recorded to a maximum depth of 12.0 m. A minimum temperature of 2.81 ˚C was observed on March 12 at a 1 m depth and a maximum temperature of 24.70 ˚C was noted on July 18, 2024, at 1 m depth. Results of temperatures observed on different dates and depths are illustrated in Figure 4. Fork Lake temperature sampling data showed uniform temperature profiles, except for July 18, 2024, which displayed thermal stratification. Temperature declined from 24.70 ˚C at 1 m depth to 14.50 ˚C at 12.0 m.

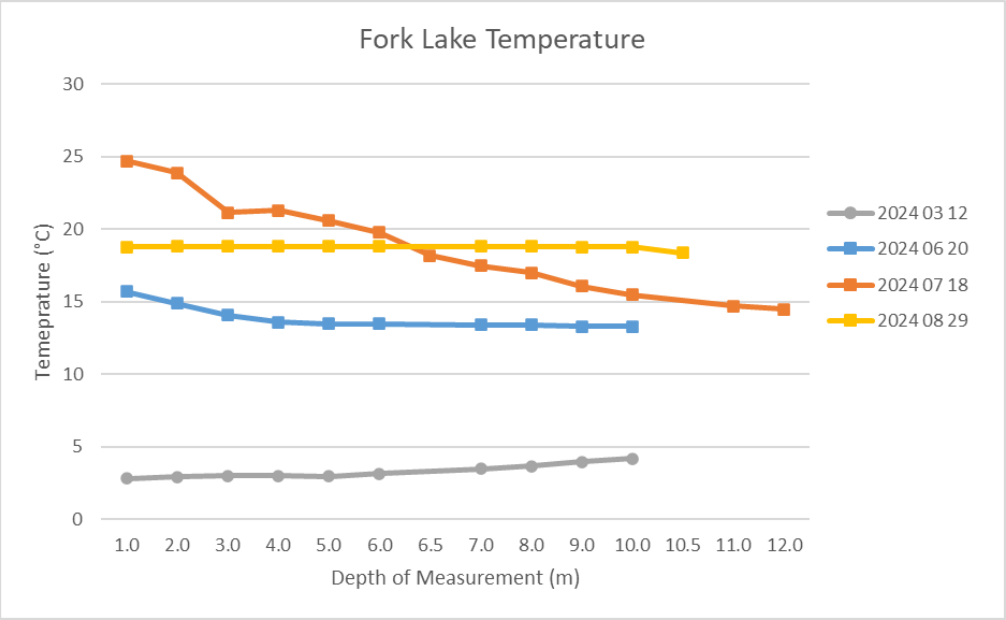

Figure 4: Temperature profile in Fork Lake – 2024

4.4 Nutrients

Excessive levels of nitrogen and phosphorus are found in many lakes across Alberta leading to excessive growth of algae and aquatic plants. Decay of aquatic vegetation causes oxygen depletion in the water column and contributes to eutrophication. Consequently, the decreased levels of oxygen can suffocate fish and other aquatic organisms. High nutrient conditions foster algal blooms and can result in the proliferation of toxin-producing blue-green algae (e.g., cyanobacteria). The input of nutrients into aquatic systems can occur naturally, but large amounts of nutrients typically originate from indirect, non-point anthropogenic sources, including improperly treated sewage, residential use of fertilizers and agricultural operations.

In 2024, two types of lake water samples for analysis of nutrients were collected from Fork Lake; composite samples and Kemmerer samples (obtained from different depths using a Kemmerer device). These samples were analyzed for total nitrogen and total phosphorus.

Total Nitrogen

Total nitrogen is an essential nutrient for plants and animals; however, excessive amounts of nitrogen in lake water may lead to low levels of dissolved oxygen and negatively affect water quality and health of aquatic life within the lake. Nitrogen concentrations in the water are typically measured in three forms: ammonia, nitrates and nitrites. Total nitrogen is the sum of total Kjeldahl nitrogen (ammonia, organic and reduced nitrogen), nitrate and nitrite. Nitrogen levels in lakes are also affected by atmospheric deposition and this refers to nitrogen in the air being deposited into the water system. Nitrogen oxides (NOx) are added to the atmosphere due to the burning of fossil fuels, so emissions from motor vehicles and industrial facilities can also affect nitrogen levels in aquatic environments.

Composite Samples

Composite lake water samples for analyses of total nitrogen were collected on June 20, July 18, and August 29, 2024. The results indicated that total nitrogen concentration in composite samples ranged from 2.01 mg/L to 2.10 mg/L. Nitrogen concentrations displayed a uniform trend throughout the sampling season. The analytical results are presented in Figure 5.

Nitrogen concentrations in the composite samples collected from the lake in 2024 had an average of 2.05 mg/L of total nitrogen which exceeded the applicable regulatory guidelines. The average total nitrogen indicates that Fork Lake is Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen from composite samples.

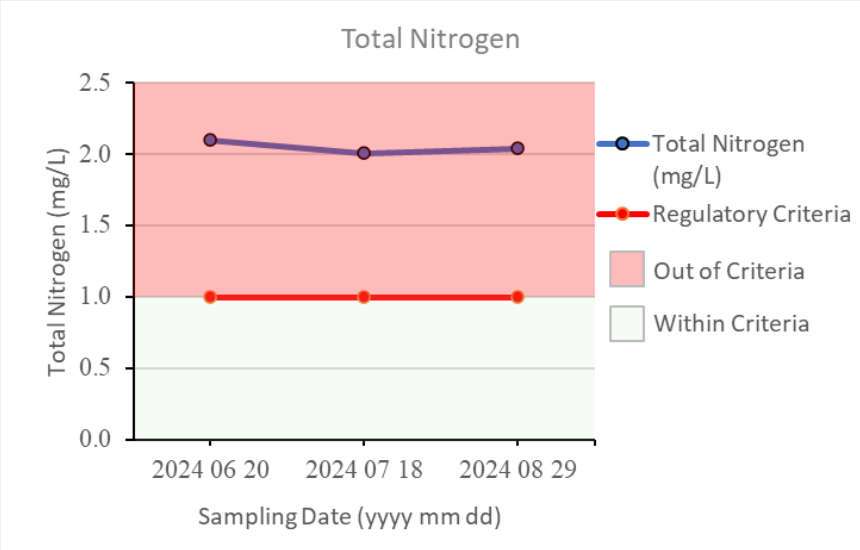

Figure 5: Total nitrogen from composite samples of Fork Lake – 2024

Kemmerer Sampling

Kemmerer water samples are collected from different depths of the lake by using a Kemmerer device which makes it possible to obtain a sample of water from specific depths. Kemmerer samples were collected on March 12, 2024, at depths of 0 m, 3 m, 6 m, and 9 m, and on August 29, 2024, at depths of 3, 6, and 9 m. These were analyzed for total nitrogen by ALS laboratories. Total nitrogen concentrations ranged from 2.04 mg/L to 2.85 mg/L with an average of 2.49 mg/L. Analytical results of total nitrogen are presented in Figure 6.

Total nitrogen concentrations in all samples from all depths exceeded the applicable regulatory guideline of 1.0 mg/L. The results from the Kemmerer sampling resulted in the same trophic state classification as the composite samples which are Hypereutrophic (excessive productivity, nutrients, and algae growth) based on total nitrogen.

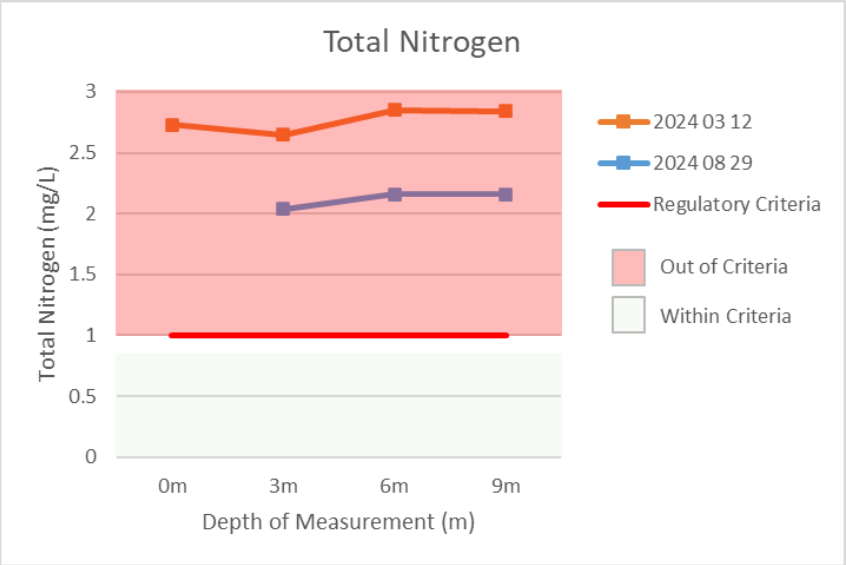

Figure 6: Total nitrogen from Kemmerer samples of Fork Lake - 2024

Total Phosphorus

Increased phosphorus concentrations are the largest cause of degradation in water quality within lakes, causing 'dead zones', toxic algal blooms, a loss of biodiversity and increased health risks for plants, animals and humans that encounter polluted lake waters. Run-off from agriculture, human sewage and industrial practices results in increased phosphorus concentrations in lake water and lakebed sediments (Wetzel, 2001). Long-term monitoring activities following the control of phosphorus sources to lakes indicate that plants and animals do not recover from the effects of excessive phosphorus for several years.

Composite Sampling

Composite lake water samples for analyses of total phosphorus were collected on June 20, July 18, and August 29, 2024, and the total phosphorus concentrations ranged from 0.053 mg/L to 0.65 mg/L. Total phosphorus concentrations were recorded at a maximum concentration of 0.074 on August 29, 2025, and a minimum concentration of 0.053 on July 18, 2024. The analytical results are presented in Figure 7.

Total phosphorus concentrations in the composite samples had an average of 0.064 mg/L of total phosphorus which does not exceed the applicable regulatory guideline of 0.05 mg/L. This average total phosphorus concentration classifies Fork Lake as Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus from composite samples.

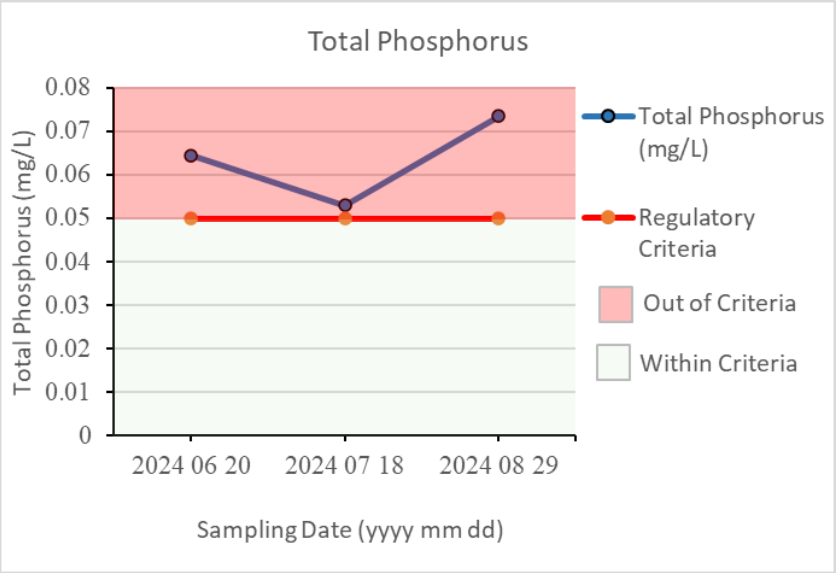

Figure 7: Total phosphorus in composite samples of Fork Lake - 2024

Kemmerer Sampling

Kemmerer water samples using the Kemmerer device were collected on March 12, 2024, from depths of 0 m, 3 m, 6 m, and 9 m, and on August 29, 2024, from depths of 3 m, 6 m, and 9 m. These were analyzed for total phosphorus by ALS laboratories. A minimum concentration of 0.077 mg/L was recorded on August 29 at 3 m, and a maximum concentration of 0.15 mg/L was recorded on March 12 at 9 m. An increasing trend in total phosphorus concentrations was observed with an increase in lake depth on both sampling dates. The results of total phosphorus concentrations for Fork Lake at different lake depths are presented in Figure 8.

Total phosphorus concentrations in all samples exceeded the applicable regulatory guideline of 0.05 mg/L, with an average concentration of 0.099 mg/L. The results from the Kemmerer sampling resulted in the same trophic state classification as the composite samples for total phosphorus which is Eutrophic (high productivity, nutrients, and algae growth) based on total phosphorus.

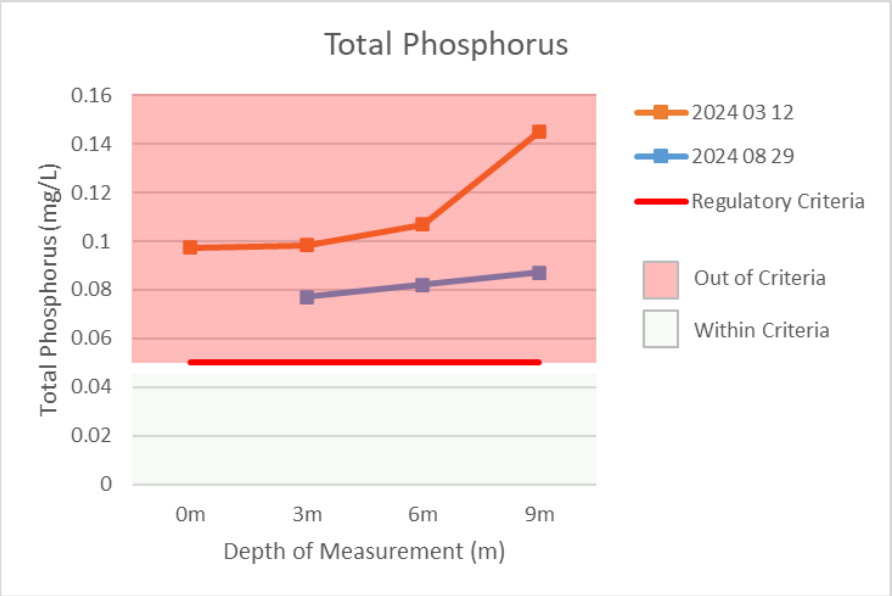

Figure 8: Total phosphorus from Kemmerer samples of Fork Lake – 2024

N:P Ratio

The Redfield Ratio describes the optimal balance of total nitrogen to total phosphorus for aquatic plant growth and has an optimal value of 16:1 (Teubner and Dokulil 2002). If the ratio is lower than 16:1, phosphorus is no longer considered a limiting nutrient, and aquatic vegetation and cyanobacteria can use the dissolved and atmospheric nitrogen for growth by using the high amounts of phosphorus available in lake waters. If the ratio is higher than 16:1, it indicates that the phosphorus concentrations are occurring at levels much less than nitrogen and hence limits the growth within lakes.

Average N:P ratios in Fork Lake were 32:1 and 25:1 for composite and Kemmerer samples, respectively. These ratios are higher than the Redfield Ratio of 16:1, indicating that total phosphorus concentration is considered low enough for phosphorus to be considered the main nutrient limiting growth in Fork Lake.

4.5 Chlorophyll-a

Chlorophyll-a is used as a measurement of algal biomass present in lake water. It is a green pigment found in plants, algae, and cyanobacteria, which allows these organisms to photosynthesize. All algae and cyanobacteria produce chlorophyll-a, hence its usage as a proxy for algal biomass. High concentrations of chlorophyll-a indicate an elevated number of algae in the lake water. Due to the presence of chlorophyll-a in cyanobacteria, the measurement can be an underestimate of algae biomass when blue-green algae are present in the lake water.

Composite lake water samples for filtering and analysis of chlorophyll-a were collected on June 20, July 18, and August 29, 2024. The analytical results of these samples are presented in Figure 9 below. A minimum concentration of 13.3 µg/L was observed on July 18, 2024. Chlorophyll-a concentrations peaked on June 20, 2024, with a concentration of 28.8 ug/L. Total chlorophyll-a concentrations in the samples collected during the summer of 2024 had an average of 22.33 µg/L, which classifies Fork Lake as Eutrophic (high productivity, nutrients, and algae growth).

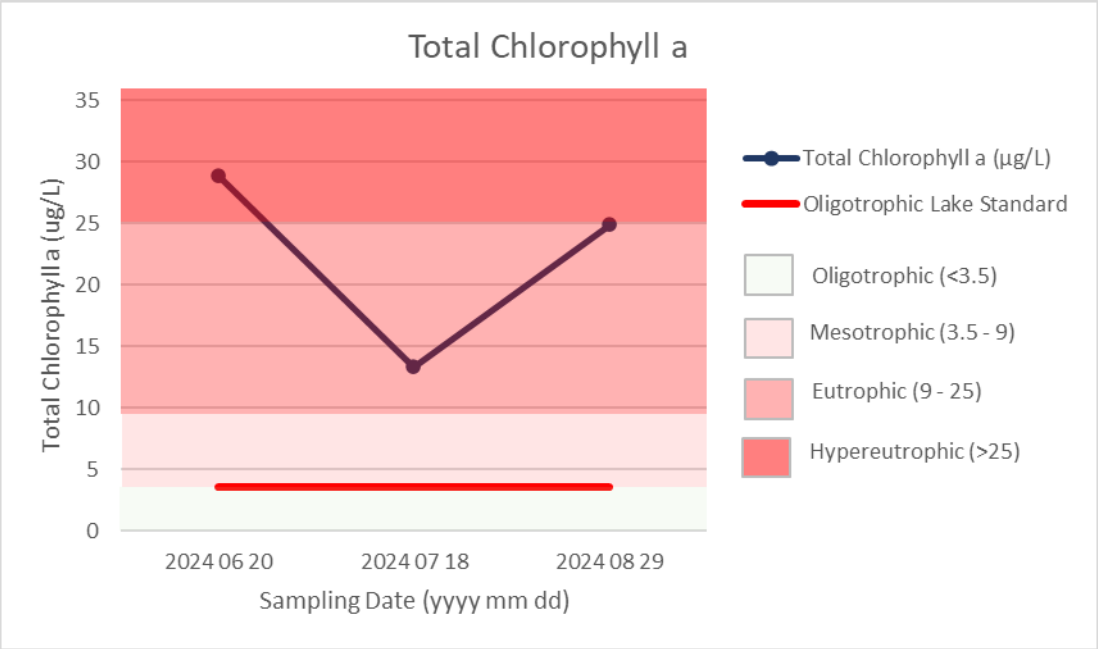

Figure 9: Total Chlorophyll-a in Composite samples of Fork Lake - 2024

4.6 Routine Water Chemistry

Results of routine water chemistry of samples collected from Fork Lake are presented in Table 4, Appendix A.

The average measured pH for Fork Lake was 8.39 which was consistent with the average of past years. The pH of water determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. The ability of a lake to neutralize these hydrogen ions is referred to as a buffering capacity. Any lake with a total alkalinity of more than 100 mg/L is considered to have high buffering capacity (Mitchell and Prepas 1990). The pH in Fork Lake is likely buffered against change by its high alkalinity. The high alkalinity in Alberta lakes is derived from the rich calcareous glacial till over which the lakes have formed.

4.7 Metals

Metals enter the water naturally through the weathering of rocks and soil and are generally non-toxic and in low concentrations. However, metals can also come from a wide variety of anthropogenic and non-point pollution sources including runoff from urban areas, wastewater discharge, improperly managed sewage treatment, industrial activities, and agricultural runoff. The analytical results of total dissolved metals in the Kemmerer and composite water samples collected from Fork Lake are presented in Table 5.

Concentrations of all metals analyzed from the composite and Kemmerer samples were generally below detection limits and/or below the applicable regulatory guidelines (Table 5).

5 HISTORICAL TREND ANALYSIS

The objective of the historical trend analysis is to provide an overview of water quality conditions in a lake with time, and to evaluate the impact of watershed management practices on lake water quality.

Three parameters are significant in trend analyses for lake water quality: Secchi depth, total nitrogen, and total phosphorus; all of which are also used for trophic classification of lakes.

5.1 Secchi Depth

Historical data shows that Secchi Depth in Fork Lake has always been less than the standard Oligotrophic Secchi depth of 4 m. Results of these samples are presented in Figure 10. A Secchi Depth of 2 m was measured in 2005 but gradually decreased to 1 m in 2017; the Secchi depth then increased to 2.5 m in 2018. The low Secchi depth means that the lake water has poor transparency due to suspended materials. The overall trend shows that the Secchi Depth is improving. However, the Secchi depth readings may not provide an exact measure of the water transparency due to various errors such as time of the day, sun's glare on the water, and eyesight of the observer.

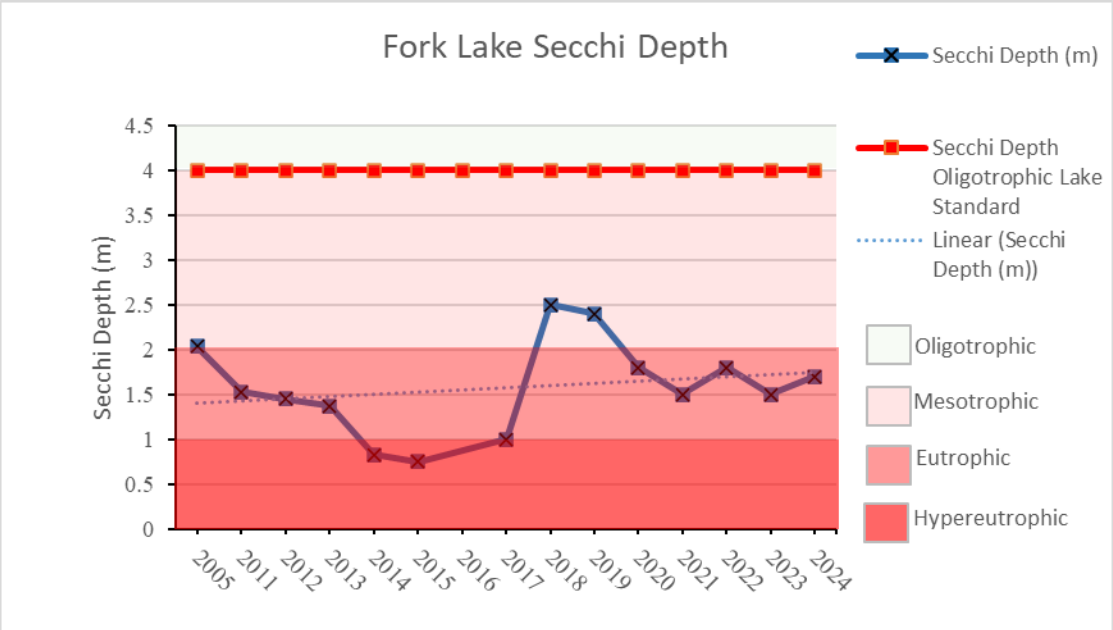

Figure 10: Historical trend for Secchi Depth in Fork Lake

5.2 Total Nitrogen

Historical data shows that total nitrogen in Fork Lake ranged from 1.20 mg/L to 2.42 mg/L and consistently exceeded the regulatory guideline of 1.0 mg/L (Figure 11). Total nitrogen concentrations of 1.70 mg/L measured in 2005 decreased to 1.25 mg/L in 2011; however, a temporal increasing trend in total nitrogen concentrations has been observed since then. Total nitrogen concentrations have historically been classified as Hypereutrophic (excessive productivity, nutrients, and algae growth).

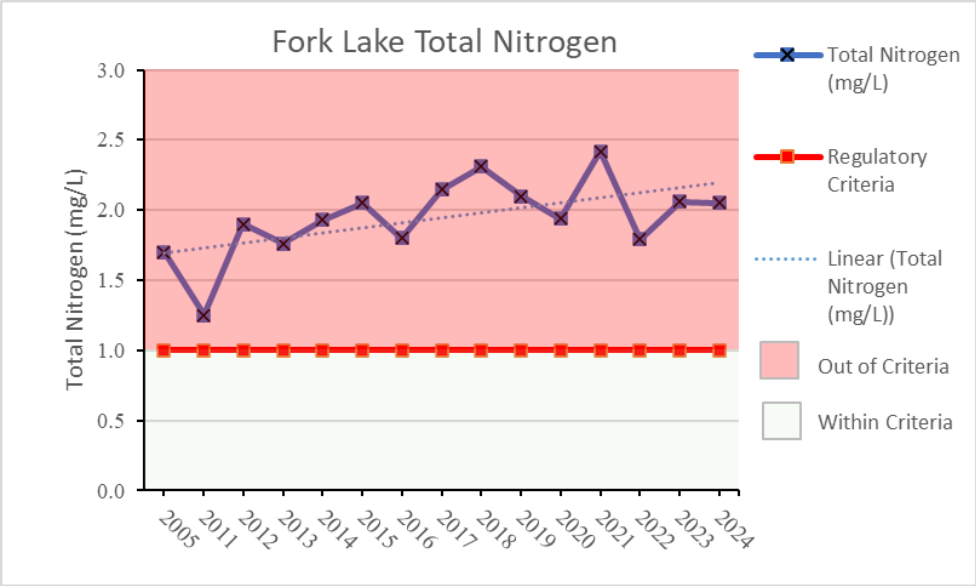

Figure 11: Historical trend of total nitrogen concentrations in in Fork Lake

5.3 Total Phosphorus

Historical data shows that total phosphorus concentrations in Fork Lake ranged from a minimum of 0.031 mg/L in 2024 to a maximum of 0.070 mg/L in 2018 as presented in Figure 12. Total phosphorus concentrations fluctuated over time; however, an increasing trend in total phosphorus concentration is seen in Figure 12 below. The average historical total phosphorus has exceeded the applicable regulatory guideline of 0.05 mg/L. Total phosphorus concentrations have historically been classified as Eutrophic (high productivity, nutrients, and algae growth).

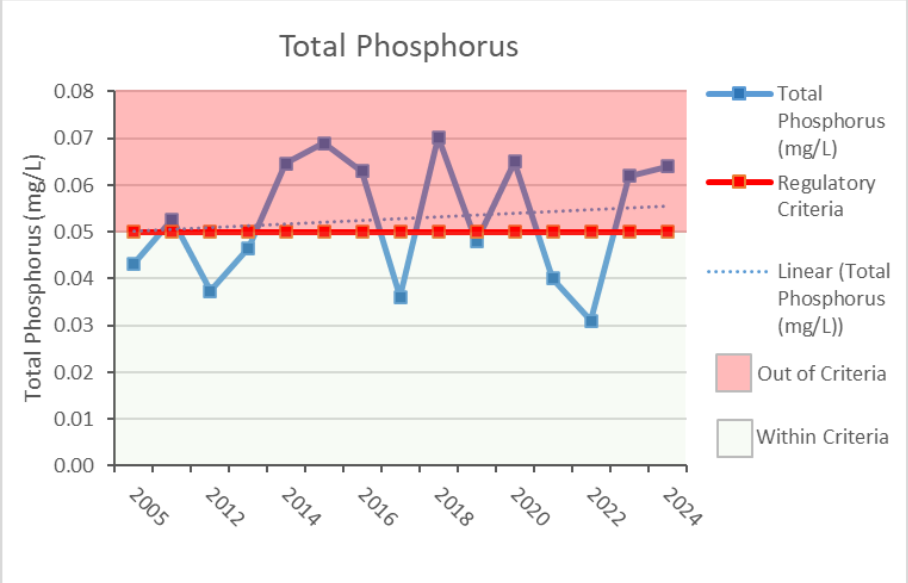

Figure 12: Historical trend of total phosphorus concentrations in Fork Lake

6 DISCUSSION

Trophic State Index (TSI) is a classification system designed to rate lakes based on the amount of biological activity they sustain. The concentrations of nutrients (nitrogen and phosphorus) are the primary determinants of TSI. Increased concentrations of nutrients tend to result in increased plant growth, followed by an increase in subsequent trophic levels. Nurnberg (1996) used parameters including Secchi depth, chlorophyll, total nitrogen and total phosphorus concentrations in lake waters to determine the trophic state of the lakes, which is provided as Table 1 in Appendix A. TSI is a useful tool for evaluation and management of lake health and setting objectives including sport and recreational activities related to the lake. The trophic classification of Fork Lake based on Secchi depth and nutrients is presented in Table 2.

There are four classes of trophic states which include: Oligotrophic which would be the highest quality of water with low productivity, nutrients, and algae; Mesotrophic which is fair quality water with some productivity, nutrients and algae; Eutrophic which is relatively poor-quality water with high productivity, nutrients and algae; and Hypereutrophic which is the poorest quality water with excessive productivity, nutrients, and algae.

Fork Lake would be considered Eutrophic based on the average of the four water parameters: Secchi depth, total nitrogen, total phosphorus, and total chlorophyll-a. The trophic status would be Eutrophic based on Secchi depth, Hypereutrophic based on total nitrogen, Eutrophic based on total phosphorus, and Eutrophic based on total chlorophyll-a.

7 RECOMMENDATIONS

It is recommended that Lac La Biche County continues to monitor the water quality of Fork Lake on a regular basis. Continuous monitoring will help the County to determine how the lake management strategies and policies such as the Watershed Management Plan and Riparian Setback Matrix Model are impacting the lake water quality, and what the net effect on human and environmental health is.

Monitoring and sampling should continue to be conducted under a strategic plan and in a uniform manner to ensure that results produced are meaningful and are useful for establishing a correlation with the past results. This may include sampling at same period of the year each time, recording the same parameters critical to lake health, obtaining samples from the same depths, and implementing a quality assurance program for reliability of analytical results.

Nutrient loading is the main source of eutrophication in Fork Lake which is degrading the water quality, leading to algae growth, foul smells, and a reduction in water recreation. Therefore, action must be taken to slow down the eutrophication process and improve water quality. Best management practices would include the education of the public on appropriate land use restoration and protection of riparian areas (water buffers); and strengthening laws and regulations governing land use such as municipal sewer hookups and protection of environmental reserves.

Lac La Biche County updated the Lac La Biche Watershed Management Plan, which was adopted by Council in May 2021. This plan includes specific action items based on the recommendations that were formulated while drafting the plan. Although Fork Lake is not within the Lac La Biche watershed, the recommended action items may still apply.

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APPENDIX A

Table 1: Trophic status classification based on lake water parameters (Nurnberg 1996)

Trophic State	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)	Secchi Depth (m)	Chlorophyll-a (µg/L)
Oligotrophic	<0.01	<0.35	>4	<3.5
Mesotrophic	0.01 – 0.03	0.35 – 0.65	4 - 2	3.5 – 9
Eutrophic	0.03 – 0.10	0.65 – 1.20	2 - 1	9 – 25
Hypereutrophic	>0.10	>1.20	<1	>25

Table 2: Trophic status of Fork Lake based on lake water parameters (Nurnberg 1996)

Trophic State	Secchi Depth	Total Nitrogen	Total Phosphorus	Total Chlorophyll-a
	(m)	----------(mg/L) ----------		(µg/L)
Oligotrophic	>4	<0.35	<0.01	<3.5
Mesotrophic	4 – 2	0.35 – 0.65	0.01 – 0.03	3.5 - 9
Eutrophic	2 – 1	0.65 – 1.2	0.03 – 0.1	9 – 25
Hypereutrophic	<1	>1.2	>0.1	>25
Fork Lake Data 2024	1.7	2.05	0.064	22.3
Trophic State of Fork Lake in 2024	Eutrophic	Hypereutrophic	Eutrophic	Eutrophic

Table 3: Average lake water N:P ratios for composite and Kemmerer samples from Fork Lake

Sampling Event	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	N:P
Composite Sampling	2.05	0.064	32:1
Kemmerer Sampling	2.49	0.099	25:1

Table 4: Routine water chemistry analysis from composite samples of Fork Lake – 2024

Date of Sampling	June 20, 2024	July 18, 2024	August 29, 2024
	mg/L		
pH	8.72	8.25	8.19
Temperature (°C)	13.87	18.84	18.77
Ammonia, Total (as N)	0.0224	0.0396	0.0192
Nitrate (as N)	<0.020	<0.020	<0.020
Nitrite (as N)	<0.010	<0.010	<0.010
Nitrate and Nitrite (as N)	<0.0300	<0.0300	<0.0300

* Based on average pH and temperature of 8.22 and 18.46 °C of Fork Lake in 2024

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Table 5: Dissolved metals from Kemmerer samples in Fork Lake

Date of Sampling	Kemmerer Sampling (6 m depth) March 12, 2024	Kemmerer Sampling (6 m depth) August 29, 2024	Criteria[1]	Criteria[2]
Parameters	----------(mg/L)----------			
Aluminum (Al)-Total	0.0043	0.0243	0.1[a]	0.1
Arsenic (As)-Total	0.00144	0.00136	0.005[a]	0.005
Barium (Ba)-Total	0.0729	0.0664	NS	NS
Beryllium (Be)-Total	<0.000020	<0.000020	100[b]	NS
Boron (B)-Total	0.09	0.084	1.5[a]	1.5
Cadmium (Cd)-Total	<0.0000050	<0.0000050	0.00009[a]	0.00033
Chromium (Cr)-Total	0.00074	<0.00050	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	0.05[a]	0.0012
Copper (Cu)-Total	<0.00050	<0.00050	0.0040[a]	0.022
Iron (Fe)-Total	<0.010	<0.010	0.3[a]	0.3
Lead (Pb)-Total	<0.000050	<0.000050	0.007[a]	0.007
Lithium (Li)-Total	0.0379	0.0369	2.5[b]	NS
Manganese (Mn)-Total	41.2	0.108	0.2[b]	NS
Mercury (Hg)-Total	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000198	<0.000050	0.073[a]	0.073
Nickel (Ni)-Total	<0.00050	<0.00050	0.150[a]	0.11
Selenium (Se)-Total	<0.000050	<0.000050	0.001[a]	NS
Silver (Ag)-Total	<0.000010	<0.000010	0.00025[a]	0.00025
Thallium (Tl)-Total	<0.000010	<0.000010	0.0008[a]	0.0008
Tin (Sn)-Total	<0.00010	<0.00010	NS	NS
Titanium (Ti)-Total	<0.00030	0.00092	NS	NS
Uranium (U)-Total	0.000069	0.00007	0.01[b]	0.015
Vanadium (V)-Total	0.00053	<0.00050	0.1[b]	NS
Zinc (Zn)-Total	<0.0030	<0.0030	0.007[a]	0.03

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Table 6: Historical data of routine chemistry and other parameters for Fork Lake

	Year														
Parameter	**2005**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
pH	8.62	8.53	8.60	8.40	8.20	8.80	8.30	8.73	7.94	8.26	8.54	7.92	8.03	8.22	8.39
Secchi Depth (m)	2.04	1.53	1.45	1.38	0.83	0.75		1.00	2.50	2.40	1.8	1.5	1.8	1.5	1.7
Total Nitrogen (mg/L)	1.70	1.25	1.90	1.76	1.93	2.05	1.80	2.03	2.31	2.10	1.94	2.42	1.79	2.06	2.05
Total Phosphorus (mg/L)	0.010	0.020	0.020	0.020	0.020	0.030	0.020	0.044	0.070	0.048	0.065	0.04	0.031	0.046	0.064
Nitrate/Nitrite (mg/L)	0.01	0.05	0.10	0.09	0.41	-	0.06	0.01	<0.02	<0.022	<0.022	<0.022	0.032	<0.0300	<0.0301
Ammonia (mg/L)	0.04	<0.05	<0.05	<0.05	0.07	0.02	<0.022	<0.036	0.125	<0.050	<0.050	<0.050	0.019	0.0214	0.0847
Specific Conductivity (µS/cm)	496	522	545	537	549	479	573	493	766	822	800	784	1143.7	394.60	1252.68

Table 7: Historical trend of total dissolved metals in Fork Lake

Dissolved Metals	2020	2021	2022	2023	2024	Criteria[1]	Criteria[2]
	----------(mg/L) ----------						
Aluminum (Al)	<0.0039	<0.0030	0.0057	<0.0030	0.0243	0.1[a]	0.1
Arsenic (As)	0.00146	0.00138	0.00143	0.00145	0.0014	0.005[a]	0.005
Barium (Ba)	0.0702	0.0688	0.07075	0.0743	0.06965	NS	NS
Beryllium (Be)-Total	<0.00010	<0.00010	<0.000020	<0.000020	<0.000020	100[b]	NS
Boron (B)	0.087	0.077	0.087	0.089	0.087	1.5[a]	1.5
Cadmium (Cd)	<0.0000050	<0.0000050	<0.000050	<0.0000050	<0.0000050	0.00034[a]	0.00034
Chromium (Cr)	<0.00010	<0.00010	<0.00050	<0.00050	0.00074	NS	NS
Cobalt (Co)-Total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.05[a]	NS
Copper (Cu)	<0.00050	<0.00050	0.00101	<0.00050	<0.00050	0.0040[a]	0.04
Iron (Fe)	<0.010	<0.010	<0.010	<0.010	<0.010	0.3[a]	0.3
Lead (Pb)	<0.000050	0.0415	0.000074	<0.000050	<0.000050	0.007[a]	0.007
Lithium (Li)-Total	0.0325	0.0297	0.0356	0.0358	0.0374	2.5[b]	NS
Manganese (Mn)	0.0905	0.0389	0.032	0.06965	20.654	0.2[b]	NS
Mercury (Hg)	<0.0000050	<0.0000050	0.000013	<0.0000050	<0.0000050	0.000026[a]	NS
Molybdenum (Mo)-Total	0.000066	<0.000050	<0.000050	<0.000050	0.000198	0.073[a]	0.073
Nickel (Ni)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.150[a]	0.12
Selenium (Se)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.001[a]	NS
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.00025[a]	0.00025
Thallium (Tl)-Total	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.0008[a]	0.0008
Tin (Sn)-Total	<0.00010	0.00024	<0.00010	<0.00010	<0.00010	NS	NS
Titanium (Ti)-Total	<0.00030	<0.00030	0.0022	<0.00030	0.00092	NS	NS
Uranium (U)	0.000066	0.000065	0.000066	0.000064	0.0000695	0.01[b]	0.015
Vanadium (V)-Total	<0.00050	<0.00050	<0.00050	<0.00050	0.00053	0.1[b]	NS
Zinc (Zn)	0.0072	<0.0030	0.0072	<0.0030	<0.0030	0.007[a]	0.03

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