A Water Quality Assessment of Cusheon Lake (Saltspring Island, British Columbia): A Summary of Data Collected between 1974 and 2003

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Executive Summary

Cusheon Lake is located on Salt Spring Island, BC. It is a relatively small lake with a surface area of 0.3 km^2, and a watershed area of 7.24 $km^{2.}$ The lake is an important water source, recreation area, and habitat for fish and other aquatic life. Ongoing algal blooms have resulted in the necessity to understand lake water quality conditions, and seek out reasons for these occurrences. Through a review of water quality data that has been collected at Cusheon Lake since 1974, this report has identified the following major conclusions:

Water Quality Criteria

1. Total Phosphorus exceeded the Drinking Water and Recreation Criteria in 76% of years sampled, and the Aquatic Life Criteria was exceeded in 41% of years sampled. The highest values initiate from the bottom depths during the summer/fall. Recent year's peak surface and mid depth values do not indicate an increasing trend, although bottom values continue to fluctuate.
2. Temperature values exceeded the Drinking Water Criteria in 35% of samples. These exceedances result from high summer temperatures affecting surface and mid depths.
3. Dissolved Oxygen exceeded the Aquatic Life Criteria for stages other than buried alevin in 62% of samples, and for buried embryo/alevin in 45% of samples. Values typically fell below the Criteria in the mid and bottom depths during the spring/summer period.
4. Total Organic Carbon exceeded the Drinking Criteria for chlorinated water in 91% of samples. Peaks occur between July and October.
5. Dissolved Chloride values were identified as increasing with time, indicating a possible disturbance by Holms (1999). This parameter has not exceeded the Drinking Water Criteria, and since 1995 appears to be fluctuating without a definite trend.
6. Chlorophyll a exceeded the Drinking Water Criteria for all years sampled. Peaks occur in the fall. A trend of summer averages decreasing with time is evident.
7. Fecal Coliforms exceeded the Drinking Water Criteria for untreated water in 2 of the 6 samples collected.
8. True Colour exceeded the Drinking Water Criteria in 54% of samples. Peaks occur during the summer period.
9. Extinction (Secchi) Depth did not meet the Recreation Criteria in 4% of samples. Data from recent years (2000s) indicates improvement over prior years.
10. Manganese Total, exceeded the Drinking Water Criteria in 23% of samples.
11. Total Sodium was monitored as an indicator of possible disturbance, as recommended by Holms (1999). Although the Drinking Water Criteria has not been exceeded, a trend of gradual increase over time is evident.
12. Specific Conductivity was also monitored as an indicator of possible disturbance. Although the Criteria were not exceeded, an increasing trend for summer values was evident.
13. Turbidity exceeded the Drinking Water Criteria for untreated water in 67% of samples and for treated water in 19% of samples. Peak values occurred during the summer and fall months, with an overall trend of increasing peak values evident.

Trophic State and Algae Growth

14. Cusheon Lake is currently mesotrophic with some eutrophic characteristics.
15. The Total Nitrogen : Total Phosphorus ratio indicates that phosphorus is the limiting factor for algae growth for 37/51 (or 72%) of months sampled. Nitrogen was a limiting factor for 1 sample.
16. The key factor affecting algae growth in Cusheon Lake appears to be internal phosphorus loading where anoxic bottom conditions result in the release of phosphorus from the sediments. This phosphorus mixes throughout the water column during fall overturn. This issue perpetuates itself with runoff events contributing phosphorus to the system from throughout the watershed, and with the overall heightened algae biomass contributing to increased phosphorus at depth (as the algae die off) resulting in low dissolved oxygen, and a continuation of the cycle.

Perimeter Site Influences

17. Total phosphorus values for the Perimeter sites were all proximal to one another in terms of average and maximum values. Data available since 1999 indicated that high Perimeter site total phosphorus values influenced surface Mid Lake site values. Perimeter site clearly had an influence on Sept. 7, '99, and may have also contributed to the peaks on Oct. 29, '01 and, Nov 12, '02 (which also appeared to be influenced by fall turnover).
18. Perimeter site and Mid Lake site peaks for dissolved nitrate + nitrite generally occurred during the winter months. Peaks are most likely related to high winter flows flushing nutrient rich waters into the systems. Since 1999, all perimeter sites have contributed to the Cusheon Lake to varying degrees, with Horel Road exhibiting the greatest maximum and average values. During the sampling period, Mid Lake values appeared to be directly related to Perimeter site influences.
19. For the samples collected between 1999 and 2003, most of the Mid Lake peaks for turbidity appear to be linked to Perimeter site influences. Perimeter sites have contributed to the turbidity peaks to varying degrees, with the North Shore and Cusheon Lake Road having the highest average and maximum values.
20. Peak inputs of Fecal Coliform from the Perimeter sites occurred frequently, fluctuating between sites, at various times throughout the year. Cusheon Lake Road and the North Shore had the highest maximum and average values. Limited collection of Mid Lake data, made a conclusion on the overall influences to the lake impossible.
21. A comparison of the maximum and average values for all the reviewed parameters indicated that the Cusheon Lake Road and the North Shore sites tended to most frequently have the highest values, whereas Blackburn Creek and the South Shore sites most frequently had the lowest. Discharge data would be valuable to confirm significance of these values in terms of total contributions to Cusheon Lake.

Acknowledgements

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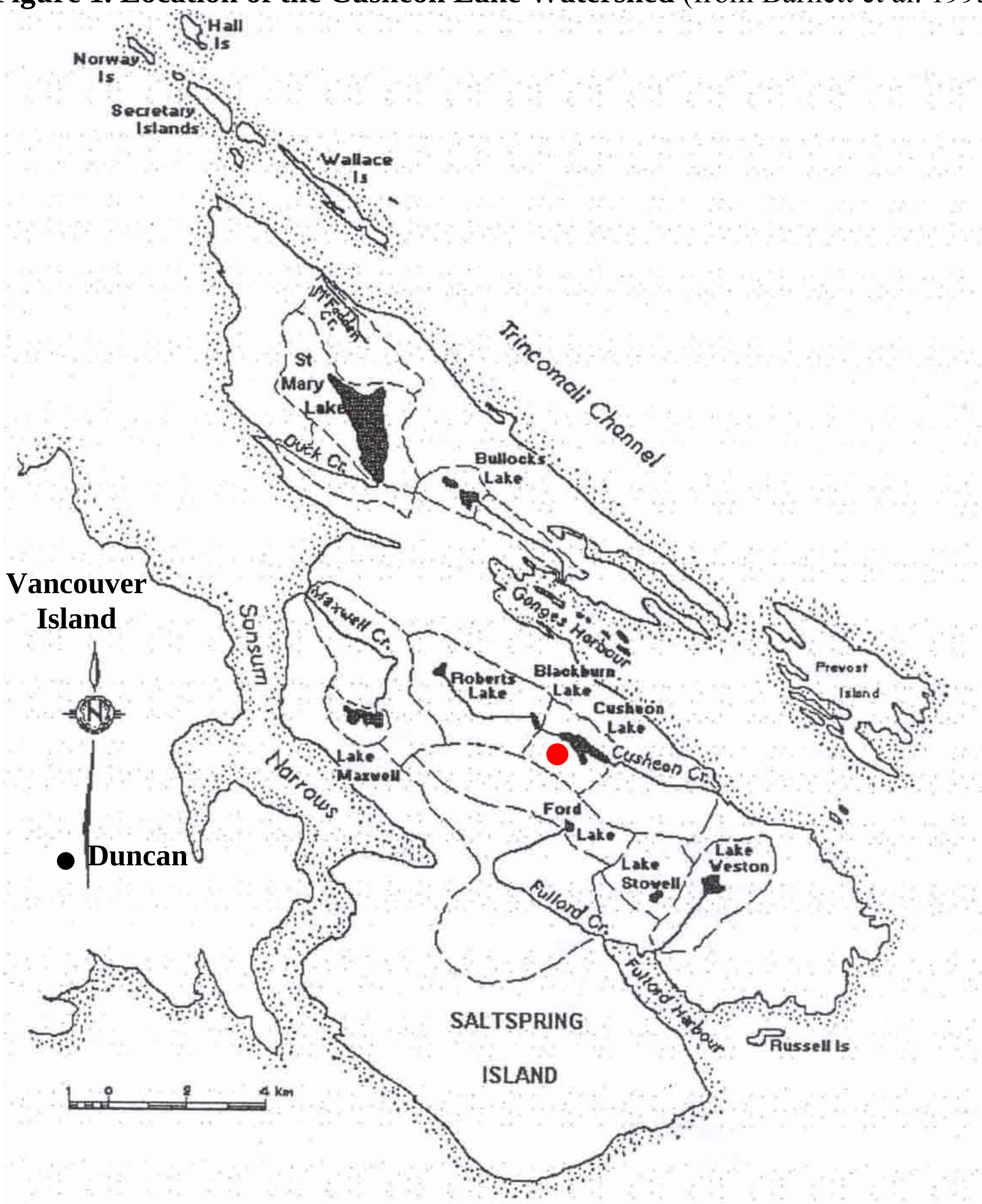
1.0 Introduction

This report provides a comprehensive review of the water quality conditions of Cusheon Lake, located on Salt Spring Island. The review was completed for the Ministry of Water Land and Air Protection, which has been active in monitoring the water quality status of the lake since 1974. Cusheon Lake has received this attention because of its importance as a water source, recreational area, and a habitat for fish and other aquatic organisms. Understanding the water quality status of the lake is also important in providing insight to the overall ecological health of the watershed. This understanding is valuable to watershed managers, local stewards and general users who have an interest in balancing the maintenance of a healthy system, with the inevitable development and growth pressures.

1.1 Study area

Figure 1. Location of the Cusheon Lake Watershed (from Barnett et al. 1993)



Cusheon Lake is located on Salt Spring Island, British Columbia (Fig. 1.). Figure 1 also outlines Salt Spring Island Watershed boundaries, including that of Cusheon Lake. The major inflow into Cusheon Lake is Blackburn Creek, which flows southeast from Blackburn Lake. Cusheon Lake drains into Cusheon Creek, which flows into the Pacific Ocean at Trimcomali Channel (see Figures 1 & 3). Table 1 summarizes the general characteristics of Cusheon Lake. The bathymetric map (Figure 2) depicts the lake in detail.

Table 1. General Characteristics of Cusheon Lake

Elevation (m)	Watershed Area (km^2)	Max. Length (km)	Lake Surface Area (km^2)	Lake Volume (m^3)	Max. Lake Depth (m)	Mean Lake Depth (m)	Volume ($x10^6 m^3$)
91	7.24	1.52	0.31	$1.16x10^6$	9.5	4.4	1.34

(from Holms, 1999; and Spafard et. al., 2000).

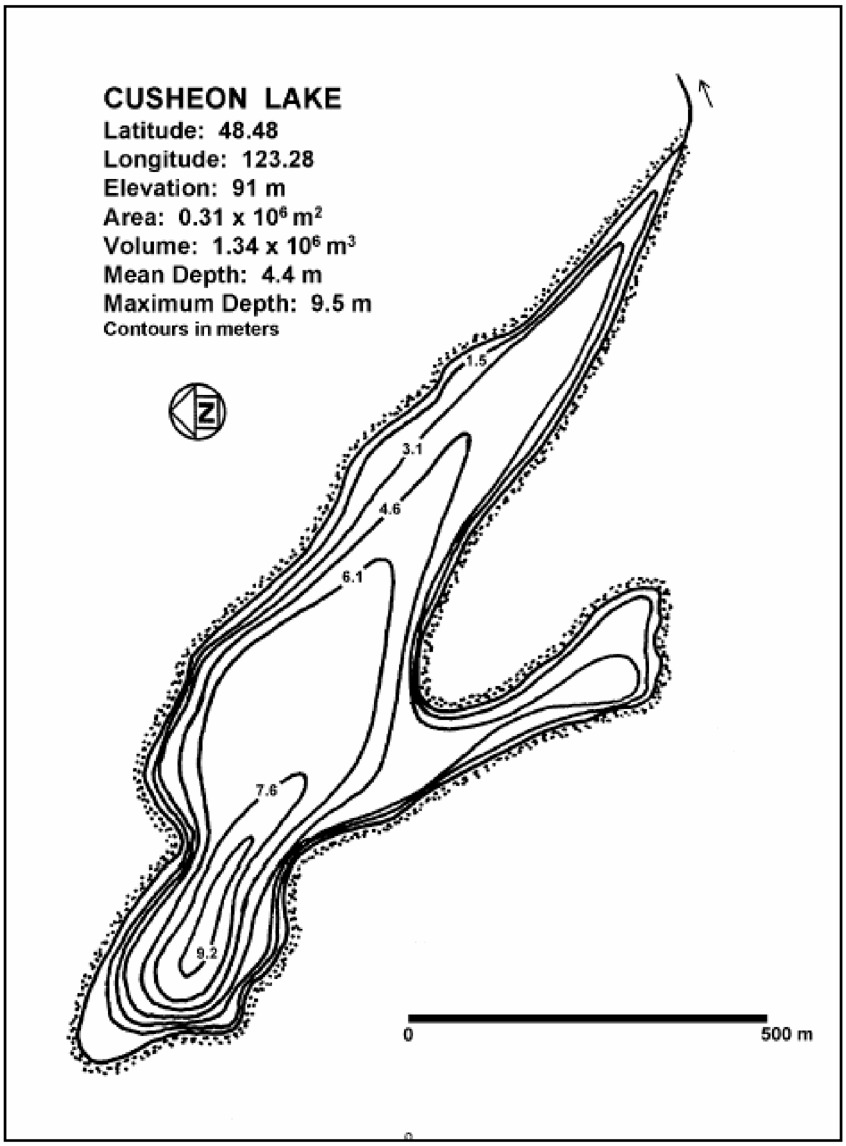


Figure 2. Cusheon Lake Bathymetric Map (from Spafard, S.A, et al., 2002).

1.2 Land Use

Figure 3 provides an overview satellite image with elevation contours of the Cusheon Lake Watershed. Detailed information on the watershed and its land use can be found in the *Cusheon Water Management Plan*, developed in 2004, by the Cusheon Watershed Steering Committee. Key excerpts summarizing watershed use are as follows:

> Most of the watershed has been logged in the past, with some areas of mature trees remaining. Much of the riparian area around Cusheon Lake, and along stream banks has been removed, resulting in stream bank stability and erosion concerns; however, areas higher in the watershed including Roberts Lake and Blackburn Lake generally have intact riparian vegetation.
>
> The basin is mostly rural residential, containing about 350 household residences, and some tourism establishments. Much of which are clustered around Cusheon Lake (70 residences) and near the mouth of Cusheon Creek. All residences are on septic fields, with the smallest lots having questionable space for drainage fields or septic tanks. Small farms and pasture lands are also found in the basin. A golf course and waste garbage transfer station are located upstream of Blackburn Lake.

Figure 3. Land Satellite Image and Elevation Contours for the Cusheon Lake Watershed.

1.3 Water Use

Goddard (1976), identified five water uses for Cusheon Lake, these being: domestic consumption, primary (e.g. swimming) and secondary (e.g., canoeing and angling), recreation, irrigation, aquatic life, and wildlife, and industrial use.

The Cusheon Lake watershed is the second largest supply of drinking water to residents on Salt Spring Island (Epps, 2004). There are currently 46 water licences on Cusheon Lake, 2 are for waterworks, 40 for domestic supply, 3 for irrigation, and 1 is for enterprise (Land and Water BC, 2004). Some residents in the watershed use ground water for a source of drinking water (Epps, 2004).

Cusheon Lake contains Cutthroat Trout (both resident and anadroumous), Rainbow Trout, Sculpin, Smallmouth Bass and Threespine Stickleback. The lake is stocked annually with approximately 1000 Cutthroat Trout. Obstructions on Cusheon Creek negate Coho passage up to Cusheon Lake (Fish Wizard, 2004).

1.4 Water Quality Concerns and Algae Blooms

Water quality status has become a concern over the past years. A major problem associated with drinking water from Cusheon Lakes is the presence of algae (see Figure 4). Algae can cause increased cost of water treatment, complaints regarding taste and odour and some health risk. Epps (2004), has described problems at Cusheon Lake as follows:

> Cusheon lake has been described as eutrophic, and has experienced problems with algal blooms including blue-greens, which have raised concerns about drinking water safety. During the summer low flow, a thick skin of blue-green algae (cyanobacteria) occurs along the shoreline of the entire lake (similar to the film on an open can of paint). These blooms are so thick that they clog the water intakes for many residents. Because of low oxygen and warm temperatures, the potential for fish kill is also significant during this time.

The Cusheon Steering Committee (2004), further added:

> The most serious water quality problem was the bloom of blue-green algae in the late summer of 1999. Fortunately, these species were not great producers of toxin, but there was a precautionary ban on drinking water from the lake, with advice to use alternative sources. This bloom of blue-greens is a standard symptom of enrichment.

There are several potential causes for lake enrichment and the algae blooms including: fertilization, sewage, bordering pasture areas, and erosion. This report will look at the extent of the problem today through a review of the water quality data, and from the data, attempt to identify any evident sources for the problem.

Figure 4. Algae bloom on the surface of Cusheon Lake. Nov. 26, 2002.
(Photo courtesy of Wayne Hewitt).

1.5 Monitoring and Reporting History

The Ministry of Water Land and Air Protection (herein WLAP) has been conducting water quality monitoring at the deepest point of Cusheon lake - the Mid Lake site West Arm, between 1974 and 2003 (Figure 4). Monitoring was initiated in response to concern expressed by residents regarding the quality of water in the lake, and was intended to continue indefinitely to provide early notification of changes (Goddard, 1976). This long-running data set is also important to identify long-term changes in water quality as a consequence of development within the watershed, and to determine how the changes would impinge on certain uses of water from the lake (Holmes, 1999).

The water quality data was initially reviewed in 1976 by Goddard, in a report titled *Cusheon Lake, Saltspring Island, Data Report For The Water Quality Monitoring Program June 1974 – June 1975*. Goddard's report looked at water chemistry, aquatic macrophytes, phytoplankton and zooplankton. Goddard identified high concentrations of dissolved and total nitrogen, lower concentrations of dissolved and total phosphorus. He reported a low mean annual algal population density, indicative of an oligotrophic lake, which did not appear to be limited by nutrient availability (although nitrogen and phosphorus levels were equivalent to that of St. Mary's Lake, which had higher algae densities).

Holmes followed in 1999, with the completion of a report titled *State of Water Quality of Cusheon Lake 1974-1999*. Holms' report identified several areas of concern with the water quality of Cusheon Lake. It concluded that the following parameters exceeded the upper provincial guidelines for drinking water, aquatic life and/or recreation at various times during the period of study: total phosphorus, chlorophyll a, total organic carbon, true colour, dissolved oxygen, water temperature, total iron, extinction depth, and turbidity. Holms also identified that

sodium, chloride and specific conductivity levels indicated disturbances within the watershed and that phosphorus was the limiting nutrient for algal growth.
As a result of these findings, one of Holms' recommendations was to conduct further monitoring in order to identify: water quality objectives; sources of nutrients and contaminants; and changes resulting from lake biological activity, development within the watershed and non-point discharges. In response to this, WLAP, the University of Victoria (U.Vic.), and the Cusheon Lake Stewardship Group, all took roles in the completion of further monitoring.

WLAP continued the collection of water quality data at the Mid Lake site, and set-up monitoring sites at five additional proximal lake perimeter and tributary locations within the watershed (herein, the 'Perimeter sites'), with sampling completed throughout the year, from 1999-2003. Locations for all monitoring stations are depicted in Figure 5, with descriptions provided in Table 2. All data collected through the Provincial Government, has been stored in the Province's EMS data-base.

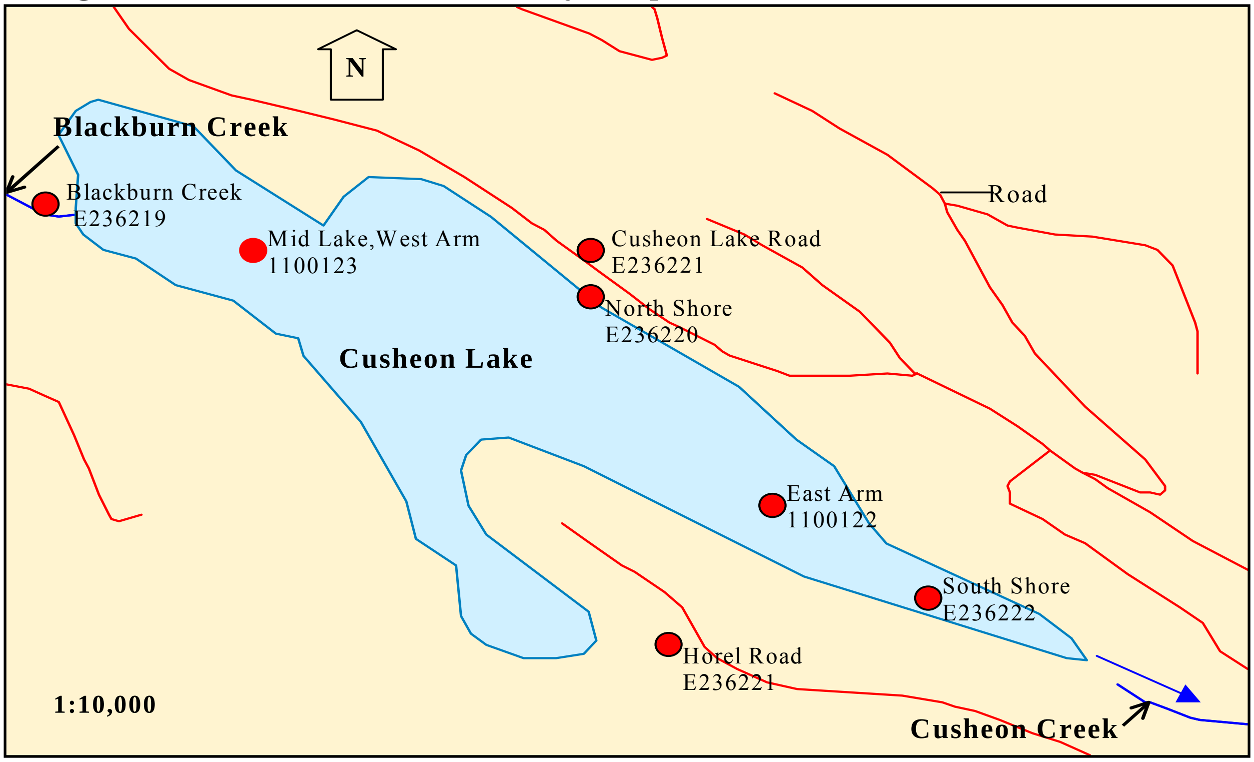
Other parties have also taken an interest and role in collection of water quality data from Cusheon Lake, and have provided their data for synthesis in this report. Dr. Rick Nordin from the University of Victoria's Environmental Management of Drinking Water Program, conducted sampling at the Cusheon Mid Lake site several times per year, from 2000- 2003. Wayne Hewitt, a Cusheon Lake Steward also has been collecting temperature, dissolved oxygen, and secchi depths, at the Mid Lake site, and has provided his data collected from June – October 2003 to this study.

Historical data also exists for the East Arm site. Because only limited water quality data was collected at this site over a short duration (10 days between 1974 and 1976, and 1 day in 1980), the data will not be considered in this report, other than as a map notation and in summary format.

Table 2. Cusheon Lake Water Quality Monitoring Site Descriptions

EMS Station #	Site Name	Site Description
1100122	East Arm	S.E. arm of lake. Water depth is about 12.7 feet.
1100123	Mid Lake, West Arm.	N.W. arm at deepest point of lake.
E236219	Blackburn Creek.	Near creek mouth, before it empties into Cusheon Lake.
E236220	North Shore.	Shallow station (0.3m), where there are a number of residences. In front of yellow house.
E236221	Horel Road	Small stream/ditch at the end of Horel Road that drains into the bay at the south end of Cusheon Lake.
E236222	South Shore	Shallow station in 0.3m of water close to the shore. Access from Horel Road.
E236223	Cusheon Lake Road	Drainage to the lake on the north shore, in the low area near the Beddis Waterworks treatment plant.

Figure 5. Cusheon Lake Water Quality Sample Site Locations and EMS numbers.



1.6 Study Objectives

The overall objective of this study is to conduct an analysis of Cusheon Lake's water quality data. This objective will be met by completion of the following activities:

1. **To identify the current general status, and water quality trends in Cusheon lake;**
2. **To identify patterns and influences on trophic state and algae growth in Cusheon Lake, including tributary or lake perimeter site influences;**
3. **To provide information in a detailed form which would be understandable to community members, government regulators, and scientists.**

In order to complete these activities, the report will be broken into two components. The first component will analyze and report on the general water quality of Cusheon Lake, by consolidating and reviewing the last 29 years of intensive water quality sampling data for the Mid Lake site. This component will also target water quality parameters noted as concerns in Holms' 1999 report. The second component will review key parameters linked to identifying lake trophic status and understanding algae growth, as well as possible influences from the Perimeter sites.

2.0 Methods

2.1 Limnological Sampling

Water samples were collected, primarily by WLAP field staff and UVic students (2000-2003), following the methodologies and practices laid out in the following BC Sampling Manuals:

- MELP, 1994. Ambient Fresh Water and Effluent Sampling Manual.
- MELP, 1994. Biological Sampling Manual.

Water samples requiring laboratory analysis were shipped according to protocols, to the laboratory under contract to the Provincial Government at the time. The laboratories used to complete the water chemistry analysis are as follows:

- 1974 - Dec. 31, 1989. Ministry of Environment Laboratory
- Jan. 1, 1990 - Dec. 28, 1995. Zenon Environmental (Currently PSC)
- Dec. 29, 1995 - Dec. 31, 2001. Environmental Canada, PESC
- Jan 1, 2002 – Present. PSC Analytical

All laboratories followed the Canadian Standard Analysis Methodologies provided in the Standard Methods Book (20th edition), and samples were analysed using equipment that was available at the time.

2.2 Water Quality Guidelines

In order to report on the status of Cusheon Lake, tables were developed which identified and statistically summarized all parameters sampled for Cusheon Lake and its perimeter and tributary sites. For data collected at the Mid Lake site, a comparison to the British Columbia Approved Water Quality Guidelines (1998), and the Canadian Council of Ministers of the Environment, Canadian Environmental Quality Guidelines (together herein identified as 'the Criteria'), was completed and reported on.

2.3 Replicate Samples

A pattern existed in the EMS Mid Lake data set, for data collected between the period of June 21, 2000 and January 31, 2001. This pattern reported replicate samples for a particular date and time, with depths not being identified. No explanation could be found, other than that these replicates were most likely obtained to determine accuracy in collection and chemical analysis procedures. For statistical purposes they were averaged.

2.4 Values Below Detection Limits:

Statistical analysis involved providing a count, a minimum and a maximum, an average, and a standard deviation for each parameter at all sample sites. Values below detection limits, are preceded by a less than (<) symbol. For statistical purposes in this study, the less than values were only considered when calculating the minimum; unless all values for a particular parameter were less than detection limits, in which case the less than values could be included for maximum and average values.

When averaging was completed for replicate samples, values below detection limits were not averaged with regular values.

In some instances when comparing less than and non-less than values for a particular parameter, the lowest of values was identified as the value without a less than symbol. For these occurrences, it was assumed that there were different analytical techniques used (i.e. onsite versus laboratory), or that detection abilities have improved over time.

2.5 Graphing with Depth

For parameters requiring graphs, both measured values and respective depths were presented, to best depict trends and relations to lake dynamics. To complete this, while keeping graphs relatively unencumbered, data was grouped into standard depth ranges. Through a review of where the limnetic zones (epilimnion, metalimnion, and hypolimnion) on average occurred when the water column was stratified, it was determined that the following grouping of depths would be used for producing graphical results:

- 0 - 4 m.
- 4.1 – 6.9 m.
- 7 – 12 m.

Because the depth groupings related to average values for limnetic zones, U.Vic's data, which was provided in reference to limnetic zones (rather than specific depths), were accurately transferred to the depth groupings defined above.

3.0 Results and Discussion

3.1 General Status of Water Quality in Cusheon Lake

Summaries of water quality data, which have been collected for Cusheon Lake and its tributaries, are provided in **Appendix 1** (Tables 4-14). The Cusheon Mid lake data (Table 4) shows that a full range of data has been collected since 1974 at various intervals and frequencies. Because of the large size of the file, the raw data for the Mid Lake site is not included in this report. A copy of the raw Mid Lake Data for Cusheon Lake, can be obtained through a request to the WLAP Nanaimo Regional Office.

The data for the Perimeter sites (Tables 5-14) has been provided in full and in statistical summary form. The complete data set has been presented to allow for an actual comparison between sites for a given parameter. Results of the Perimeter sites will be discussed in more detail later in the report.

Each parameter at the Mid Lake site, which had established Water Quality Criteria, had its values reviewed. For a given parameter, data was compared to the limits set for all applicable defined water uses (i.e. estuary and marine use limits not considered). Water uses having limits within range of a given parameter's data and/or those sensitive to being exceeded were defined (i.e. with drinking water, aquatic life, and recreation being the most commonly triggered for review). Criteria exceedances and the frequency of the exceedances are summarized in **Appendix 2** (Table 15). Results can be categorized into the following groups:

<u>Parameters that have not exceeded the Criteria at any point throughout the period of study</u>. These include:

- aluminum, total
- ammonia
- barium
- boron
- chloride, dissolved
- chromium, total
- cobalt, total
- magnesium, dissolved
- molybdenum, total
- nickel, total
- nitrate, dissolved
- nitrite, dissolved
- residue, filterable (total dissolved solids)
- sodium
- specific conductance
- sulfate, total
- vanadium, total
- zinc, total

<u>Parameters that have exceeded the Criteria in recent years (since 1999)</u>:

- carbon, total organic
- chlorophyll a,
- colour, true
- coliforms, fecal
- temperature
- extinction depth
- manganese
- oxygen, dissolved
- phosphorus, total
- turbidity

<u>Parameters that exceeded criteria in the past, but in recent years (since 1999), have rarely (once) or never exceeded the Criteria:</u>

- cadmium, total
- iron, total
- pH

<u>Parameters where Criteria have not been exceeded (or rarely exceeded before 1999), but which also have especially limited data available</u>, making overall conclusions on their water quality influences difficult. Sampling frequency is provided to show limits of data availability:

- aluminum, dissolved (1 sample 1980; Criteria not exceeded)
- coliform, total (2 samples in 1976 and 2 sample in 1980; Criteria exceeded once in 1980)
- flouride, total (1 sample set 1997 & 1998, and 2 sample sets in 1999; Criteria not exceeded)
- hardness, total dissolved (5 sample sets sampling in 1980; Criteria not exceeded)
- lithium, total (1 sample set in 2003, Criteria not exceeded)
- mercury, total (2 sample sets in 1974, and 1 in 1975; Criteria not exceeded)
- uranium, total (1 sample in 2003; Criteria not exceeded)

<u>Parameters where Criteria have not been exceeded (or rarely exceeded before 1999), but where the detection limits for the data are higher than the Criteria</u>, making an accurate comparison and overall conclusion on their water quality influences not possible:

- antimony, total
- arsenic, total
- copper, total
- lead, total
- selenium, total
- silver, total
- thallium, total

3.2 Parameters That Have Exceeded Criteria In Recent Years At The Mid Lake Site.

Parameters that have exceeded the criteria in recent years will be reviewed in more detail. Sodium, chloride and specific conductivity, which were identified as increasing concerns by Holms (1999), will also be looked at more closely in this section. All figures are provided in **Appendix 3** (Figures 6- 18). The three key parameters –Total Phosphorus, Temperature and Dissolved Oxygen will be reviewed first, and the remaining parameters will follow in alphabetical order.

3.2.1 Total Phosphorus.

The RIC manual - Guidelines for Interpreting Water Quality Data (1998) summarizes the importance of phosphorus as follows:

> Phosphorus is an essential plant nutrient and is often the most limiting nutrient to plant growth in fresh water. Because of this, its input to fresh water systems can cause extreme proliferations of algal growth. Inputs of phosphorus are the prime contributing factors to eutrophication in most freshwater systems. Anthropogenic sources include sewage effluent, agriculture, urban developments (particularly from detergents) and industrial effluents.

Nordin (1985), described that the best approximation of bioavailable phosphorus in lakes is total phosphorus, and that spring overturn data is the standard reference for gauging the supply of phosphorus to the lake over the following summer growing period. Nordin, also specified that in order to use spring overturn phosphorus, the summer epilimnetic water residence time of the lake should be longer than about 6 months. Cusheon lake, with an average flushing rate of once in 0.8 years (every 9.6 months), meets this criteria (Holms, 1999). Spring overturn is defined as the time when the water column is isothermal prior to the presence of significant algal growth (Nordin, 2001). However, in coastal British Columbia, low elevation lakes such as Cusheon Lake remain isothermal through the winter. As such, spring overturn sampling is done in late winter/early spring just prior to the developing thermocline. It should be noted that with this definition, biomass as chlorophyll a should be less than 0.5µg/L (Nordin, 2000); however, this requirement could not be met for Cusheon Lake, with the chlorophyll a content rarely (only 3 out of 83 samples) reaching levels below 0.5 µg/L.

Total phosphorus was collected in 1974, ‘76, ’80, ’81, ’87,’89, ‘92-‘03. A review of all collected data, identifies that values ranged from <3 to 435 µg/L, and averaged 30 µg/L. The total phosphorus Criteria for Drinking Water and Recreation is 10 µg/L maximum, and for Aquatic Life it is a range between 5 µg/L and 15 µg/L (to protect salmonids from oxygen depletion in the hypolomnion) (Nordin, 1985).

During the 17 years where spring overturn data was collected (Figure 6A), 13 years (76%) (1975, ‘76, ‘80, ‘87, ‘90, ‘92, ‘93, ‘97- 2002) were above the Drinking Water and Recreation Criteria, and 7 years (41%) (1976, 1993, 1997-2001) exceeded the Aquatic Life Criteria.

The average monthly data (Figure 6B) indicates that the spring values tend to be the lowest. Total phosphorus values are relatively constant throughout the water column during the spring, and where there are differences, the tendency is for surface values to be slightly higher. Since 1999, spring values have been decreasing. The monthly data also indicates that generally the highest annual total phosphorus values occur in the bottom depths in the summer/fall (June – October). These peaks appear to trigger subsequent increases in mid and surface values.

Figure 6C portrays summer/fall data as annual averages. From this data an overall trend is difficult to confirm, with the availability of data limited to 1974 (2 sample sets), 1976 (2 samples sets), 1980 (4 sample sets), and 2000-2002 (5 sample sets each). It does not appear however, that recent years (2000-2002) surface and mid depth data is increasing. Bottom values continue to fluctuate.

A surface value of 930 µg/L on September 17, 2001 was considered an outlier and was not included in the data set. Bottom values can easily be affected during sampling if the sediments are disturbed. It was uncertain whether bottom data values of 200+ µg/L were accurate, but they were left in the data set, because their timing seems to be associated with expectations for highs. This parameter will be discussed more in the section on trophic state and algae growth.

3.2.2 Temperature

The RIC manual (1998) summarizes the importance of temperature as follows:

> Temperature affects the solubility of many chemicals and can therefore influence the effect of pollutants on aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. Vertical stratification patterns that naturally occur in lakes affect the distribution of dissolved and suspended compounds.

Temperature data was collected at the Mid Lake site in 1974 -‘76, ‘80, ’81, ’94, ‘00-‘03. Values ranged from 1.5 to 27 ^{o}C, averaging 12.8 ^{o}C. The Drinking Water Criteria of 15 ^{o}C was exceeded in 35% of the individual samples collected. Temperatures generally exceed the Criteria in the surface depths starting in June, progressing into the mid depths in August and September as temperatures rise.

Figures 7 and 9 display the results of the temperature data (respectively as monthly averages, and as a profile for 2001). The seasonal temperature cycle is generally that the lake is mixed having a constant (or near constant) temperature from surface to bottom after fall turnover in October through the winter months to spring (March). Stratification then occurs between April and September, as surface temperatures increase, and bottom depths stay cool. Peak values tend to occur in July and Aug., with 2003 values representing the highest on record (with a surface value average of 24.2^{o}C in August).

3.2.3 Dissolved Oxygen (DO)

The RIC manual - Guidelines for Interpreting Water Quality Data (1998) summarizes the importance of DO as follows:

> DO is essential to the respiratory metabolism of most aquatic organisms. It affects the solubility and availability of nutrients, and therefore the productivity of

aquatic ecosystems. Low levels of DO facilitates the release of nutrients from the sediments. Eutrophic (high nutrient) lakes tend to have decreased concentrations of DO in the hypolimnion relative to the epilimnion.

DO was collected at the Mid Lake Site in 1974 -'76, '80, '81, '94, '00-'03. Values ranged from 0 to 33 mg/L, averaging 8.39 mg/L. DO values did not meet the minimum Criteria of 5 mg/L for Aquatic Life Stages Other Than Buried Embryo/Alevin in 62% of all samples tested, and did not meet the Criteria of 9 mg/L for Buried Aquatic Life Embryo/Alevin in 45% of samples. Values fell below these minimums annually in the mid and bottom depths, between May and September (May-August 2001). The frequency of DO not meeting the Criteria would be expected to impact aquatic life inhabiting cooler waters in the mid and bottom depths, including that of trout which is stocked annually. Habitat and food sources for these species would likely be affected by the low oxygen conditions.

Figure 8 provides the monthly average results, and Figure 9 depicts the 2001 profile. Generally, DO follows a similar annual pattern to temperature, where values are constant with depth (although for DO they are at their highest) when the water column is mixed between October and March. The summer months bring decreasing DO levels with depth, with bottom values all below 2.5 mg/L, and frequently falling below 1 mg/L. DO will be looked at in more detail in the section reviewing algae growth.

3.2.4 Carbon, Total Organic (TOC)

Total Organic Carbon is a measure of the dissolved and particulate organic carbon in water, which is mainly composed of humic substances and partly degraded plant and animal materials. Organic carbon is resistant to microbial degradation. Carbon is important because it is a nutrient required for biological processes. High levels of organic carbon coincide with a lowering of DO concentrations. Anthropegenic sources include agriculture, municipal and industrial waste discharge. (RIC 1998)

TOC was collected at the Mid Lake Site in 1974-'76, '80, '97-'03. Values ranged between 3 and 12 mg/L, averaging 6 mg/L. 91% of sampled values exceeded the Drinking Criteria for chlorinated water of 4 mg/L. With these results, if the drinking water is chlorinated, there would be trihalomethane (a potential carcinogen) formation concerns (RIC, 1998).

Monthly average TOC results are shown in Figure 10. Seasonally, values tend to be at their lowest for a short period in the spring, (at a point between April and June). Values rise through the summer, peaking at varying months between July and October. Peaks occur at varying depths, with the highest value recorded in Oct. 1980 at the bottom (12 mg/L).

An overall trend of whether the values are increasing or decreasing with time is difficult to confirm, because data between 1997 and 1999 was limited to spring overturn, and 2000-2003 data was generally limited to surface depths. From what is available, it appears that the extreme of peaks seen in the 1970s and 1980s has not occurred in the 2000s. Other than this, neither a decreasing nor increasing trend is evident.

3.2.5 Chloride, Dissolved

Chloride is a halide. Chloride is important in terms of metabolic processes, as it influences osmotic salinity balance and ion exchange. Higher chloride concentrations can reduce the toxicity of nitrite to aquatic life. Anthropogenic sources include municipal water supply disinfection, sewage treatment plant effluents, urban development, industrial effluents and mining.

Holms (1999), identified that dissolved chloride values were increasing with time, possibly indicating a disturbance, and that it should continue to be monitored as a measure of changes in the rate that ions are released within the watershed.

Dissolved Chloride data was collected at the Mid Lake Site in 1975, ’80, ’89, ’92, ’93, ’95, ’97-’02. Values ranged from 5.7 – 16 mg/L, averaging 9 mg/L. The Drinking Water Criteria for chloride (aesthetics) is 250mg/L, and Cusheon Lake values have thus not exceeded the Criteria.

Figure 11 portrays the annual results of the data. Holms looked at values collected between 1975 and 1995. Since this time values have fluctuated, peaking in March 1999 at 16 mg/L. They dropped in September 1999 to 8 mg/L, and from there have gradually increased through the summer of 2000 and 2001 to a maximum of 10.9 in July 2001. Slight dips are evident in the winter/spring data. A reliable overall trend could not be defined.

3.2.6 Chlorophyll-a

Chlorophyll-a is a measure of phytoplankton (microscopic plants) or periphyton (microscopic plants on substrata) biomass in a body of water. High concentrations are a direct result of high nutrient inputs. Anthropogenic sources include agriculture, sewage treatment effluent, forest harvesting, urban development, and recreation. (RIC, 1998)

Chlorophyll a data was collected in 1980 and in 2000-2003. Based on raw data, values ranged from 0.01 –34 µg/L, averaging 8 µg/L. The Drinking Water Criteria for chlorophyll a is 2-2.5 µg/L based on a summer average. Figure 12, which depicts the chlorophyll a results for the Mid Lake site, shows that all summer averages exceed this Criteria and that summer water column averages collected have been decreasing with time.

From figure 12, which identifies average values with depth, annual peaks appeared at the following times: Nov. ‘80 (33 µg/L); Sept.’00 (31 µg/L); Sept. ‘01 (14 µg/L), and Dec. 18, 02 (7.87 µg/L). The annual cycle appears for chlorophyll a to increase in value from a low at spring, through the summer, peaking in the fall, staying high into the early winter. Mid depth values in comparison to surface and bottom depths tend to be highest during the summer (June-Aug.). In the early fall (Sept./Oct.), surface values are highest. Late fall/early winter highs then appear to be linked most to the bottom depths.

Chlorophyll a data is somewhat limited, with multiple season data only available in 1980 and ‘00-‘02. More data would be valuable to confirm these trends. This parameter will be discussed in more detail in the section on algae growth.

3.2.7 Coliforms, Fecal

RIC (1998), provides a definition of the Fecal Coliform variable, which has been summarized as follows:

> Fecal Coliform data is an estimate of the degree of fecal contamination from human and animal wastes. Fecal Coliforms are common to the intestinal tracts of humans and warm blooded animals, and are distinct from the non-fecal coliforms which are found naturally in soils and on vegetation. Fecal Coliform bacteria is used as an indicator organism; whereby, if there is evidence of fecal contamination of the water, then pathogenic organisms may also be present. Sources include sewage treatment plants, recreation areas, pulp and paper mills, livestock, and urban runoff.

Fecal coliform data is has only been collected in recent years, and is limited. Data available through EMS is as follows:

- Sept. 7/99 (2.0 CFU/100mL)
- June 8/00 (<1.0 CFU/100mL)
- July 25/01 (<1.0 CFU/100mL)
- Sept. 17/01 (1.0, <1.0 CFU/100mL)
- Nov. 12/02 (3.0 CFU/100mL)

Because of the small data set, a graph of results was not produced. The Drinking Water Criteria of 0/100 mL for untreated water for drinking, livestock, industrial was exceeded in 2 of the 6 samples (Sept. '99 and Nov. '02). Although not enough samples were taken to provide confirmation (require 10 in a 30 day period), from the data available, the next sensitive Criteria of 10/100 ml for drinking, livestock, and industrial water that is only disinfected, has not been exceeded.

More fecal coliforms data can also be obtained from the Ministry of Health - who completes monthly sampling, as well as any water purveyors on Cusheon Lake (i.e. the Beddis Water Works). Refer to Ministry of Health or the local Health Authority for more information in this area.

3.2.8 Colour, True

> True colour is a measure of dissolved colouring compounds in water. Colour is regarded as a pollution problem in terms of aesthetics, and increased colour may interfere with light passage impeding photosynthesis. Anthropogenic influences include agriculture and industrial effluents (RIC, 1998)

True colour data was collected in 1980, '92-'95, and '97-'03. Values ranged from 5 – 400 true colour units (TCU), with an average of 29 TCU. The Drinking Water Criteria (for aesthetics) of 15 TCU was exceeded in 54% of samples.

Figure 13. depicts annual True Colour data with depth. Much of the data is limited to collection in the spring, with summer samples available only during 1980, 2000 and 2001. An accurate pattern or trend is thus difficult to identify, because peaks tend to occur during the summer. Timing for annual peaks varied. 1980 highs occurred in Aug. and Oct., 2000's in March, and

2001's in June, July and Sept. (with a record high of 206 TCU). Peak values fluctuated between surface and bottom depths. No clear trend is identifiable for the spring data.

3.2.9 Extinction (Secchi) Depth

Secchi depth measures the transparency of water to light, and in productive lakes, is a way to estimate the approximate density of phytoplankton populations (Wetzel, 1975).

Secchi data was collected at the Mid Lake site in 1974 -'76, '80, '94 and '00-'03. Values ranged from 0.76 m. to 9.3 m., averaging 3.5 m. At the Mid Lake Site, only 4% of samples did not meet the Recreation Criteria of 1.2 m. minimum. These low readings occurred in the summers of 1976, 1980, and 2000.

Figure 14. depicts the data as monthly averages. Seasonally, the secchi depth highs vary, occurring generally in the summer months (i.e. July, August). Low values vary as well, occurring in June, October, September, July and even February. An overall trend is difficult to ascertain with certainty because of limited data. When month by month comparisons are made, results indicate that values in the 2000's are improved or higher than those of 1980, and other than the 2 samples in 1975, 2002 had the highest values.

3.2.10 Manganese, Total

> Manganese is an essential element in trace amounts, for plants and animals. In aquatic environments, manganese toxicity is slight to moderate and is influenced by several factors such as water hardness, salinity, pH, and the presence of other contaminants. It often reduces the hazard posed by other metals. Anthropogenic sources include mining effluents, municipal sewage and sludge, and landfills. The primary concerns to drinking water is its taste and its capacity to stain plumbing and laundry. (Nagpal, 2001)

Data has been collected in 1980, '92, -'95, and '97-'03. Most of the sampling, other than in 2000, is limited to the spring. The minimum value was 15µg/L, the maximum is 237 µg/L, and the average was calculated as 47 µg/L. The Drinking Water Criteria (aesthetics) for manganese is less than or equal to 50 µg/L. This has been exceeded in 23% of samples.

Total manganese data with depth for the Mid Lake site is depicted in Figure 15. The results indicated a general uniformity with depth. Surface values peaked and exceeded Criteria in March 1993, April 1994, June and September 2000, and January 2001. Average spring values were reviewed, and a reliable trend could not be defined.

3.2.11 Sodium, Total

> Sodium is a cation, involved primarily in ion transport and exchange. Sodium is required in only a few plants, but its requirement is particularly high in some

species of blue-green algae. A threshold level of 4 mg/L is required for near optimal growth of many species, with maximal growth of several at 40mg/L. The enrichment of waters with high levels of sodium and phosphorus (i.e. such as from domestic effluents with synthetic detergents), is a potential contributor to blue-green algae out competing other species under bloom conditions. (Wetzel, 1975)

Holms (1999), reported on dissolved sodium, indicating that its values increased between 1975 and 1993. Even though it met the criteria, Holms recommended that sodium be monitored into the future, as a measure of change in the rate that ions are released within the watershed and as an indicator of possible disturbance.

Total sodium was reviewed in this report, as opposed to dissolved sodium, because dissolved values were not collected after 1993. Total sodium data was collected during spring overturn in 1992, and '97-'03. In 2000, summer data was also obtained. Values ranged from 4.7-9.3 mg/L, and averaged at 6.1 mg/L. The Drinking Water Criteria of 20 mg/L (set as an alert for people on low sodium diets), has not been exceeded.

Figure 16. depicts the results of total sodium at the Mid Lake Site. The results show uniform values with depth; values which increased in the summer; and a trend of a gradual increase over time, with the values peaking in February of 2003 (6.9 mg/L).

3.2.12 Specific Conductivity

Specific conductivity is the measurement of the ability of water to conduct an electrical current- the greater the content of ions (dissolved metals and other dissolved materials) in the water, the more current the water can carry. It may be used to estimate the total ion concentration of the water, and is often used as an alternative measure of dissolved solids. Anthropogenic sources include mining, roads (de-icing salts), industrial and municipal effluents. (RIC, 1998).

Holms (1999) reviewed specific conductivity between 1974 and 1995. Although the Drinking Water Criteria of 700 µS/cm was not exceeded, Holmes identified that increases in this parameter indicated possible disturbances. A review of the data collected between 1974 and 2003 indicates that values continue to remain much lower than the Criteria maximum. The overall range for specific conductivity is 58 – 210 µs/cm, with a calculated average of 92 µs/cm.

Figures 17A depicts that the specific conductivity stays relatively uniform with depth, and tends to peak annually during the summer. Summer data was thus averaged with depth, and charted to identify any trends (Figure 17B). Because summer data since 1995 was limited to 1 sample set in 2000 and 3 in 2001, it is difficult to accurately confirm a trend, however; the existing information shows that since 1975, the summer values have been on the increase, with the 2001 values being the highest, (peaking in September with a column average of 146µs/cm.). A reliable trend line could not be produced for the spring data.

3.2.13 Turbidity

Turbidity is a measure of the suspended particulate matter in a water body, which interferes with the passage of a beam of light through the water (and can be an alternative to secchi readings). Silt, clay, organics or micro-organisms can contribute to turbidity. High turbidity, results in a high surface area of suspended solids for bacteria to grow on. It also reduces light penetration, impairing photosynthesis, which in turn may suppress fish productivity. Turbidity interferes with drinking water disinfection and is aesthetically unpleasant. Anthropogenic sources include: forest harvesting, road building, agriculture, urban developments, sewage effluents, mining and industrial effluents. (RIC, 1998)

Turbidity data was collected in 1974, ’75, ’80, ’94, ’95, ’97-’03. Values ranged from 0.1 to 15.3 NTU, with an average of 2.7 NTU. The Drinking Water Criteria (for aesthetics) is 1 NTU for raw-untreated water, and 5 NTU for raw-treated water. These Criteria were exceeded for 67% (if untreated) and 19% (if treated) of samples.

Figure 18 shows the results of the turbidity data as monthly averages, graphed with depth. Frequency of data collection varies from year to year, making absolute understanding of trends difficult. The highest recorded values, for example, occurred at the surface in September 1999 and November 2002. Additional summer data for these years would have helped confirm the trends, and allowed for comparisons with other years. For years where data has been collected throughout the summer months, highest annual turbidity values occurred at the bottom depths during the summer and fall months (1974 in June, 1980 in June and October, and 2001 in June). A record high of 15.3 occurred at the surface in Nov. 2002. Values tended to decrease through the winter, reaching lows in the spring. The trend appears to be that the annual peak values are increasing with each passing year.

3.3 Trophic State and Algae Growth in Cusheon Lake

There are a variety of parameters that can be used to gain an understanding of the characteristics of algal species or algal communities. Generally, no one indicator should be used by itself to provide an answer, but rather a number of indicators, when considered together provide the best information for an interpretation of growth rates, relative state of health, limiting nutrients, etc. (Nordin, 1985).

In attempts to understand why there is an algae growth issue at Cusheon Lake this section will complete the following three components:

1. Identify the current trophic state of Cusheon Lake,
2. Discuss Mid Lake findings in terms of algae requirements and the nutrient cycle,
3. Review tributary influences on key parameters linked to algae growth.

3.3.1 Trophic Classification of Lakes

Nordin (1985), described that the concept of lake trophic levels is based on grouping lakes into a category of oligotrophy, mesotrophy or eutrophy, based on their level of biological production. Nordin, further provided a variety of ways that trophic levels can be characterized. Table 3 below, presents characterization ranges for nutrient and phytoplankton parameters available to the Cusheon Lake data set. Cusheon Mid Lake values have been incorporated into the table so that its trophic level can be determined.

Table 3. Typical Ranges of Nutrient Parameters for Different Trophic Levels in Lakes

	Total Phosphorus (µg/L) at spring overturn	**Total Nitrogen (µg/L) at spring overturn**	**Chlorophyll a (µg/L) growing season mean****	**Secchi Disc (m) growing season mean****	**Hypolimnetic Oxygen Depletion Rate (mgo^2/m^2/day)**
Oligotrophic	1-10	**<100**	**0-2**	**>6**	**<250**
Mesotrophic	**10-30**	**100-500**	**2-7**	**3-6**	
Eutrophic	**>30**	**500-1000**	**>7**	**<3**	**>500**
Cusheon Lk. 1970s	13.5	705	-	3.2	
Cusheon Lk. 1980s	11.3	937	8.3	2.4	
Cusheon Lk. 1990s	14.4	695	-	-	
Cusheon Lk. 2000s	13.8	755	4.5	4.3	250.8***

*From Nordin (1985), who created this table using a number of sources.

**Growing Season Mean for both chlorophyll a and secchi disc was determined by averaging June – October data

***Cusheon hypolimnetic oxygen depletion rate supplied by U.Vic. (2004).

Results indicate that Cusheon Lake is currently mesotrophic with some eutrophic characteristics. Historically parameter values have fluctuated, with 1980's values more closely reflecting eutrophic conditions. Phosphorus values (when measured at spring overturn) have consistently remained within the range of a mesotrophic system, while total nitrogen values have remained at eutrophic levels throughout sampling history. Cusheon Lake appears sensitive to becoming eutrophic, and limiting nutrient inputs would thus seem important to keep the lake from becoming eutrophic and to improve overall lake conditions.

3.3.2 Factors Controlling Algal Growth in Cusheon Lake

The eutrophication of temperate lakes leads to increases in algal biomass and changes in community structure (Pick and Lean, 1987). As is seen in Cusheon Lake, blue green algae often become the dominant group in enriched lakes. These algae have received much attention because they create surface scums, taste and odour problems (Pick and Lean, 1987); they are potentially toxic to fish, livestock and even humans (Carmichael, 1981); and when large populations decline in small shallow lakes, the high oxygen demand can lead to fish kills (Barica, 1975). Efforts to understand their physiological requirements and control their populations are worldwide and have been ongoing for decades.

The blue green algae have several competitive advantages over other algae, making them so successful. Some of these strategies include: occurring in large colonies, the ability to fix nitrogen under aerobic conditions (for most filamentous types), being tolerant of higher temperatures, having mucilage sheaths and gas vacuoles to reduce their sinking rate allowing them to remain in the photic zone, and with their gas vacuoles the ability to regulate their buoyancy so they can position themselves in most favourable chemical and physical gradients (Wetzel 1975)

There are various important factors regulating algal biomass and/or production in lakes including: light and temperature, the ability to remain in the photic zone, inorganic nutrients, organic micronutrients, interactions of organic compounds with inorganic nutrient availability, and biological factors of competition (Wetzel, 1975). Because of the overriding significance to algae growth, the Cusheon Lake cycle for key nutrients (nitrogen and phosphorus) and interrelationships affecting their availability (including oxygen influences) will be discussed in more detail. Cusheon Mid Lake findings will be the focus for this analysis.

3.3.2.1 Nitrogen to Phosphorus Ratio

Algae require nitrogen and phosphorus in specific proportions to meet their metabolic needs. The N:P ratio (based upon total nitrogen and total phosphorus) provides an indication of the relative availability of these two important nutrients. Ratios of N:P in water of less than 5:1 are indicative of nitrogen limitation and ratios of greater than 15:1 indicate phosphorus limitation (Nordin, 1985)

The N:P ratio for the Mid Lake Site was calculated by averaging monthly water column values. Results are depicted in Figure 19, and they indicate the following:

- Phosphorus was the limiting factor for 37/51 (or 72%) of the values.

- Ratio peaks occurred during the spring (March-May). For these spring values, ratios tended to fluctuate from year to year; however, the highest calculated values occurred in recent years, with March 2003 having a ratio of 84, and March 2002 having a ratio of 69. The average value at spring overturn is 52.
- From the spring high, ratios tend to rapidly fall during the summer to annual lows, which persist through to late fall/early winter. A ratio below 5, indicative of nitrogen limitation, only occurred once, in Sept. 2001.

This establishes that phosphorus is the limiting nutrient, and it will thus be the focus for discussion in the following section looking at algae growth.

3.3.2.2 Phosphorus Cycle and Algae

Water on the Web (WOW, 2003), describes that *aquatic organisms influence and are influenced by the chemistry of the surrounding environment. Essential nutrients such as the bioavailable forms of phosphorus and nitrogen (dissolved phosphate, nitrate, and ammonium) typically increase in spring from snowmelt runoff and from the mixing of accumulated nutrients from the bottom during spring turnover.* Because of the mild conditions of Salt Spring Island, snowmelt is not a factor for Cusheon Lake, and the lake tends to be isothermal through the winter without a spring turnover event. As a result, total phosphorus at the Mid Lake site exhibits peak values following fall turnover, and winter high-flow/runoff events. Fall turnover is the time when mixing attributed to the water column becomes uniform in temperature (isothermal), distributing nutrient rich waters from bottom depths throughout the water column. Chlorophyll a data, which is a measure of phytoplankton (Figure 12) substantiates this, showing blooms, and peaks levels throughout the fall/winter period.

WOW continues by explaining that *nutrient concentrations typically decrease in the epilimnion during summer stratification as nutrients are taken up by algae and eventually transported to the hypolimnion when the algae die and settle out*. This explains Cusheon Lake's low spring and summer total phosphorus values. The chlorophyll a data corroborates this with low values in spring as nutrients diminish. The chlorophyll a values, at the surface, generally remain low through the high temperature and low nutrient availability summer months.

WOW, further provides that *during this period, any "new" input of nutrients into the upper water may trigger a "bloom" of algae; and such inputs may be from upstream tributaries after rainstorms, die-off of aquatic plants, pulses of urban storm water, direct runoff of lawn fertilizer, or from leaky lakeshore septic systems*. One or a combination of these inputs are the likely cause for the spring/summer surface phosphorus peaks at Cusheon lake seen in Apr. '76, Apr. '80, Mar. '99, and that of Sept. '99 (Figure 6B). Perimeter site input can confirm these occurrences/peaks and will be discussed in more detail in Section 3.3.3.

An injection of nutrients may also occur simply from high winds that mix a portion of the nutrient enriched hypolimnion into the epilimnion (WOW, 2003).

During the summer, nutrients are redistributed from the upper water to the lake bottom as the dead plankton gradually sink to lower depths and decompose (WOW. 2003). This likely contributes to the summer peaks for phosphorus in the mid and bottom depths, that were recorded in ’74,’76, ’80, ‘00, ‘01, and ’02 (Figure 6B). A more significant influence on these peaks is likely internal loading of phosphorus (from the sediments) in the late summer and early fall when deeper waters become anoxic (to be discussed further in the following section).

3.3.2.3 Oxygen Influence on Phosphorus

> *The DO concentration in the epilimnion remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, conditions in the hypolimnion vary with trophic status. In eutrophic (more productive) lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and continue to consume oxygen. The bottom layer of the lake and the entire hypolimnion may eventually become anoxic, or totally devoid of oxygen.* (WOW. 2003.)

The described summer hypolimnetic DO declines, are experienced annually at Cusheon Lake (Figure 8 & 9). This DO depletion can result in a number of problems, including:

- Release of phosphorus from the sediments into the overlying water, which is a major component of the phosphorus cycle (Wetzel, 1975). WOW (2003), describes that *when the DO levels drop below 1 mg0_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus. When the lake mixes in fall this new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth.* This can exacerbate water quality deterioration (WOW, 2003), beginning a general acceleration of the eutrophication process (Nordin, 1985).
- Changes for lake biota. Effects are expected in zooplankton migration, growth, reproduction and survival; and fish with changes to their food supply (i.e. benthos zooplankton), and habitat (loss of summer cool water) (Nordin 1985).
- Diminished drinking water quality, which Nordin (1985) describes: …*the preferred location for water intakes is in the hypolimnion where algal biomass is low and water temperatures are cool. If oxygen falls to zero in the hypolimnion, water drawn from this zone would have a variety of undesirable characteristics such as the presence of hydrogen sulphide, iron, manganese, etc*.

In summary, the key factor affecting algae growth appears to be internal phosphorus loading where anoxic bottom conditions cause the release of phosphorus from the sediments. This phosphorus mixes throughout the water column during fall overturn. This issue perpetuates itself with runoff events contributing phosphorus to the system from throughout the watershed, and with the overall heightened algae biomass contributing to increased phosphorus at depth (as the algae die off) resulting in low dissolved oxygen, and a continuation of the cycle.

This situation can be improved with time, for as Wetzel (1985) summarizes, *reduction of phosphorus inputs to productive lakes results in the quantitative reduction of the phosphorus cycle, and a relatively rapid decline of the productive capacity of the lake system.*

3.3.3 Perimeter Site Influences on Cusheon Lake

The key parameters linked to algae growth were reviewed for the Perimeter sites and compared to the Mid Lake site values collected during the same period, to identify any Perimeter site influences. Parameters reviewed were total phosphorus, nitrate+nitrite, turbidity, and fecal coliforms. The Mid Lake surface depth data was used for the comparison, because the surface waters are the first contact for the Perimeter site inflow, and thus most greatly affected by runoff inputs. Where beneficial, comparisons were made to the Mid Lake parameters (i.e. data graphed with depth, and temperature data) to help confirm conclusions. All figures are provided in Appendix 3.

The North Shore and South Shore data was compared to the relevant Water Quality Criteria, in the event that water intakes, recreation activities or aquatic life were located within their proximity. The Blackburn Creek, Cusheon Lake Road, and Horel Road site data was not compared to the Criteria for this study, because they are tributary sites, not located within the lake.

3.3.3.1 Perimeter Site Influences on Total Phosphorus

Wetzel (1975), discussed phosphorus inputs, saying that the rates of biological productivity of many lakes are dependant on the rate of phosphorus cycling in relation to the input loading of phosphorus from external sources. He noted that phosphorus loading to lakes has increased in recent times by human's accelerated use and inefficient recovery of phosphorus from agricultural, industrial, and domestic (i.e. detergent) waste products.

Because total phosphorus directly relates to algae growth, it was reviewed to determine perimeter site loading and linkages with Mid Lake peaks. Table 13. provides total phosphorus results for the Perimeter sites. Figure 20 depicts these results, including surface Mid Lake Site data for the corresponding period. Findings are summarized as follows:

- Values for the Perimeter sites were proximal to one another, with the highest average and maximum calculated for the Cusheon Lake Road site (35 avg. and 145 µg/L max.), and the lowest for Blackburn Creek (29 avg. and 76 µg/L max.).
- 93% of the North Shore and South Shore values were above the Drinking Water Criteria (10µg/L). 78% of the South Shore values and 67% of the North Shore values were above the Recreational Criteria (15 µg/L).
- Generally, surface Mid Lake values tend to be within range of the Perimeter site values.
- During the Mid Lake peak of 90 µg/L on September 7, 1999, values appear to be increasing at all Perimeter sites. No measurements were collected at the Mid lake site in October, but on the 13^{th}, the other sites all showed extreme values, with Horel Rd. at 135 µg/L having the highest value, and Blackburn Ck. having the lowest at 76 µg/L. Cross reference with the Phosphorus with depth data (Figure 6B), confirms that Mid Lake mid or bottom depth values were not an influence.
- During the Sept. 21, 2000 Mid Lake peak of 36 µg/L, no tributary or perimeter values were collected to allow for a relation to be made. Cross reference with Figure 6B indicates that this peak may have been associated with bottom values because mid depth values were higher (46 µg/L). The temperature data (Figure 7) may help confirm this, as conditions were nearing fall turnover (which occurred by Oct. 4).

- During the surface Mid Lake peak of 39 µg/L on <u>Oct. 29, 2001</u>, Perimeter site values were not available for comparison. Perimeter values collected shortly after on Nov. 15, indicated quite high values at the Cusheon Lake Rd. site (145 µg/L) and the North Shore site (126 µg/L), which could have been contributors. Temperature data (Figure 7), indicates that on October 29conditions were isothermal, which was also a likely contributor, as mixing would have brought phosphorus up from lower depths. Mid or bottom phosphorus values were unavailable to help confirm a relationship.
- On <u>Nov. 12, 2002</u> a surface Mid Lake peak of 31µg/L occurred. On this date Horel Rd. was the key contributor, exhibiting a high of 95 µg/L. The other Perimeter sites did also have slightly elevated values, all of which were within range of the Mid Lake site. High mid and bottom depth values available on Oct. 30 and Nov. 27 (Fig. 6B), indicate that bottom depths were also contributing. The peak was likely influenced by phosphorus release from depth during turnover; however, temperature data was not available to provide confirmation.

In summary, data available since 1999 indicates that high Perimeter site total phosphorus values do appear to have influences on surface Mid Lake site values. In particular the peak on Sept. 7, ’99, and may have contributed to that of Oct. 29, ’01 and, Nov 12, ’02. Fall turnover, also appeared to contribute to increased phosphorus values, during the 2000, ‘01 and ‘02 peaks. Stream flow and lake volume data would be valuable to help confirm if these highs were related to high flow events washing nutrients into the lake. All sites have influenced the peaks throughout the study period fairly closely.

3.3.3.2 Perimeter Site Influences on Nitrogen

Nordin (1985), describes the importance of nitrogen for algae growth as follows:

> A second major nutrient required by algae is nitrogen, and although phosphorus limits algae growth in the majority of cases, nitrogen can be the limiting form in some circumstances. Nitrogen limitation of freshwater algal growth is less common than phosphorus limitation because of potential for nitrogen fixation by blue-green algae from the atmosphere when nitrogen becomes limiting.

Although nitrogen is generally not the limiting nutrient for algae growth it was reviewed to gain an understanding of timing, extent and location of inputs to the lake, which could provide insight to major runoff periods, and key areas contributing discharge of concern (i.e. septic leakage).

Of the nitrogen forms, dissolved nitrate + nitrite was selected for review because of its importance to plant growth. Nitrate is particularly important because, as the RIC manual (1998) describes, it is the most stable form of nitrogen in a water body, and is the primary form of nitrogen used by plants as a nutrient to stimulate growth. RIC further provides that nitrite is an intermediate form of nitrogen, which is unstable and rapidly oxidizes to nitrate or reduced to nitrogen gas. RIC identified the anthropogenic sources of these nitrogen forms include sewage treatment effluents, agriculture, urban developments, recreation, industrial effluents, and blasting residues. When measured together, nitrate concentrations predominate and the nitrite portion is minimal.

Nitrate, nitrite, and nitrate + nitrite values for the Perimeter sites are provided in Tables 10 and 11. Relationships between values at the Perimeter sites and the surface values for the Mid Lake site are depicted in Figure 21. Results are as follows:

- The Drinking Water Criteria for Nitrate is 10 mg/L and the Aquatic Life Criteria is 200 mg/L max. For Nitrite, the Drinking Water Criteria is 1 mg/L and the Aquatic Life maximum is 0.06 mg/L (worse case when Chloride <2 mg/L). Perimeter site data indicates that neither the South Shore nor the North Shore locations exceeded the criteria.
- Nitrate + nitrite values at the perimeter sites (Table 10), identify that:
  - Horel Road had the highest maximum (12.3 mg/L) and average (1.1 mg/L) values.
  - Cusheon Lake Road followed with a max. of 4.0 mg/L and an avg. of 0.5 mg/L.
  - And the North Shore (2.2 mg/L max., 0.3 mg/L avg.), Blackburn Creek (0.8 mg/L max., 0.2 avg.), and South Shore (0.5 mg/L max, 0.116) sites ensued with decreasing contributions.
- From the graphed data (Fig 21), Mid Lake site values appeared to rise and fall in accordance with the Perimeter site values; although, the Mid Lake values tended to be buffered, not reaching the extremes of the Perimeter sites.
- In <u>1999</u>, the North Shore site values were the highest with peaks on May 12, 1999 (0.6 mg/L) and Nov. 30 (2.2 mg/L). All other sites showed increases during the Nov. 30 high, which appeared to gradually decline with time, not reaching lows until July 31, '00. The Mid Lake values followed.
- In <u>2001</u>, peaks were experienced at Horel Road (12 mg/L on Nov. 15) and Cusheon Lk. Road (4 mg/L on Nov 29). On Nov. 29, the North Shore, Horel Road and Blackburn Creek sites also had highs (ranging between 0.8 and 1.1 mg/L). No Mid Lake site data is available for a direct comparison, but data available for early 2002 indicates peaks in Feb. (0.5 mg/L), which are likely related to the Perimeter site highs.
- Through the winter of <u>2002/03,</u> the Horel Road site values remained high (Nov. '02 – 1 mg/L, Jan. '03 - 0.6 mg/L). The Cusheon Lake road site also reached a high of 1.9 mg/L on Oct. 20 '03.

In conclusion, Perimeter site peaks for dissolved nitrate + nitrite generally occurred during the winter months. This is most likely related to high winter flows flushing waters with these nutrients into the water systems. Since, 1999, all perimeter sites have contributed to the peaks to varying degrees, with Horel Road exhibiting the highest maximum and average values. Mid Lake values appeared to be directly related to Perimeter site influences.

3.3.3.2.1 Mid Lake Dissolved Nitrate + Nitrite Values

Monthly average Mid Lake dissolved Nitrate + Nitrite values were graphed with depth to further reveal patterns related to the input of this nutrient, and to help confirm findings related to the Perimeter site influences. Results are depicted in Figure 22, and are summarised as follows:

- Dissolved nitrate+nitrite data has been collected in 1974-'76, '80,'81,'87,'89,'92-'95,'98-'03). Values ranged from a minimum of <0.002 to a maximum or 0.65 mg/L, with an average of 0.085 mg/L. A review of nitrate and nitrite values individually, identifies that neither exceeded their respective Water Quality Criteria (Table 16).
- Values appear to be relatively uniform with depth.

- Values are generally below detectable limits through the low flow months of June – November, which is likely due to algal utilization. Values then quickly peak in the winter (i.e. in Jan/Feb). Because of the lag time following fall turnover, these peaks are likely more closely related to high runoff events of winter, than with redistribution of nitrogen from bottom depths. Nitrogen, also does not get released from sediments the way phosphorus would (Deniseger, 2004)[1]. From winter peaks, values decrease slowly and remain high into the spring.
- Many years' sampling was limited to spring data collection (1981-'99), with possible peak values missed, making it difficult to identify an overall trend. From the data available it can be said that fluctuations occur from year to year, with the highest peaks evident in March 1993, and January 2003 (both at 0.65 mg/L).

3.3.3.3 Perimeter Site Influences on Turbidity

Turbidity influences from the Perimeter sites on the Cusheon Mid Lake site were reviewed to determine timing, extent and location for inputs of highly turbid waters to the lake. This information, similarly to nitrogen, could provide insight to major runoff periods and key areas contributing discharge of concern (i.e. septic leakage, erosion areas etc.), which could be related to phosphorus inputs and algae growth. For the discussion below, all units for turbidity are in NTU.

Table 15, provides turbidity data and statistics for the Cusheon Lake perimeter sites. Results identify the highest values coming from the North Shore (49.4 max., 7.2 avg.), and Cusheon Lake Rd. (37.3 max., 5.7 avg.). Horel Road's values were in the middle (18.5 max., 3.5 avg.), and the lowest values occurred at Blackburn Creek (8.12 max., 3.2 avg.) and the South Shore site (8.93 max., 2.5 avg.).

The Drinking Criteria for Turbidity of 1 NTU for raw-untreated water and 5 NTU for raw-treated water was exceeded respectively in 64% and 27% of samples at the North Shore Site, and 43% and 21% of samples at the South Shore Site.

Figure 22 provides a graph of the Perimeter site turbidity results compared to the Mid Lake site. Results are as follows:

- In 1999, moderate peaks occurred on Mar. 31 (Blackburn Ck.- 6), May 12 (South. Shore and North Shore (5), and September 7 (Horel Rd.-7.5 and all other sites between 5 and 5.7). Surface Mid Lake peaks also occurred during these times, but were higher.
- In 2000, a peak value of 12 occurred at the North Shore site on Mar. 1. This did not appear to influence the Mid Lake value, which was 0.1.
- In 2001, Blackburn Ck. had a moderate peak of 8 on July 25. In Nov. both Cusheon Lake Rd. and the North Shore site experienced the highest recorded values for the lake (with peaks of 37 and 49 respectively). Other than an increasing value of 4.6 on Sept. 17, Mid Lake data was unavailable for comparison.

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[1] Nitrogen does not get released from sediments. However, when a build-up of ammonia at bottom depths occurs in the summer (which the data indicates does happen at Cusheon Lake), it would be converted to nitrite and nitrate once oxygenated (i.e. during fall turnover) and mixed throughout the water column. (Deniseger, 2004)

- In 2002, the highest values were seen on Nov. 12 at Horel Rd. (18.5) and South Shore (8.93). The Mid Lake value appeared to be linked, because on this date, it had its highest recorded value of 15.3.

A comparison with Turbidity with depth data at the Mid Lake site (Figure 18) indicates that most of the peaks recorded for the Mid Lake site since 1999 appear to be linked to Perimeter site contributions (with the Sept. 17, 2001 influence unknown). All Perimeter sites have contributed to turbidity but because of their high average and maximum values, Cusheon Lake Road and the North Shore sites have contributed the most.

3.3.3.4 Perimeter Site Influences on Fecal Coliform Bacteria

Fecal Coliform influences from the Perimeter sites on the Cusheon Mid Lake site were reviewed to determine timing, extent and location for inputs of water with fecal coliform bacteria to the lake. This information, similarly to nitrogen and turbidity, was used to provide insight to major runoff periods and key areas contributing discharge of concern (i.e. septic leakage), which could be correlated with phosphorus and algae growth occurrences.

Fecal Coliform values for the perimeter sites are provided in Table 8, and data is depicted in Figure 23. Results are as follows (all data units are in CFU/100mL):

- The Criteria for raw water, with no treatment for drinking, livestock, and industrial purposes is 0/100 mL maximum. This has been exceeded frequently at both the North Shore Site (81%) and the South Shore Site (84%). Not enough samples were collected to determine whether the Water Criteria for other uses were exceeded.
- Cusheon Lake Road had the highest maximum of 18000 and average of 1343. In descending order, the North Shore (500 max., and 55 avg.), Blackburn Creek (226 max., 32 avg.), South Shore (130 max., 16 avg.), and Horel Road (61 max., 12 avg.) sites ensued.
- Unfortunately, no Mid Lake values were collected during the Perimeter site peaks, to allow for comparison. Mid Lake data was only available during the periods of low Fecal Coliform inputs, and as a result were equally low.
- In 1999, Cusheon Lake Rd. peaked with a value of 340 on May 12. The North Shore exhibited a high of 100 on July 21, with Blackburn Creek also had a small increase (27).
- In 2000, an extremely high value of 18000 was recorded at the Cusheon Lake Rd. site on March 1. The North Shore site also had a slight high on this day of 52. Blackburn Creek followed with a peak of 87 on June 8.
- In 2001, Blackburn Creek had a high of 226 on June 26. On November 15, the North Shore, Cusheon Lake Rd. and Horel Rd., all exhibited peaks of 500, 300, and 61 respectively. Blackburn Creek data was unavailable. Values dropped while remaining elevated for the North Shore (143) and Cusheon Lake Rd. (125) through to Nov. 29, where Blackburn Creek also had a small high (38).
- In 2002 data was limited to Nov.12, where Horel Rd. had a slight high of 54.

Generally peak inputs of Fecal Coliform occurred frequently, fluctuating between sites, at various times throughout the year. Cusheon Lake Road and the North Shore had the highest values. Limited collection of Mid Lake data, made a conclusion on the overall influences to the lake impossible. Stream discharge or lake volume data would be valuable to have to correlate peaks with possible high flow periods.

3.3.3.5 Summary of Perimeter Site Influences on Mid Lake Parameters Related to Algal Growth.

All Perimeter sites contributed to peaks to various degrees for the parameters reviewed. A comparison of the maximum and average values for all the reviewed parameters indicated that the Cusheon Lake Road and the North Shore sites tended to most frequently have the highest values; whereas Blackburn Creek and the South Shore site most frequently had the lowest values. Discharge data for the Perimeter sites would help to confirm the significance of these values in terms of overall contribution to Cusheon Lake.

A summary comparing all Perimeter site data reviewed is provided in Table 4 below. For a particular date, linkages between parameters and respective key contributors to peaks can be identified. Peaks types were determined through qualitative analysis and were defined for a range from low to very high. Mid Lake Chlorophyll a data was generally not available for the months that perimeter data was collected, making a direct relationship to algae biomass impossible. Instead, total phosphorus, because of its significance to algae growth, was used to describe the Mid Lake conditions and to compare to the Perimeter site variables.

Table 4. Correlations Between Perimeter and Mid Lake Site Peaks, for Parameters Related to Algae Growth

Date	Mid Lake Site (surface), Peak Type	Perimeter Sites Peak Type (low, moderate or high)/ Key Site(s) Contributing			
	Phosphorus, Total	**Phosphorus, Total**	**Nitrate + Nitrite, Dissolved**	**Turbidity**	**Fecal Coliforms**
May 12, 1999	No data	Low / All sites	Moderate / North Shore	Moderate / South Shore and North Shore	High / Cusheon Lake Rd.
Sept. 7, 1999	High	Moderate / All sites- Horel Rd. highest	Low / All sites	Moderate / All sites –. Horel Road highest	Low / All sites
Oct. 13, 1999	No data	High / All sites. Horel Rd and South Shore highest	Low / All sites	Moderate-Low / Horel Rd. and North Shore	Low / All sites
Nov. 30, 1999	No data	High / South Shore	High / North Shore. Moderate / Horel Rd., Blackburn Ck.	Moderate-Low / South Shore and North Shore highest	Low / Small peak at Horel Rd. and North Shore
March 1, 2000	Moderate	Moderate / North shore	Moderate / All sites	High / North Shore	Very high / Cusheon Lake Rd.
June 26, 2001	Low (very high at bottom)	Moderate / Low South Shore, North Shore	Low / All sites	Low / Moderate Blackburn Ck.	High / Blackburn Creek
Nov. 15, 2001	No data; High on Oct. 29	High / Cusheon Lake Rd. and North Shore	High / Horel Rd.	High / Cusheon Lake Rd., North Shore	High / North Shore, Cusheon Lake Rd.
Nov. 29, 2001	Low / Moderate	Moderate / North Shore, Blackburn Creek	High / Cusheon Lake Rd. Moderate / North Shore, Horel Road, Blackburn Ck.	High / Cusheon Lake Rd., North Shore	High / North Shore, Cusheon Lake Rd. Moderate / Horel Rd.
Nov. 12, 2002	Moderate	High / Horel Rd.	Moderate / Horel Rd.	High / Horel Rd. Moderate / South Shore	Moderate / Horel Rd.

4.0 Recommendations

The Cusheon Lake watershed is important to the local residents on Salt Spring Island. Not only is Cusheon Lake the main drinking water supply for the area, but it is also a valued area for recreation activities, aesthetics, aquatic habitat (including fish), and wildlife habitat.

The Cusheon Lake Stewardship Committee, prompted by excessive algal blooms in Cusheon Lake, was established in 2003. A goal for the committees was to develop a watershed management plan. This plan titled the *Cusheon Watershed Management Plan* (CWMP), was completed in March 2004. The main goal of the CWMP is to protect and restore water quality within the watershed. In developing the plan, data gaps were identified and compiled into a list of action items. A summary of all water quality data collected for Cusheon Lake was identified as a high priority action item requiring immediate attention. This report is directed at addressing that action item, and in doing so at also providing a clearer link between the algal cycle and nutrient inputs. The recommendations presented in this section are intended to support those outlined in the CWMP.

Cusheon Watershed Management Plans

1. This report identified that several parameters did not meet the Water Quality Criteria, that the lake is nearing a eutrophic state, and that internal loading and tributaries / lake perimeter sites are contributing to these problems. Because of these issues, it is recommended that the long-term plans as outlined in the CWMP (2004) be acted on. These plans include the following:
   - Completing a definitive survey of the phosphorus sources in the basin,
   - Carrying out a stewardship education program,
   - Conducting riparian zone improvement,
   - Controlling sources of nutrients from the general land areas, and
   - Improving septic tank fields, ditching procedures and vegetation in the immediate vicinity of the lake.

   The plans should be prioritized based on their feasibility and cost-effectiveness, with funding sources, timelines and measures for effectiveness outlined.

   In addition to the above watershed plans, the following items are also recommended:

Water Quality Monitoring

2. Monitoring should continue at the Mid Lake site. To provide insight on contributions and influences on the lake, it is recommended that the Tributary and Perimeter sites also continue to be monitored.

3. Monitoring should capture representative samples throughout the year. Data collection should increase in frequency during the summer and fall (i.e. monthly at least), in order to provide an understanding of lake dynamics when Water Quality Criteria exceedances are highest, and drinking water, aquatic life, and recreation values are most vulnerable. To aid in future analysis, data representing surface to bottom depths should be obtained, and

when Perimeter sites are sampled it should be at the same time as when the Mid Lake is sampled.

4. All parameters that exceeded the Criteria should continue to be monitored, including: total organic carbon, chlorophyll a, true colour, dissolved oxygen, extinction depth, fecal coliform, manganese, total phosphorus, temperature, and turbidity. Other nutrient parameters (such as nitrogen), and parameters which have associated Water Quality Criteria should also continue to be monitored, to track any changes.

5. Because of difficulty in determining whether several of the metal parameter results met the Criteria during this analysis, it is recommended that laboratory analysis provide results at sufficient detection levels, if possible.

Water Quantity Sampling

6. It is recommended that a water level gauge be installed on Cusheon Lake, so that a relationship between lake volume and parameter concentration can be made. With this, peak values in parameters of concern (i.e. phosphorus) can be compared to lake volumes to determine if high flow from tributaries may have been a cause. This approach proved valuable to the Charlie Lake Assessment (French & Carmicheal, 1999), which should be referenced prior to set-up and analysis.

7. Discharge values for the Perimeter sites during key data periods would also be valuable to identify total contributions to Cusheon Lake for a given parameter. It would be particularly valuable to have discharge data for Blackburn Creek, as it is the major inlet to the lake.

Sediment and Biota Monitoring

8. A Cusheon Lake sediment core was collected in November 2001, by the University of Victoria (Rick Nordin is the primary contact). The core is currently being analyzed. The sediment core results should be compared to the results of this report, to provide an improved understanding of the chemical history of the lake, and of both the historical and current anthropogenic impacts on the watershed.

9. Sediment should be analyzed for redox potential during key times of the year to determine if internal loading is occurring. This can be completed by measuring sulphide and ORP from a large bottom sediment sample.

10. An analysis of phytoplankton community dynamics would be valuable to determine species present throughout the year. In particular, it should be identified if significant numbers of species that produce toxic compounds are present during the blooms.

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6.0 Appendix 1 Cusheon Water Quality Data Summaries (Tables 5-15)

Table 5. Cusheon Mid Lake Site (EMS # 1100123), Summary of Water Quality Data

Cusheon Mid Lake Site, Water Quality Data Summary						
Parameter (mg/L unless otherwise stated)	**Sampling periods (sample size)**	**Minimum**	**Maximum**	**Average**	**Standard Error**	**Number < Detection Limits**
Acid:Fre (µeq/L)	1986 (1)	0.1	0.1	0.100	0.000	0
Acid:Tot (µeq/L)	1986 (1)	137	137	137.000	0.000	0
Acid<8.3 (µeq/L)	1986 (1)	49.6	49.6	49.600	0.000	0
Alkalinity pH 4.5/4.2	1990's (3) - 2000s (15)	no data provided (EMS table indicates see attached)				
Alkalinity pH 8.3	1970s (3); 2000s (2)	0.5	1	0.750	0.274	5
Alkalinity Total (µeq/L)	1980 (1)	455	455	455.000	0.000	0
Alkalinity Total 4.5	1970s (36); 1980s (18); 1990s (2); 2000s (7)	18.9	48.4	25.038	4.856	0
Aluminum Dissolved	1980s (1)	0.04	0.04	0.040	0.000	0
Aluminum Extractable	2000s (4)	<0.05	0.06	0.052	0.005	3
Aluminum Total	1980s (3); 1990s (13); 2000s (14)	0.013	0.42	0.103	0.085	11
Ammonia Dissolved	1970's (1); 1980s (54); 1990s (18); 2000s (80)	0	1.04	0.051	0.122	21
Ammonium	1980s (1)	0.02	0.02	0.020	0.000	0
Antimony Extractable	2000s (3)	<.05	<.05	<.05	0.000	3
Antimony Total	1990s (13); 2000s (15)	0.00003	0.06	0.041	0.022	26
Arsenic Extractable	2000s (3)	<0.05	<0.05	<0.05	0.000	3
Arsenic Total	1980s (1); 1990s (13); 2000s (14)	<.05	<.06	0.048	0.016	27
B.O.D.	1980s (12)	<10	<10	<10	0.000	12
Barium Extractable	2000s (3)	0.006	0.008	0.007	0.001	0
Barium Total	1990s (13); 2000s (14)	0.004	0.01	0.007	0.001	0
Beryllium Extractable	2000s (6)	<0.001	0.023	0.012	0.012	3
Beryllium Total	1990s (13); 2000s (14)	0	<0.002	0.001	0.000	26
Bismuth Total	1990s (7); 2000s (4)	0	<0.05	<0.026	0.016	10
Boron Dissolved	1970s (4)	<0.1	<0.1	<0.1	0.000	4
Boron Total	1990s (13); 2000s (13)	<0.01	0.1	0.032	0.026	5
Bromide Dissolved	1990s (6); 2000s (32)	0.0008	0.1	0.037	0.029	18
Cadmium Extractable	2000s (3)	<0.005	<0.005	<0.005	0.000	3
Cadmium Total	1970s (13); 1990s (13); 2000s (14)	0.00001	0.006	0.003	0.002	37
Calcium Dissolved	1970s (21); 1980s (18)	7.5	13.6	9.185	1.345	0
Calcium Extractable	2000s (6)	8.4	10.25	9.269	0.926	0
Calcium S	1980s (1)	10.6	10.6	10.600	0.000	
Calcium Total	1980s (33); 1990s (16); 2000s (13)	7.6	14.1	9.919	1.250	0
Carbon Dissolved Inorganic	2000s (32)	3.3	9.3	6.518	1.393	0
Carbon Organic Dissolved	1980 (27); 2000s (35)	<10	34.2	10.63	7.45	40
Carbon Total	1990s (4); 2000s (16)	9.5	14.1	11.933	1.258	0
Carbon Total Dissolved	2000s (11)	11.033	13.8	12.288	0.728	0
Carbon Total Inorganic	1970s (30); 1980s (39); 1990s (4); 2000s (30)	1	17	6.000	2.426	0
Carbon Total Organic	1970s (36); 1980s (39); 1990s (4); 2000s (44)	3	12	5.930	1.497	0
Chloride Dissolved	1970s (4); 1980s (6); 1990s (15); 2000s (14)	5.7	16	9.167	2.206	0
Chloride S	1986 (1)	9.75	9.75	9.750	0.000	0
Chlorophyll A	1980s (34); 2000s (49)	0.00001	0.034	0.008	0.009	0

Cusheon Mid Lake Site, Water Quality Data Summary						
Parameter (mg/L unless otherwise stated)	**Sampling periods (sample size)**	**Minimum**	**Maximum**	**Average**	**Standard Error**	**Number < Detection Limits**
Chromium Extractable	2000s (4)	<0.005	0.007	0.006	0.001	3
Chromium Total	1990s (13); 2000s (16)	0	0.035	0.006	0.006	20
Cobalt Extractable	2000s (4)	<0.005	0.007	0.006	0.001	3
Cobalt Total	1990s (13); 2000s (16)	0.0001	0.0085	0.008	0.015	25
Coliform Total (MPN)	1976 (2), 1980 (2)	2	13	5.500	5.196	0
Coliforms Fecal (CFU/100mL)	1999 (1), 2000s (5)	<1	3	1.500	0.837	3
Coliforms Fecal (MPN)	1976 (1), 1980 (2)	<2	5	3.000	1.732	2
Color True (Col.unit)	1980s (34); 1990s (15), 2000s (21)	5	400	29.414	52.642	0
ColorTAC (TAC)	1980s (8); 1990s (3)	9	24	18.091	4.742	0
Copper Extractable	2000s (3)	<0.005	<0.005	<0.005	0.000	3
Copper Total	1970s (13); 1980s (3); 1990s (13); 2000s (14)	0.00085	0.006	0.004	0.002	31
Dissolved Oxygen	1970s (91); 1980s (105); 1990s (4); 2000s (367)	0	33	8.393	4.972	0
Extinction Depth (m)	1970s (25); 1980s (10); 1990s (1); 2000s (36)	0.762	9.300	3.549	1.568	0
Fluoride Dissolved	2000s (12)	0.02	0.05	0.041	0.011	0
Fluoride Total	1990s (6)	0.03	0.05	0.033	0.008	0
Hardness Total	1990s (4); 2000s (13)	28.212	38.992	33.554	3.679	0
Hardness Total Dissolved	1980s (15)	34	46.7	37.167	3.056	0
Hardness Total Extractable	2000s (6)	30.4	38.192	33.999	3.854	0
Iron Dissolved	1980s (1)	0.31	0.31	0.310	0.000	0
Iron Extractable	2000s (3)	0.1455	0.1713	0.157	0.013	0
Iron Total	1970s (13); 1980s (3); 1990s (13); 2000s (13)	<0.1	1.6	0.238	0.276	6
Lead Extractable	2000s (15)	<.05	0.06	0.051	0.003	14
Lead Total	1970s (13); 1980s (3); 1990s (13); 2000s (15)	0.0002	0.07	0.029	0.026	36
Lithium Total	2000s (2)	0.0006	0.0006	0.001	0.000	0
Magnesium Dissolved	1970s (21); 1980s (18)	1.9	3.1	2.381	0.287	0
Magnesium Extractable	2000s (6)	2.3	2.967	2.581	0.320	0
Magnesium S	1980s (1)	1	2.77	2.770	2.770	0
Magnesium Total	1980s (31); 1990s (16); 2000s (13)	2	3.4	2.635	0.265	0
Manganese Dissolved	1980s (1)	0.2	0.2	0.200	0.000	0
Manganese Extractable	2000s (3)	0.0697	0.01665	0.011	0.052	0
Manganese Total	1980s (3); 1990s (13); 2000s (15)	0.015333	0.237	0.047	0.041	0
Mercury Total	1970s (10)	<0.00005	<0.00005	<0.00005	0.000	10
Molybdenum Extractable	2000s (3)	<0.01	<0.01	<0.01	0.000	3
Molybdenum Total	1990s (13); 2000s (14)	0	<.0114	<.0071	0.003	26
Nickel Extractable	2000s (3)	<0.02	<0.02	<0.02	0.000	3
Nickel Total	1970s (13); 1980s (3); 1990s (13); 2000s (14)	0.0004	<0.023	<0.013	0.006	42
Nitrate Dissolved	1980 (1); 1990s (6); 2000s (19)	<.002	0.558	0.233	0.215	6
Nitrate S (µeq/L)	1986 (1)	3.01	3.01	3.010	0.000	0

Cusheon Mid Lake Site, Water Quality Data Summary						
Parameter (mg/L unless otherwise stated)	**Sampling periods (sample size)**	**Minimum**	**Maximum**	**Average**	**Standard Error**	**Number < Detection Limits**
Nitrate + Nitrite Dissolved	1970s (36); 1980s (53); 1990s (16); 2000s (83)	<0.002	0.65	0.085	0.203	59
Nitrogen - Nitrite Dissolved	1980 (1); 1990s (8); 2000s (79)	0	0.011	0.003	0.002	28
Nitrogen Kjel:Total	1970s (36); 1980s (53); 1990s (12)	0.12	1.18	0.431	0.186	0
Nitrogen Organic Total	1980 (48)	0.22	0.86	0.439	0.156	0
Nitrogen Total	1970s (21); 1980s (48); 1990s (6); 2000s (82)	0.022	1.7	0.562	0.243	0
ORP (mV)	1980s (7); 2000s (18)	219	357	313.920	55.184	0
Orthophosphate Dissolved	1970s (36); 1980s (50); 1990s (4); 2000s (78)	0	0.254	0.013	0.032	76
pH (pH units)	1970s (37); 1980s (46); 1990s (12); 2000s (96)	6.21	8.6	7.175	0.384	0
pH Rain (pH units)	1986 (1)	7.31	7.31	7.310	0.000	0
Phaeophytin A	1980 (40)	<.0005	<.0005	<.0005	0.000	40
Phosphorus Extractable	2000s (3)	<.01	<.01	<.01	0.000	3
Phosphorus Total	1970s (36); 1980s (53); 1990s (18); 2000s (82)	<0.003	0.435	0.030	53.125	2
Phosphorus Total Dissolved	1970s (21); 1980s (53); 1990s (18); 2000s (82)	<.0026	0.33	0.016	0.039	6
Potassium Dissolved	1970s (4); 1980s (3)	0.4	0.6	0.457	0.079	0
Potassium Extractable	2000s (6)	0.45	0.6	0.508	0.049	0
Potassium S	1980s (1)	0.19	0.19	0.190	0.000	0
Potassium Total	1990's (10); 2000s (13)	0.333	1	0.591	0.199	2
Residue Filterable 1.0µ (Total Dissolved Solids)	1980s (3); 1990s (5); 2000s (2)	70	116	85.800	14.801	0
Residue Fixed Non-filterable	1980 (38)	<1	4	1.342	0.708	5
Residue Non-filterable (suspended solids)	1980s (38); 1990s (5); 2000s (2)	<1	12	3.422	3.026	6
Residue Total	1980s (42); 1990s (12); 2000s (9)	70	106	82.111	7.679	0
ResT:Fx	1980 (39)	34	68	48.513	6.739	0
ResT:Vol (%(W/W))	1985 (1)	34.8	34.8	34.800	0.000	0
ResVolNF	1980 (3)	1	3	1.333	0.577	0
Selenium Extractable	2000s (3)	<.05	<.05	<.05	0.000	3
Selenium Total	1990s (13); 2000s (14)	0	0.063	0.044	0.017	25
Silica Dissolved	1980s (30); 1990s (14); 2000s (25)	5	12.7	8.734	1.824	0
Silica Total	1990s (16); 2000s (10)	2.7	3.88	4.196	0.580	0
Silicon Extractable	2000s (6)	3.957	4.417	4.312	0.177	0
Silver Extractable	2000s (3)	<0.01	<0.01	<0.01	0.000	3
Silver Total	1990s (13); 2000s (14)	0	<0.03	0.014	0.009	26
Sodium Dissolved	1970s (4); 1980s (6); 1990s (5)	4.7	9.3	6.107	1.275	
Sodium Extractable	2000s (6)	5.3	6.283	5.700	0.458	
Sodium S	1986 (1)	5.58	5.58	5.580	0.000	0
Sodium Total	1990s (10); 2000s (13)	5	6.99	5.830	0.534	0
Specific Conductance (µS/cm)	1970s (129); 1980s (39); 1990s (15); 2000s (35)	58	210	92.161	24.933	0
Strontium Extractable	2000s (3)	0.072	0.08	0.077	0.004	0
Strontium Total	1990s (13); 2000s (15)	0.056	0.082	0.068	0.007	0

Cusheon Mid Lake Site, Water Quality Data Summary						
Parameter (mg/L unless otherwise stated)	**Sampling periods (sample size)**	**Minimum**	**Maximum**	**Average**	**Standard Error**	**Number < Detection Limits**
Sulfate:S	1986 (1)	11.6	11.6	11.600	0.000	0
Sulfate Dissolved	1980s (18); 1990s (9); 2000s (59)	<.858	12.8	7.826	3.101	3
Sulfate Total	1997 (2)	9	9	9.000	0.000	0
Sulfur Extractable	2000s (3)	2.88	3.09	3.02	0.118	0
Sulfur Total	1990s (7); 2000s (15)	2.6	3.5	3.063	0.217	0
TanLig.Total	1980 (25)	0.2	1.3	0.712	0.280	0
Tellurium Total	1990s (9); 2000s (3)	<.002	<.005	<.0275	0.014	12
Temperature (^{o}C)	1970s (94); 1980s (114); 1990s (4); 2000s (457)	1.5	27	12.849	5.851	0
Thallium Total	1990s (9); 2000s (5)	0	0.004	0.020	0.014	11
Tin Total	1990s (13); 2000s (15)	0.00001	0.06	0.038	0.022	26
Titanium Extractable	2000s (4)	<.002	0.003	0.002	0.001	1
Titanium Total	1990s (13); 2000s (15)	<.002	0.017	0.004	0.004	14
Turbidity (NTU)	1970s (21); 1980s (39); 1990s (10); 2000s (19)	0.11	15.3	2.733	2.930	0
Uranium Total	2003 (1)	0.000004	0.000004	0.000	0.000	0
Vanadium Extractable	2000s (3)	<.01	<.01	<.01	0.000	3
Vanadium Total	1990s (13); 2000s (15)	0.0003	0.0004	0.007	0.004	26
Zinc Extractable	2000s (4)	<.002	.002	.002	0	3
Zinc Total	1970s (13); 1980s (3); 1990s (13); 2000s (17)	0.0016	0.012	0.005	0.003	31
Zirconium	1990s (9); 2000s (3)	<.003	<.005	<.0035	0.001	12

Table 6. Water Quality Data Summary of Cusheon East Arm Site (EMS# 1100122)

WATER QUALITY DATA SUMMARY OF CUSHEON LAKE, EAST ARM						
Parameter	**Sampling periods (sample size)**	**Minimum**	**Maximum**	**Average**	**Standard Error**	**Number < detection limit**
General						
Alkalinity Total 4.5 (mg/L)	1970s (14)	19.5	27	23.164	2.502	0
Chlorophyll A (mg/L)	1980s (4)	0.0036	0.0058	0.0044	0.001	0
Chlrid:D (MPN)	1970 (1)	5.8	5.8	5.8	0	0
Extinction Depth (m)	1970s (9)	0.762	3.962	2.733	1.260	0
pH (pH units)	1970s (14)	7.1	7.6	7.364	0.206	0
Phaeophytin A (mg/L)	1980s (4)	<.0005	<.0005	<.0005	0	4
Specific Conductance (µS/cm)	1970s (61)	57	290	88.573	41.968	0
Turbidity (NTU)	1970s (6)	0.5	1.9	1.066	0.516	0
Temp (^oC)	1970s (47)	5.3	22.2	14.026	5.741	0
Nutrients (mg/L)						
Ammonia Dissolved						
Boron Dissolved	1970s (1)	<.1	<.1	<.1	0	1
Calcium Dissolved	1970s (6)	7.5	8.6	8	0.434	0
Carbon Total Inorganic	1970s (12)	<1	7	4.25	1.602	1
Carbon Total Organic	1970s (14)	3	11	6.071	1.940	0
Iron Total	1970s (5)	<.1	0.6	0.22	0.217	3
Magnesium Dissolved	1970s (6)	1.9	2.3	2.125	0.140	0
Nitrate + Nitrite Dissolved						
Nitrogen Kjeldahl Total	1970s (14)	0.11	0.59	0.314	0.137	
Nitrate +Nitrite Diss.	1970s (14)	<.02	0.36	0.096	0.114	8
Nitrogen Total	1970s (6)	0.24	0.69	0.415	0.184	0
Oxygen Dissolved	1970s (47)	<.8	12	9.040	2.616	0
Orthophosphate Dissolved	1970s (14)	<.003	0.017	0.0045	0.004	0
Phosphorus Total	1970s (14)	0.008	0.041	0.0185	0.0117	0
Phosphorus Total Dissolved	1970s (6)	0.005	0.024	0.012	0.0076	0
Potassium Dissolved	1970s (1)	0.3	0.3	0.3	0	0
Sodium Dissolved	1970s (1)	4.7	4.7	4.7	0	0
Bacteria						
Coli:Fec (MPN)	1970s (1)	5	5	5	0	0
Coli:Tot (MPN)	1970s (1)	5	5	5	0	0
Metals (mg/L)						
Cadmium Total	1970s (5)	< 0.0005	< 0.0005	< 0.0005	0	5
Copper Total	1970s (5)	<.001	<.001	<.001	0	5
Mercury Total	1970s (3)	<0.00005	<0.00005	<0.00005	0	3
Nickel Total	1970s (5)	<.01	<.01	<.01	0	5
Lead Total	1970s (5)	<.001	<.001	<.001	0	5
Zinc Total	1970s (5)	<.005	<.005	<.005	0	5

Table 7. Ammonia and Bromide Data, for Cusheon Lake Perimeter and Tributary Sites

Ammonia, Dissolved (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	**0.005**	0.005	**0.005**	0.005	**0.005**
05/12/99	0.01	0.035	0.017	0.024	0.014
07/21/99	0.014	**0.005**	**0.005**	**0.005**	**0.005**
09/07/99	0.005	**0.005**	0.006	0.008	0.005
10/13/99	0.196	0.334	0.274	0.238	0.216
11/30/99	0.037	0.009	0.095	0.068	0.007
03/01/00	0.016	**0.005**	0.007	0.01	0.006
06/08/00	0.014	0.008	0.013	0.011	0.009
07/31/00	0.023	**0.005**	**0.005**	**0.005**	**0.005**
06/26/01	0.013			0.012	0.008
07/25/01	0.048	0.014	0.01	0.006	0.008
09/17/01	0.025	0.006	0.005	0.008	0.009
11/15/01		0.015	0.034		0.026
11/29/01	0.023	0.016	0.026	0.038	0.017
11/12/2002	0.016	0.13	0.037	0.035	0.038
1/23/2003		**0.005**			
10/20/2003			**0.014**		
Statistics					
Number	14	15	15	14	15
Minimum	<0.005	<0.005	<0.005	<0.005	<0.005
Maximum	0.196	0.334	0.274	0.238	0.216
Average	0.032	0.040	0.037	0.034	0.025
Standard Error	0.049	0.087	0.070	0.061	0.054

Bromide, Dissolved (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
05/12/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.13**
07/21/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
09/07/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
10/13/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
07/25/01	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
11/29/01	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Statistics					
Number	7	7	7	7	7
Minimum	<0.05	<0.05	<0.05	<0.05	<0.05
Maximum	<0.05	<0.05	<0.05	<0.05	<0.13
Average	<0.05	<0.05	<0.05	<0.05	<.061
Standard Error	0	0	0	0	0.030
Note - Bolded values indicate that the data is preceded by a < symbol, indicating a value "less than" the recorded value					

Table 8. Chloride and Fecal Coliform Data, for Cusheon Lake Perimeter and Tributary.Sites.

Chloride, Dissolved (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	7.3	4.9	6.7	7.5	7.5
05/12/99	7.7	7.8	7.9	7.8	18
07/21/99	8	7.9	8	7.9	8
09/07/99	8.4	8.1	8.2	8.2	8.1
10/13/99	8.6	8.7	8.6	8.5	8.7
07/25/01	10.9	11.1	10.9	10.9	11
11/29/01	9.9	5.3	7.3	10.9	14.8
Statistics					
Number	7	7	7	7	7
Minimum	7.3	4.9	6.7	7.5	7.5
Maximum	10.9	11.1	10.9	10.9	18
Average	8.686	7.686	8.229	8.814	10.871
Standard Error	1.280	2.096	1.331	1.459	4.047
Coliforms, Fecal (CFU/100mL)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	19	1	4	130	21
05/12/99	5		340		4
07/21/99	27	7	6	2	100
09/07/99	**2**	**2**	**2**	4	4
10/13/99	2	**2**	**2**	**2**	2
11/30/99	4	18	2	**2**	18
03/01/00	10	12	18000	2	52
06/08/00	87	2	1	3	**1**
07/31/00	8	1	8	28	3
06/26/01	226			2	3
07/25/01	1	**1**	11	8	1
09/17/01	**1**	**1**	**1**	14	**1**
11/15/01		61	300		500
11/29/01	38	6	125	3	143
11/12/2002	12	54	7	11	21
1/23/2003		**1**			**1**
Statistics:					
Number	14	14	14	13	16
Minimum	<1	<1	<1	<2	<1
Maximum	226	61	18000	130	500
Average	31.571	12.071	1343.500	16.231	54.688
Standard Error	60.500	19.936	4795.444	34.993	125.583
Note 1 - Bolded values indicate that the data is preceded by a < symbol, and indicates a value "less than" the recorded value					

Table 9. True Colour, and Flouride Data for Cusheon Lake Perimeter and Tributary Sites.

Colour, True (Col. unit)					
Date	**Blackburn Ck.**	**Horel Rd.**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
03/31/99	35	12	25	20	20
05/12/99	25	18	18	20	20
07/21/99	20	18	15	15	18
09/07/99	30	25	20	25	30
10/13/99	25	25	25	30	25
11/30/99	40	12.5	20	20	25
03/01/00	25	17.5	25	20	60
06/08/00	45	18.5	18.5	18.5	18.5
07/31/00	35	20	20	20	20
06/26/01	45			18	18
07/25/01	14	14	16	16	14
09/17/01	13	14	13	17.5	13
11/15/01		45	140		175
11/29/01	55	22.5	35	18	65
11/12/2002	80	160	15	15	15
1/23/2003		20	**50**		
Statistics					
Number	14	15	15	14	15
Minimum	13	12	13	15	13
Maximum	80	160	140	30	175
Average	34.786	29.467	30.367	19.500	35.767
Std. Error	17.812	36.980	31.746	3.961	41.569
Flouride, Dissolved (mg/L)					
Date	**Blackburn Ck.**	**Horel Road**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
07/25/01	0.04	0.05	0.04	0.04	0.04
11/29/01	0.06	0.03	0.08	0.04	0.04
Statistics					
Number	2	2	2	2	2
Minimum	0.04	0.03	0.04	0.04	0.04
Maximum	0.06	0.05	0.08	0.04	0.04
Average	0.050	0.040	0.060	0.040	0.040
Std. Error	0.014	0.014	0.028	0.000	0.000
Flouride, Total (mg/L)					
Date	**Blackburn Ck.**	**Horel Road**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
03/31/99	0.03	0.02	0.03	0.03	0.03
05/12/99	0.04	0.03	0.04	0.03	0.02
07/21/99	0.05	**0.01**	0.04	0.04	0.04
09/07/99	0.05	0.05	0.05	0.05	0.05
10/13/99	0.05	0.03	0.03	0.03	0.03
Statistics					
Number	5	5	5	5	5
Minimum	0.03	<0.01	0.03	0.03	0.02
Maximum	0.05	0.05	0.05	0.05	0.05
Average	0.044	0.028	0.038	0.036	0.034
Std. Error	0.009	0.015	0.008	0.009	0.011
Note 1 - Bolded values indicate that the data is preceded by a < symbol, and indicates a value "less than" the recorded value					

Table 10. Nitrate, and Nitrate + Nitrite Data, for Cusheon Lake Perimeter and Tributary Sites.

Nitrate (NO3), Dissolved (mg/L)					
Date	Blackburn Ck.	Horel Rd.	Cusheon Lk. Rd.	South Shore	North Shore
03/31/99	0.288	0.111	0.417	0.409	0.413
05/12/99	0.046	0.094	0.088	0.087	0.595
07/21/99	0.021	**0.002**	**0.002**	**0.002**	**0.002**
09/07/99	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
10/13/99	0.02	0.033	0.019	0.026	0.02
11/30/99	0.522	0.54	0.257	0.251	2.228
03/01/00	0.437	0.408	0.436	0.454	0.369
06/08/00	0.232	0.189	0.137	0.136	0.141
07/31/00	0.089				
06/26/01	0.072			0.043	0.044
07/25/01	**0.002**	**0.002**	**0.007**	**0.002**	**0.002**
09/17/01				**0**	
11/15/01		12.289	0.257		0.098
11/29/01	0.84	0.97	3.96	0.114	1.05
11/12/2002	0.163	1.006	0.027	0.031	0.036
1/23/2003		0.605			
Statistics					
Number	13	13	12	13	13
Minimum	<0.002	<0.002	<0.002	0	<0.002
Maximum	0.84	12.289	3.96	0.454	2.228
Average	0.210	1.250	0.467	0.120	0.385
Std. Error	0.254	3.336	1.111	0.156	0.635
Nitrate + Nitrite, Dissolved (mg/L)					
Date	Blackburn Ck.	Horel Rd.	Cusheon Lk. Rd.	South Shore	North Shore
03/31/99	0.293	0.116	0.422	0.414	0.418
05/12/99	0.051	0.099	0.093	0.092	0.6
07/21/99	0.026	**0.007**	**0.007**	**0.007**	**0.007**
09/07/99	**0.007**	**0.007**	**0.007**	**0.007**	**0.007**
10/13/99	0.025	0.038	0.024	0.031	0.025
11/30/99	0.535	0.549	0.266	0.259	2.24
03/01/00	0.444	0.412	0.443	0.461	0.374
06/08/00	0.234	0.191	0.139	0.138	0.143
07/31/00	0.092	**0.002**	**0.002**	**0.002**	**0.002**
06/26/01	0.074			0.045	0.046
07/25/01	0.007	**0.007**	**0.012**	**0.007**	**0.007**
09/17/01	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
11/15/01		12.3	0.259		0.1
11/29/01	0.845	0.975	3.965	0.119	1.055
11/12/2002	0.169	1.02	0.03	0.035	0.04
1/23/2003		0.61			
10/20/2003			1.89		
Statistics					
Number	14	15	15	14	15
Minimum	<0.002	<0.002	<0.002	<0.002	<0.002
Maximum	0.845	12.3	3.965	0.461	2.24
Average	0.200	1.089	0.504	0.116	0.338
Std. Error	0.252	3.121	1.070	0.154	0.605
Note - Bolded values indicate that the data is preceded by a < symbol.					

Table 11. Nitrite, and Nitrogen Total Data, for Cusheon Lake Perimeter and Tributary Sites.

Nitrite, Dissolved (mg/L)					
Date	**Blackburn Ck.**	**Horel Road**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
03/31/99	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
05/12/99	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
07/21/99	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
09/07/99	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
10/13/99	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
11/30/99	0.013	0.009	0.009	0.008	0.012
03/01/00	0.007	0.004	0.007	0.007	0.005
06/08/00	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
07/31/00	0.003	**0.002**	**0.002**	**0.002**	**0.002**
06/26/01	**0.002**			0.002	**0.002**
07/25/01	0.005	**0.005**	**0.005**	**0.005**	**0.005**
09/17/01	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**
11/15/01		**0.002**	0.002		0.002
11/29/01	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**
11/12/2002	0.006	0.014	0.003	0.004	0.004
1/23/2003		0.005			
10/20/2003			0.009		
Statistics					
Number	14	15	15	14	15
Minimum	<0.002	<0.002	<0.002	<0.002	<0.002
Maximum	0.013	0.014	0.009	0.008	0.012
Average	0.005	0.005	0.005	0.004	0.004
Std. Error	0.003	0.003	0.002	0.002	0.003
Nitrogen, Total (mg/L)					
Date	**Blackburn Ck.**	**Horel Road**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
03/31/99	0.58	0.25	0.66	0.67	0.63
05/12/99	0.31	0.51	0.45	0.59	0.77
07/21/99	0.3	0.33	0.33	0.32	0.3
09/07/99	1.2	1.2	0.93	1.2	0.88
10/13/99	0.73	1.9	0.99	1.2	0.83
11/30/99	0.98	0.82	0.85	1.49	2.94
03/01/00	0.68	0.53	0.72	0.71	0.58
06/08/00	0.6	0.45	0.43	0.44	0.44
07/31/00	0.5	0.38	0.31	0.35	0.37
06/26/01	0.41			0.38	0.38
07/25/01	0.38	0.34	0.35	0.37	0.35
09/17/01	0.37	0.38	**0.02**	0.42	0.38
11/15/01		12.1	0.87		0.76
11/29/01	1.4	1.2	4.3	0.61	1.4
11/12/2002	0.7	2.29	0.41	0.43	0.4
1/23/2003		0.81			
10/20/2003			**2.76**		
Statistics					
Number	14	15	15	14	15
Minimum	0.3	0.25	<0.02	0.32	0.3
Maximum	1.4	12.1	4.3	1.49	2.94
Average	0.653	1.566	0.959	0.656	0.761
Std. Error	0.335	2.976	1.118	0.374	0.670
Note - Bolded values indicate that the data is preceded by a < symbol.					

Table 12. Orthophosphate and pH data, for Cusheon Lake Perimeter and Tributary Sites.

Orthophosphate (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
05/12/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
07/21/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
09/07/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
10/13/99	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
07/25/01	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
11/29/01	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Statistics					
Number	7	7	7	7	7
Minimum	<0.05	<0.05	<0.05	<0.05	<0.05
Maximum	<0.05	<0.05	<0.05	<0.05	<0.05
Average	<0.05	<0.05	<0.05	<0.05	<0.05
Standard Error	0	0	0	0	0
pH (pH units)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	7.36	6.83	7.24	7.15	7.2
05/12/99	7.51	7.51	7.36	7.4	7.32
07/21/99	6.97	7.68	7.68	7.6	7.41
09/07/99	8.82	8.19	8.46	8.46	8.59
10/13/99	7.34	6.91	7.21	7.11	7.14
11/30/99	7.35	7.01	7.51	6.89	7.23
03/01/00	7.72	7.33	7.46	7.38	7.6
06/08/00	7.78	7.53	7.55	7.65	7.66
07/31/00	7.46	7.6	7.73	7.68	7.68
06/26/01	7.72			7.74	7.71
07/25/01	7.67	7.62	7.54	7.57	7.69
09/17/01	7.24	7.82	7.88	7.85	7.79
11/15/01		6.63	6.93		7.07
11/29/01	7.18	6.56	6.87	7.33	6.99
11/12/2002	7.7	7.2	7.5	7.4	7.4
1/23/2003		7			
10/20/2003			7.4		
Statistics					
Number	14	15	15	14	15
Minimum	6.97	6.56	6.87	6.89	6.99
Maximum	8.82	8.19	8.46	8.46	8.59
Average	7.559	7.295	7.488	7.515	7.499
Standard Error	0.435	0.467	0.383	0.380	0.397
Note - Bolded values indicate that the data is preceded by a < symbol, and indicates a value "less than" the recorded value.					

Table 13. Total Dissolved and Total Phosphorus data, Cusheon Lake Perimeter and Tributary Sites

Phosphorus, Total Dissolved (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lake Rd**	**South Shore**	**North Shore**
03/31/99	0.012	0.008	0.011	0.009	0.01
05/12/99	0.008	0.005	0.005	0.004	0.012
07/21/99	0.01	0.006	0.006	0.007	0.006
09/07/99	0.008	0.008	0.007	0.008	0.008
10/13/99	0.042	0.04	0.048	0.043	0.038
11/30/99	0.015	0.012	0.02	0.017	0.014
03/01/00	0.013	0.01	0.012	0.011	0.017
06/08/00	0.015	0.01	0.007	0.009	0.008
07/31/00	0.016	0.014	0.013	0.012	0.012
06/26/01	0.01			0.004	0.004
07/25/01	0.006	0.006	0.006	0.006	0.007
09/17/01	0.007	0.005	0.007	0.006	0.005
11/15/01		0.012	0.067		0.038
11/29/01	0.017	0.006	0.037	0.012	0.016
11/12/2002	0.016	0.027	0.009	0.009	0.009
1/23/2003		0.007			
10/20/2003			**0.026**		
Statistics					
Number	14	15	15	14	15
Minimum	0.006	0.005	0.005	0.004	0.004
Maximum	0.042	0.040	0.067	0.043	0.038
Average	0.014	0.012	0.019	0.011	0.014
Standard Error	0.009	0.010	0.018	0.010	0.011

Phosphorus, Total (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Rd.**	**South Shore**	**North Shore**
03/31/99	0.025	0.012	0.018	0.018	0.017
05/12/99	0.014	0.023	0.017	0.023	0.022
07/21/99	0.018	0.015	0.013	0.017	0.014
09/07/99	0.051	0.057	0.041	0.043	0.036
10/13/99	0.076	0.135	0.094	0.108	0.085
11/30/99	0.024	0.018	0.043	0.089	0.021
03/01/00	0.027	0.023	0.021	0.021	0.036
06/08/00	0.021	0.014	0.013	0.015	0.012
07/31/00	0.027	0.024	0.019	0.017	0.018
06/26/01	0.017			0.01	0.01
07/25/01	0.016	0.012	0.012	0.015	0.012
09/17/01	0.019	0.016	0.014	0.017	0.014
11/15/01		0.022	0.145		0.126
11/29/01	0.044	0.008	0.017	0.02	0.055
11/12/02	0.027	0.095	0.029	0.029	0.021
1/23/2003		0.009			
10/16/2003		0.02			
10/20/2003			**0.041**		
10/21/2003	**0.036**				
10/27/2003			**0.017**		
11/1/2003		**0.011**			
Statistics					
Number	15	17	16	14	15
Minimum	0.014	<0.011	<0.017	0.01	0.01
Maximum	0.076	0.135	0.145	0.108	0.126
Average	0.029	0.030	0.035	0.032	0.033
Standard Error	0.017	0.034	0.037	0.030	0.033

Table 14. Specific Conductance and Sulfate Data for Cusheon Lake Perimeter and Tributary Sites

Specific Conductance (uS/cm)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	98	71	86	86	87
05/12/99	111	91	92	92	93
07/21/99	136	94	95	96	96
09/07/99	98	98	98	98	97
10/13/99	103	107	102	105	104
11/30/99	108	102	105	104	148
03/01/00	107	69	101	98	100
06/08/00	137	105	101	104	104
07/31/00	142	109	110	108	107
06/26/01	135			120	120
07/25/01	121	120	119	121	122
09/17/01	125	125	122	124	124
11/15/01		156	142		101
11/29/01	124	63	169	123	119
11/12/2002	158	78	115	112	115
1/23/2003		67			
10/20/2003			152		
Statistics					
Number	14	15	15	14	15
Minimum	98	63	86	86	87
Maximum	158	156	169	124	148
Average	121.643	97.000	113.933	106.500	109.133
Standard Error	18.299	25.425	23.614	12.101	15.638

Sulfate Dissolved (mg/L)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	8.7	4.6	7.3	7.3	7.3
05/12/99	9.8	7.5	7.6	7.6	5.4
07/21/99	8.9	8	7.9	7.9	7.9
09/07/99	6.9	6.9	6.9	6.9	6.9
10/13/99	6.2	6.3	6.2	6.3	6.2
07/25/01	9.4	9.3	9.4	9.4	9.3
11/29/01	8.4	2.6	17.6	8.8	
Statistics					
Number	7	7	7	7	6
Minimum	6.2	2.6	6.2	6.3	5.4
Maximum	9.8	9.3	17.6	9.4	9.3
Average	8.329	6.457	8.986	7.743	7.167
Standard Error	1.314	2.240	3.925	1.072	1.359

Table 15. Turbidity data for Cusheon Lake Perimeter and Tributary Sites

Turbidity (NTU)					
Date	**Blackburn Creek**	**Horel Road**	**Cusheon Lk. Road**	**South Shore**	**North Shore**
03/31/99	6.1	2.3	1.3	1.3	1.3
05/12/99	1.3	3.2	2.1	5.3	5.1
07/21/99	0.99	0.9	0.72	0.88	0.8
09/07/99	5.5	<u>7.5</u>	5.47	5.7	4.9
10/13/99	1.7	4.6	1.6	3.1	4.2
11/30/99	1.5	2.4	1.1	4.3	3.8
03/01/00	2.8	3.9	0.92	0.97	12
06/08/00	2.38	0.49	0.28	0.54	0.67
07/31/00	1.5	1.1	0.57	0.63	0.58
06/26/01	1.6			0.75	0.71
07/25/01	8.12	0.68	1.03	0.53	0.74
09/17/01	0.52	0.69	0.69	0.93	0.65
11/15/01		3.62	37.3		49.4
11/29/01	6.4	0.84	19.4	0.9	22.5
11/12/2002	3.76	18.5	3.38	8.93	1.06
1/23/2003		1.58			
10/20/2003			9.64		
Statistics					
Number	14	15	15	14	15
Minimum	0.52	0.49	0.28	0.53	0.58
Maximum	8.12	18.5	37.3	8.93	49.4
Average	3.155	3.487	5.700	2.483	7.227
Standard Error	2.410	4.577	10.099	2.613	13.079
Note - underlined item indicates that the raw data had a star beside the original value					

7.0 Appendix 2 Summary Comparing Mid Lake Site Parameters to the Criteria (Table 16)

Table 16. Summary Comparing Cusheon Mid Lake Site (EMS #1100123) Water Quality Parameters to the Criteria.

Summary of Cusheon Mid Lake Site Water Quality Parameters Compared to Water Quality Criteria			
Characteristics	**Sampling periods (sample size)**	**Water Quality Criteria (only values within range of the mid lake data are shown)**	**Comparison of Mid Lake Data to Criteria**
Aluminum Dissolved	1980s (1)	**Drinking / Recreation / Aesthetics**: 0.2 mg/L. **Aquatic Life** (pH >6.5): 0.1 mg/L	Limited data available. Criteria not exceeded.
Aluminum Total	1980s (3); 1990s (13); 2000s (14)	**Wildlife/Livestock/Irrigation:** 5 mg/L	Criteria not exceeded.
Ammonia Dissolved	1970's (1); 1980s (54); 1990s (18); 2000s (80)	**Aquatic Life**: maximum concentration related to pH and temperature.	Criteria not exceeded.
Antimony Total	1990s (13); 2000s (15)	**Drinking**: 6 µg/L proposed interim max.	All values prior to May 15/03 are less than detection limits; uncertain if criteria are met between because noted limits of detection are so high (15-60 µg/L).
Arsenic Total	1980s (1); 1990s (13); 2000s (14)	**Drinking**: 25µg/L interim max. **Aquatic Life:** 5 µg/L	All values prior to May 15/03 are less than detection limits; uncertain if criteria are met between March 1992 and February 2003, because limits of detection are so high (50-60µg/L).
Barium Total	1990s (13); 2000s (14)	**Drinking**: 1mg/L max.	Criteria not exceeded.
Boron Total	1990s (13); 2000s (13)	**Drinking**: 5mg/L max.	Criteria not exceeded.
Cadmium Total	1970s (13); 1990s (13); 2000s (14)	**Drinking**: 5 µg/L max. **Aquatic Life**: 0.017µg/L	Aquatic Life Criteria were exceeded in October 74 at surface (0.8 µg/L) and mid depth (1.1 µg/L), representing 5% of samples. Other than this data and data collected in May ‘03, all other values are less than detection limits which range from 0.5-6 µg/L. Drinking Water Criteria are thus met.
Carbon Total Organic	1970s (36); 1980s (39); 1990s (4); 2000s (44)	**Drinking** (with chlorination): 4 mg/L from source water.	Criteria exceeded in 91% of samples (refers to values throughout water column, specific depth relating to source not specified).
Chloride Dissolved	1970s (4); 1980s (6); 1990s (15); 2000s (14)	**Drinking**: less than or equal to 250mg/L (aesthetic objective).	Criteria not exceeded.
Chlorophyll A	1980s (34); 2000s (49)	**Drinking**: 2-2.5 µg/L (summer average).	All summer averages exceed criteria.
Chromium Total	1990s (13); 2000s (16)	**Drinking**: 50 µg/L max.	Criteria not exceeded.
Cobalt Total	1990s (13); 2000s (16)	**Irrigation:** 50 µg/L	Criteria not exceeded

Summary of Cusheon Mid Lake Site Water Quality Parameters Compared to Water Quality Criteria			
Characteristics	**Sampling periods (sample size)**	**Water Quality Criteria (only values within range of the mid lake data are shown)**	**Comparison of Mid Lake Data to Criteria**
Coliform Total (MPN)	1976 (2), 1980 (2)	**Drinking**:10 total coliforms/100mL	Limited sampling data available. Exceeded criteria on June 17/80.
Coliforms Fecal (CFU/100mL)	1999 (1), 2000s (5)	**Drinking:** ranges from 0/100 mL. no treatment to 100/100 mL. partial treatment.	Exceeded drinking water criteria (no treatment) on July 31/80, Nov. 12/02.
Color True (Col.unit)	1980s (34); 1990s (15), 2000s (21)	**Drinking** (aesthetics): less than or equal to 15 TCU.	54% of values exceed criteria.
Copper Total	1970s (13); 1980s (3); 1990s (13); 2000s (14)	**Drinking:** 500 µg/L. **Aquatic Life**: 4.65 µg/L (based on lowest recorded water hardness value of 28.2 mg/L). **Aquatic Life** (CCME Criteria) 2-4 µg/L.	Drinking water criteria not exceeded. Lower range of CCME Aquatic criteria exceeded on Mar.'92 (4 µg/L. Aquatic Life criteria (related to water hardness) not exceeded where detectable values are provided. Uncertain if criteria were met between March 1997 and February 2003, because limits of detection were so high (5-7 µg/L).
Dissolved Oxygen	1970s (91); 1980s (105); 1990s (4); 2000s (367)	**Aquatic Life (water column, instantaneous minimum):** All life stages other than buried embryo/alevin): 5 mg/L. Buried embryo/alevin life stages: 9 mg/L.	Criteria for all life stages (other than buried embryo/alevin) not met in 60% samples. Criteria minimum for buried embryo/alevin life stages not met in 45% of samples.
Extinction Depth (m)	1970s (25); 1980s (10); 1990s (1); 2000s (36)	**Recreation**: 1.2 m minimum	4% of samples did not meet minimum criteria (June '76, Oct. '80, Sept. '00).
Fluoride Total	1990s (6)	**Drinking/Wildlife**: 1.5 mg/L max. **Aquatic Life**: 0.2 mg/L max. (under worse case with water hardness < 50 mg/L.)	Limited data available. Criteria not exceeded.
Hardness Total Dissolved	1980s (15)	**Drinking**: 80-100 mg/L acceptable; > 200 mg/L poor; > 500 mg/L unacceptable.	Limited data available. Criteria not exceeded.
Iron Total	1970s (13); 1980s (3); 1990s (13); 2000s (13)	**Drinking** (aesthetics) and **Aquatic Life**:Less than or equal to 0.3 mg/L .	Criteria exceeded in 11% of samples (3 times in 1974, 1 time in 1976, and 1 time in 1997).
Lead Total	1970s (13); 1980s (3); 1990s (13); 2000s (15)	**Drinking:** 50 µg/L max. **Aquatic Life:** 18 µg/L worse case maximum (based on lowest water hardness of 30 mg/L). **Aquatic Life** (CCME criteria) 1-7 µg/L	1 value exceeds all Criteria (Jan 31/01 at 70 µg/L). Lower limit of Aquatic CCME criteria exceeded on Aug '76 (3 samples @ 3µg/L), and Feb. '80 (2 samples @ 2 µg/L, and 1 sample @ 1 µg/L). Uncertain if criteria were met between 1992 and 2003 because limits of detection are so high (20-70 µg/L).
Lithium Total	2000s (2)	**Irrigation:** 2500 µg/L	Criteria not exceeded.

Summary of Cusheon Mid Lake Site Water Quality Parameters Compared to Water Quality Criteria			
Characteristics	**Sampling periods (sample size)**	**Water Quality Criteria (only values within range of the mid lake data are shown)**	**Comparison of Mid Lake Data to Criteria**
Magnesium Dissolved	1970s (21); 1980s (18)	**Drinking** (taste threshold): 100 mg/L (sensitive people).	Criteria not exceeded.
Manganese Total	1980s (3); 1990s (13); 2000s (15)	**Drinking** (aesthetic): less than or equal to 50 µg/L. **Aquatic Life**: 0.8 mg/L max. (worse case with total hardness at 25 mg/L). **Irrigation**: 200 µg/L	17% of samples exceed drinking water criteria. Aquatic life criteria not exceeded. Irrigation Criteria exceeded once in May 03 (237 µg/L).
Mercury Total	1970s (10)	**Drinking**: 1 µg/L max. **Aquatics**: 0.1µg/L	Limited data available. Criteria not exceeded.
Molybdenum Total	1990s (13); 2000s (14)	**Drinking** (untreated): 0.25 mg/L. **Aquatic Life:** 2 mg/L. **Aquatic Life** (CCME): 73 µg/L. **Wildlife/Irrigation**: 0.05 mg/L	Criteria not exceeded.
Nickel Total	1970s (13); 1980s (3); 1990s (13); 2000s (14)	**Aquatic Life:** 25-150 µg/L.	Criteria not exceeded
Nitrate Dissolved	1980 (1); 1990s (6); 2000s (19)	**Drinking/Recreation**: 10 mg/L max. **Aquatic Life:** 200 mg/L max.	Criteria not exceeded.
Nitrite Dissolved	1980 (1); 1990s (8); 2000s (79)	**Drinking**: 1 mg/L max. **Aquatic Life**: 0.06 mg/L max. when chloride is less than 2 mg/L.	Criteria not exceeded.
pH (pH units)	1970s (37); 1980s (46); 1990s (12); 2000s (96)	**Drinking & Recreation** (aesthetics): pH 6.5-8.5. **Recreation (buffering capacity) / Irrigation**: pH 5-9. **Aquatic Life**: pH 6.5-9.0	Values met the drinking/recreation (aesthetic) criteria in all but 3% of samples (reading < pH 6.5 in Aug.'02, Sept. '02, Mar. '03; reading > pH 8.5 in Aug. ''76, Sept. '00). Aquatic life criteria met in all but the 3 samples (1.6%) < pH 6.5. Criteria met for recreation buffering capacity & irrigation.
Phosphorus Total	1970s (36); 1980s (53); 1990s (18); 2000s (82)	**Drinking & Recreation**: 10 µg/L max.; **Aquatic Life:** 5-15µg/L.	Values at spring overturn indicated that drinking and recreation criteria were exceeded in 76% of the years sampled, and aquatic life criteria were exceeded in 35% of samples.
Residue Filterable 1.0u (Total Dissolved Solids)	1980s (3); 1990s (5); 2000s (2)	**Drinking** (aesthetics): 500 mg/L max.	Criteria not exceeded.

Summary of Cusheon Mid Lake Site Water Quality Parameters Compared to Water Quality Criteria			
Characteristics	**Sampling periods (sample size)**	**Water Quality Criteria (only values within range of the mid lake data are shown)**	**Comparison of Mid Lake Data to Criteria**
Selenium Total	1990s (13); 2000s (14)	**Drinking/ Irrigation**: 10 µg/L max. **Aquatic Life**: 2.0 µg/L. **Wildlife**: 4.0 µg/L.	Criteria exceeded on Jan 01 (63.33 µg/L average). Other than this value and a value of 0 µg/L on May 15/03, all remaining values are reported as being below the detection limits. It is uncertain if criteria were met because noted limits of detection are so high (30-60 µg/L)
Silver Total	1990s (13); 2000s (14)	**Aquatic Life**: 0.1 µg/L (hardness is less than 100 mg/L)	All values prior to May 15/03 are less than detection limits; uncertain if criteria are met because noted limits of detection are so high (10-30µg/L).
Sodium Total	1990s (10); 2000s (13)	**Drinking**: Less than or equal to 200mg/L (aesthetics), 20 mg/L alert for people on sodium restricted diets.	Criteria not exceeded.
Specific Conductance	1970s (129); 1980s (39); 1990s (15); 2000s (35)	**Drinking**: 700 µs/cm max.	Criteria not exceeded.
Sulfate Total	1997 (2)	**Drinking** (aesthetics): 500 mg/L max. **Aquatic Life**: 50 mg/L alert level, 100 mg/L max.	Criteria not exceeded.
Temperature	1970s (94); 1980s (114); 1990s (4); 2000s (457)	**Drinking** (aesthetics): 15 ^{o}C max. **Recreation & Aesthetics**: 30^{o}C max.	The drinking water criteria was exceeded in 35% of samples (this result is not specific to depth of intake). Recreation and aesthetic criteria were not exceeded.
Thallium Total	1990s (9); 2000s (5)	**Aquatic Life:** 0.8 µg/L	Criteria was exceeded once in Mar. '92 (4 µg/L). All other values prior to May 15/03, were less than detection limits. It is uncertain if criteria were met because noted limits of detection are so high (3 µg/L).
Turbidity	1970s (21); 1980s (39); 1990s (10); 2000s (19)	**Drinking (aesthetics)**: raw-untreated = 1 NTU max.; raw-treated = 5 NTU. **Recreation**: 50 NTU max.	The drinking criteria was exceeded in 67% (for untreated) and 19% (for treated) of samples. The recreation criteria was not exceeded.
Uranium Total	2003 (1)	**Drinking**: 100 µg/L max. **Drinking (**CCME): 20 (interim maximum)	Limited sampling. The criteria were not exceeded.
Vanadium Total	1990s (13); 2000s (15)	**Irrigation/Livestock:** 100 µg/L	Criteria not exceeded

Summary of Cusheon Mid Lake Site Water Quality Parameters Compared to Water Quality Criteria			
Characteristics	**Sampling periods (sample size)**	**Water Quality Criteria (only values within range of the mid lake data are shown)**	**Comparison of Mid Lake Data to Criteria**
Zinc Total	1970s (13); 1980s (3); 1990s (13); 2000s (17)	**Drinking & Recreation** (aesthetics): Less than or equal to 5000 µg/L. **Aquatic Life**: 33 µg/L (based on water hardness less than 90 mg/L).	Criteria not exceeded.

8.0 Appendix 3 Water Quality Graphs (Figures 4-24)

Figure 6. Total Phosphorus at the Cusheon Mid Lake Site. A. During Spring Overturn, as Water Column Averages; B. As Monthly Averages with Depth; C. As Annual Low Flow (June to October) Averages

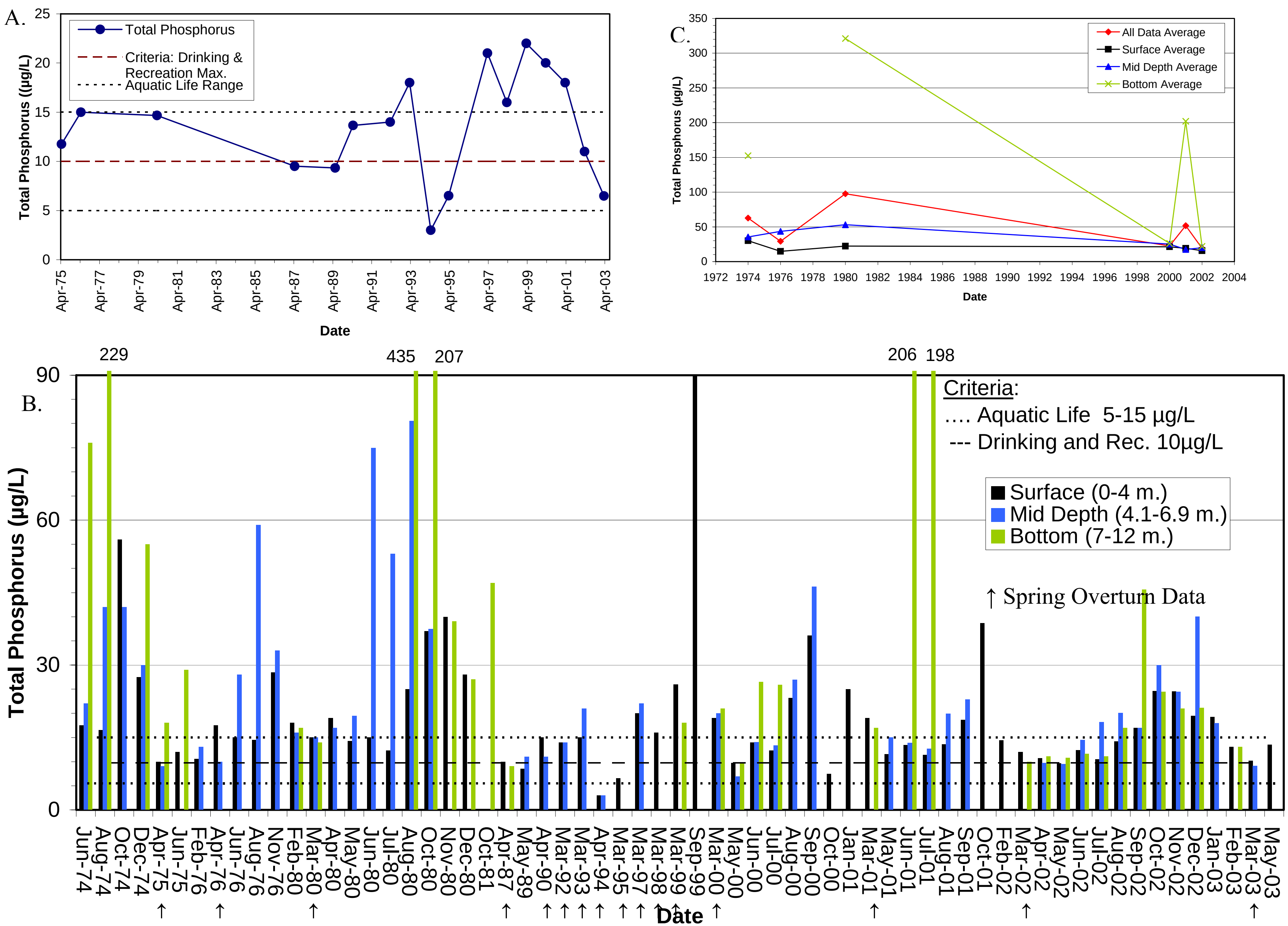


Figure 7. Monthly Average Temperature with Depth, at the Cusheon Mid Lake Site

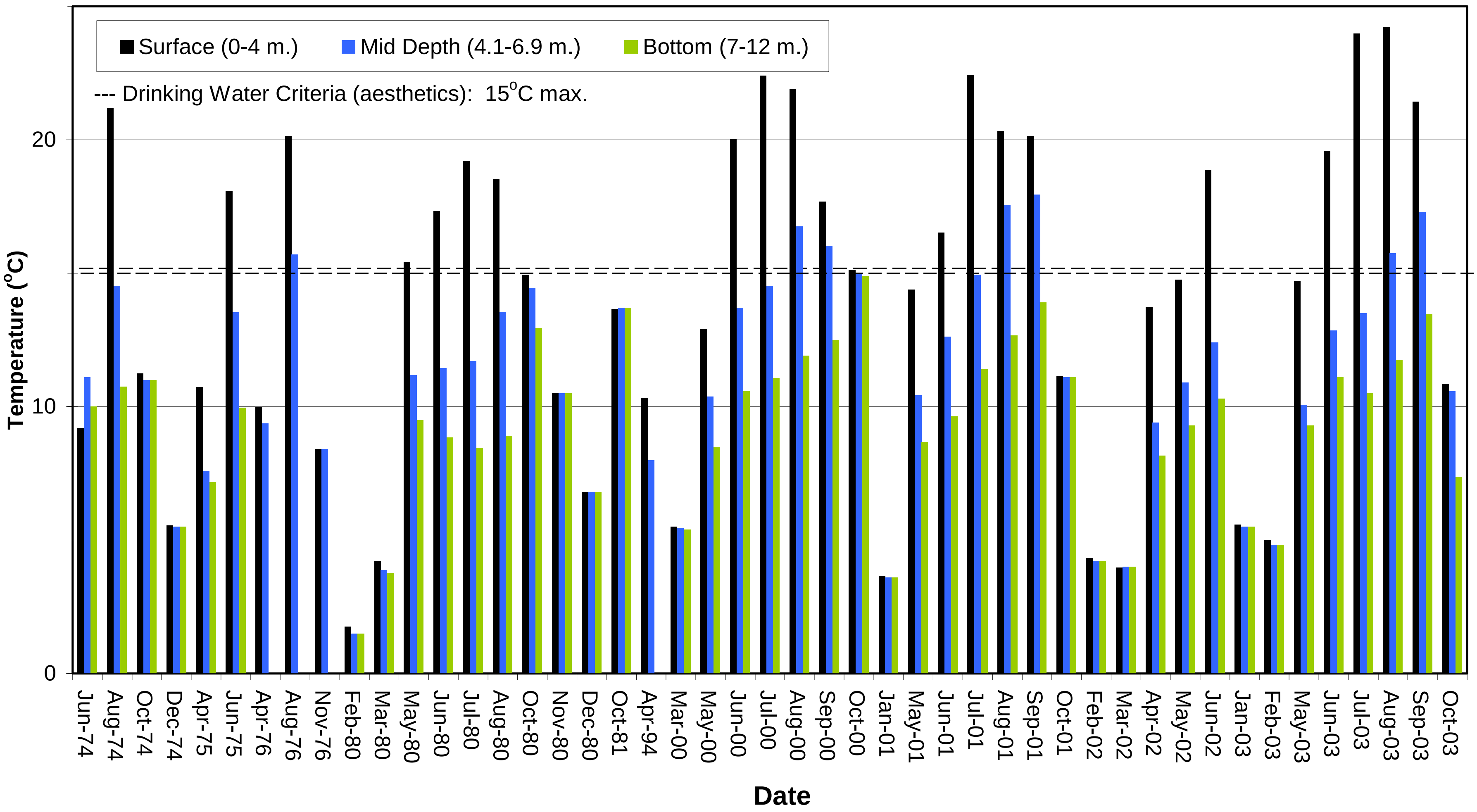


Figure 8. Monthly Average Dissolved Oxygen With Depth, at the Cusheon Mid Lake Site

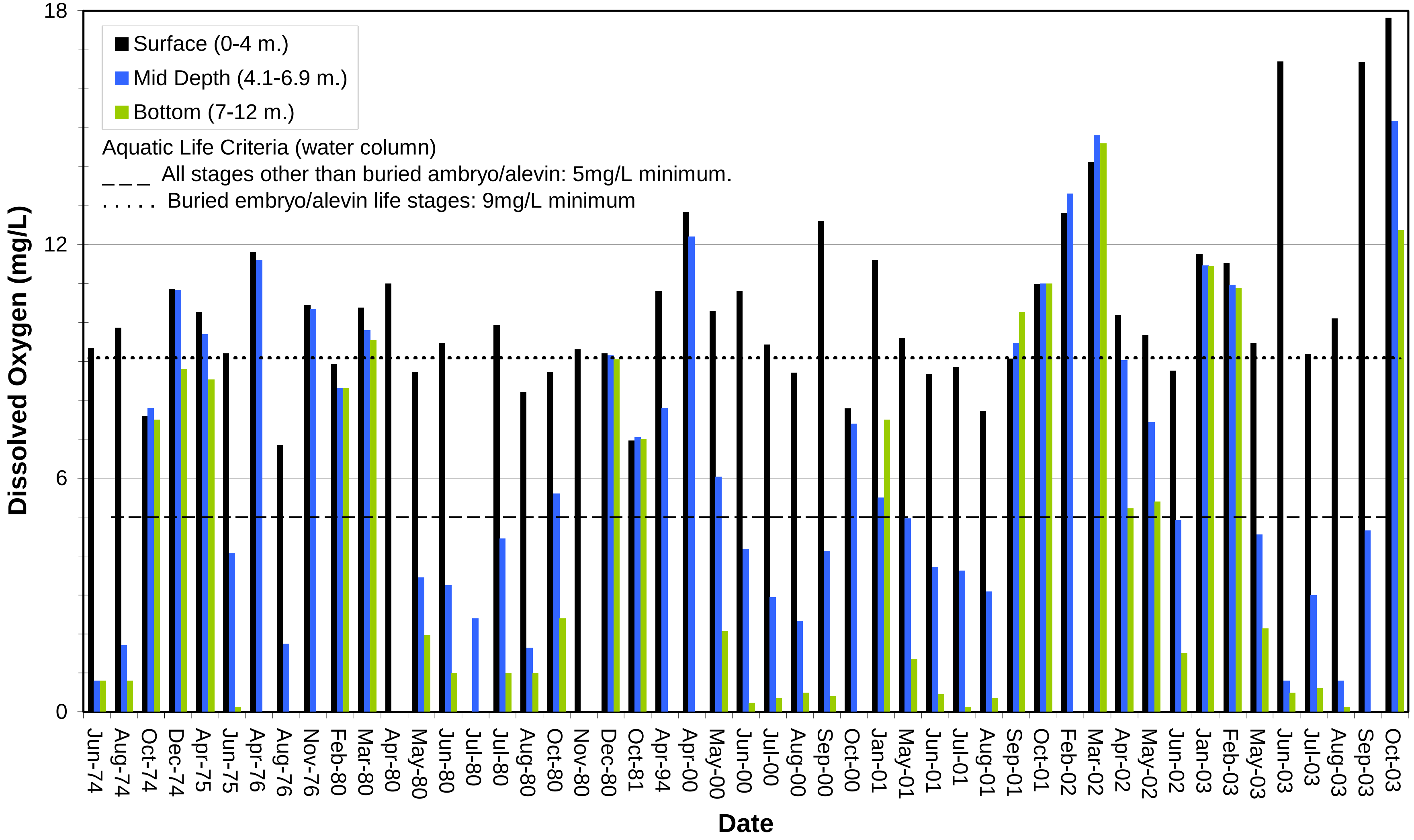
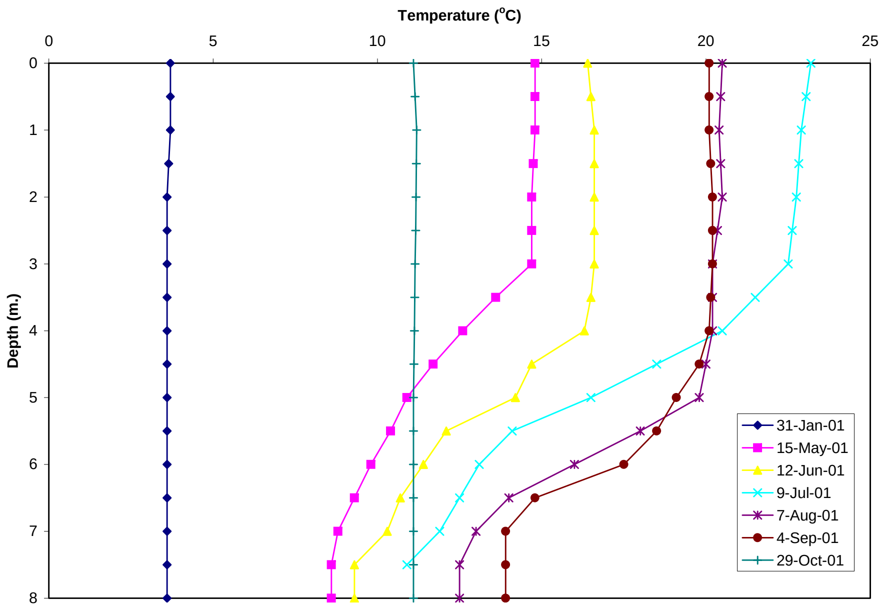


Figure 9. Temperature and Dissolved Oxygen Profiles for 2001, at the Cusheon Mid Lake Site



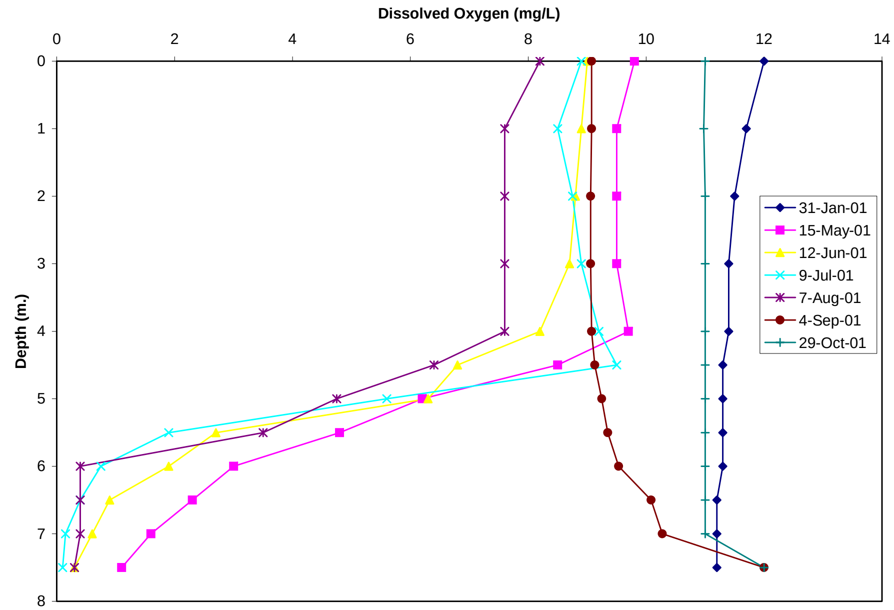


Figure 10. Monthly Total Organic Carbon, at the Cusheon Mid Lake Site

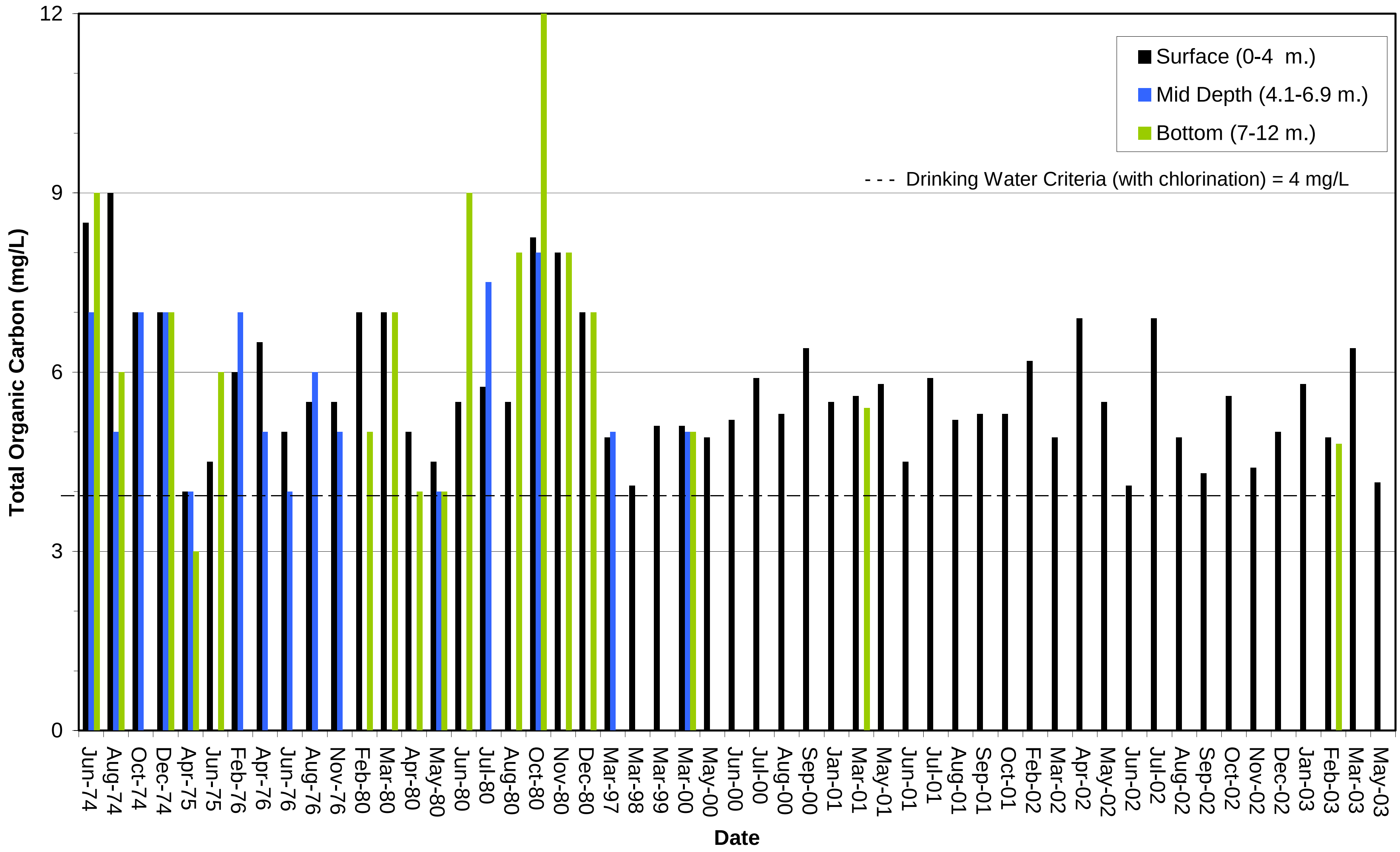


Figure 11. Dissolved Chloride, with Depth at the Cusheon Mid Lake Site

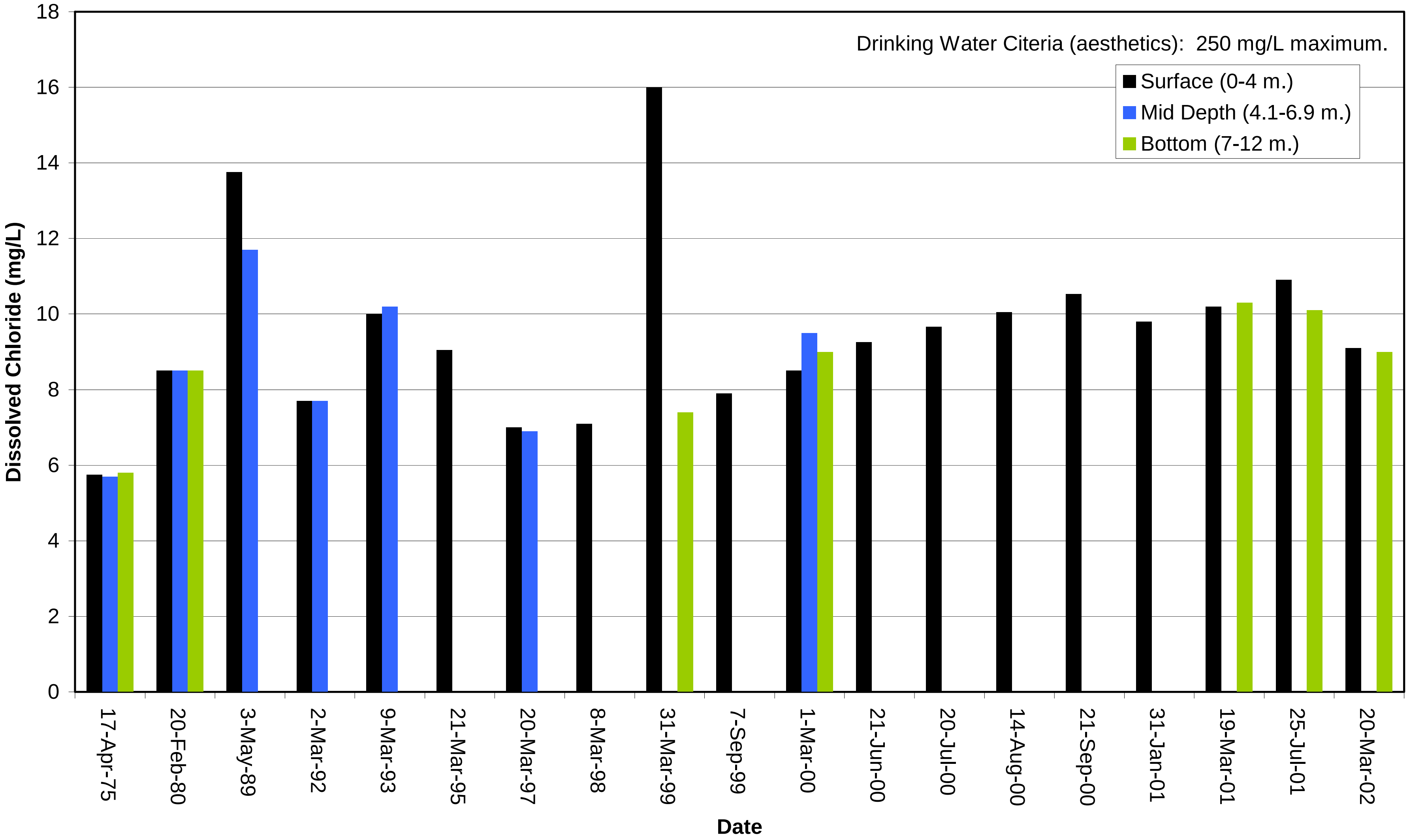


Figure 12. Chlorophyll a with Depth at the Cusheon Mid Lake Site

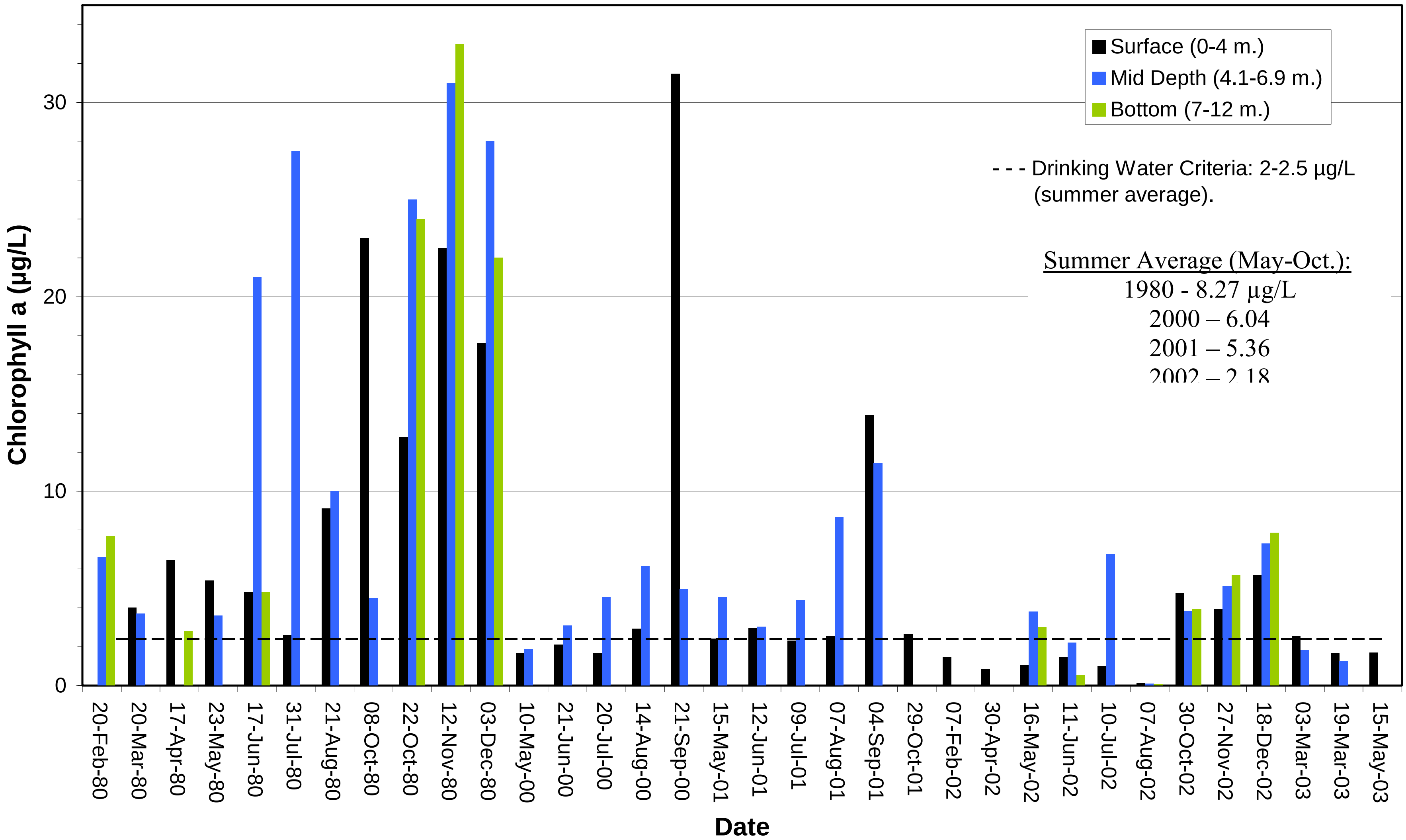


Figure 13. Colour, True with Depth at the Cusheon Mid Lake Site

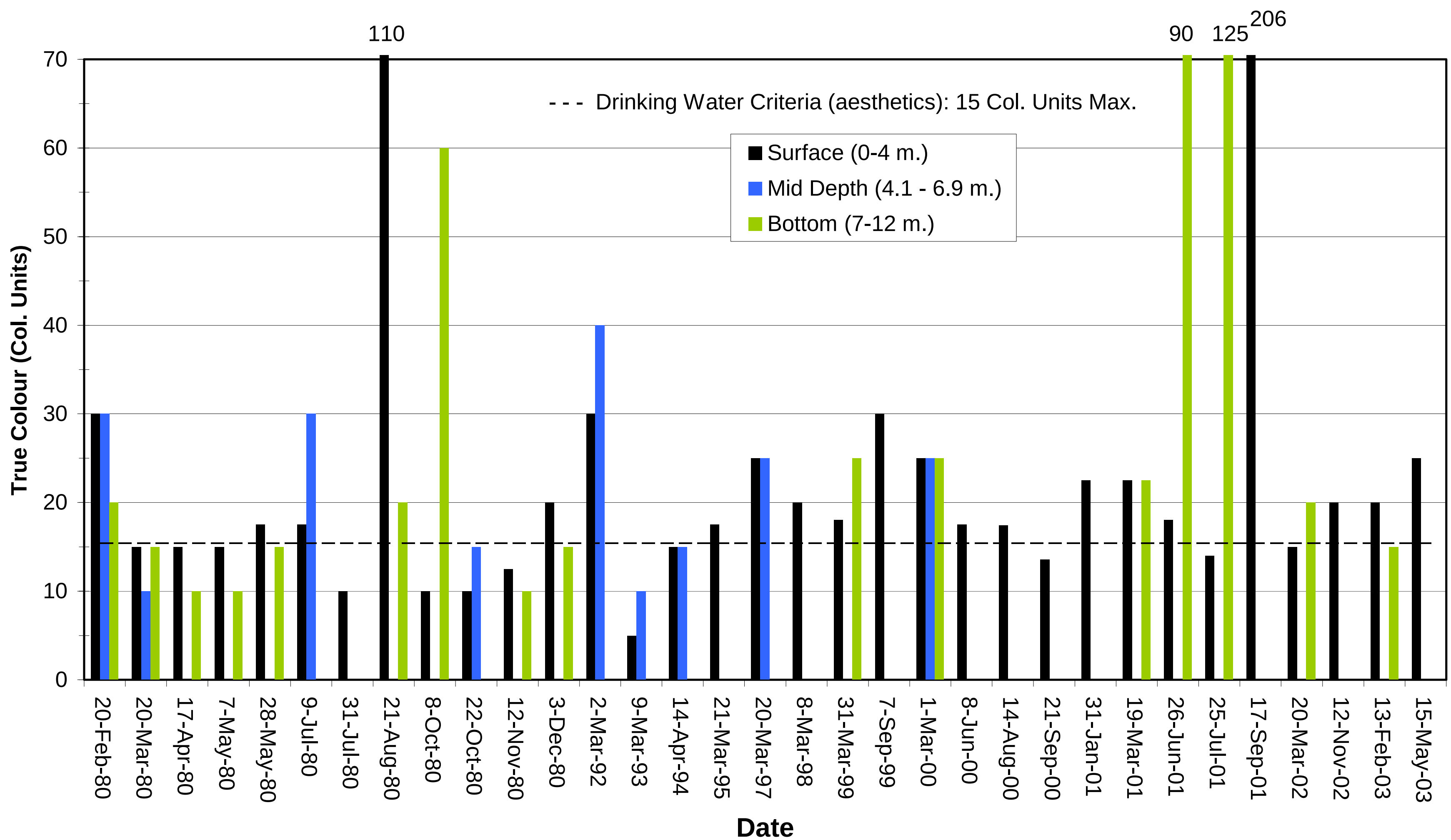


Figure 14. Monthly Average Extinction (Secchi) Depth at the Cusheon Mid Lake Site

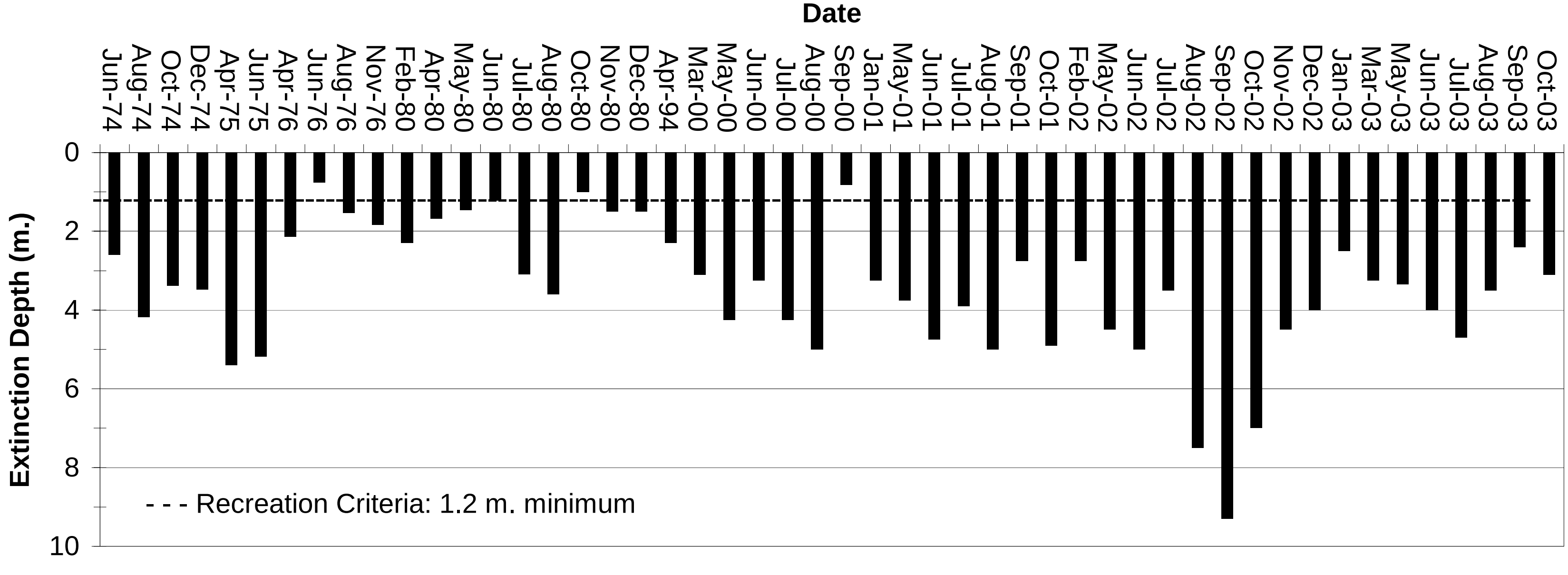


Figure 15. Total Manganese with Depth at the Cusheon Mid Lake Site

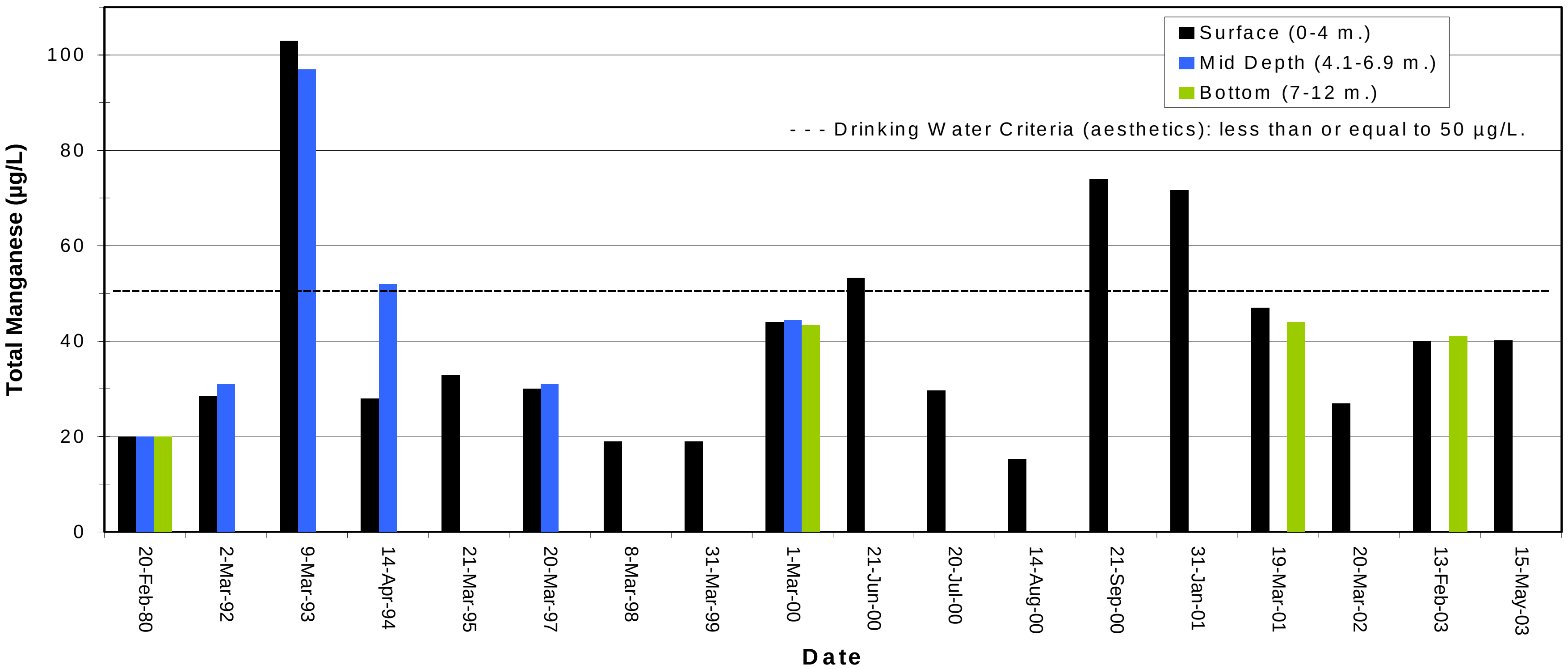
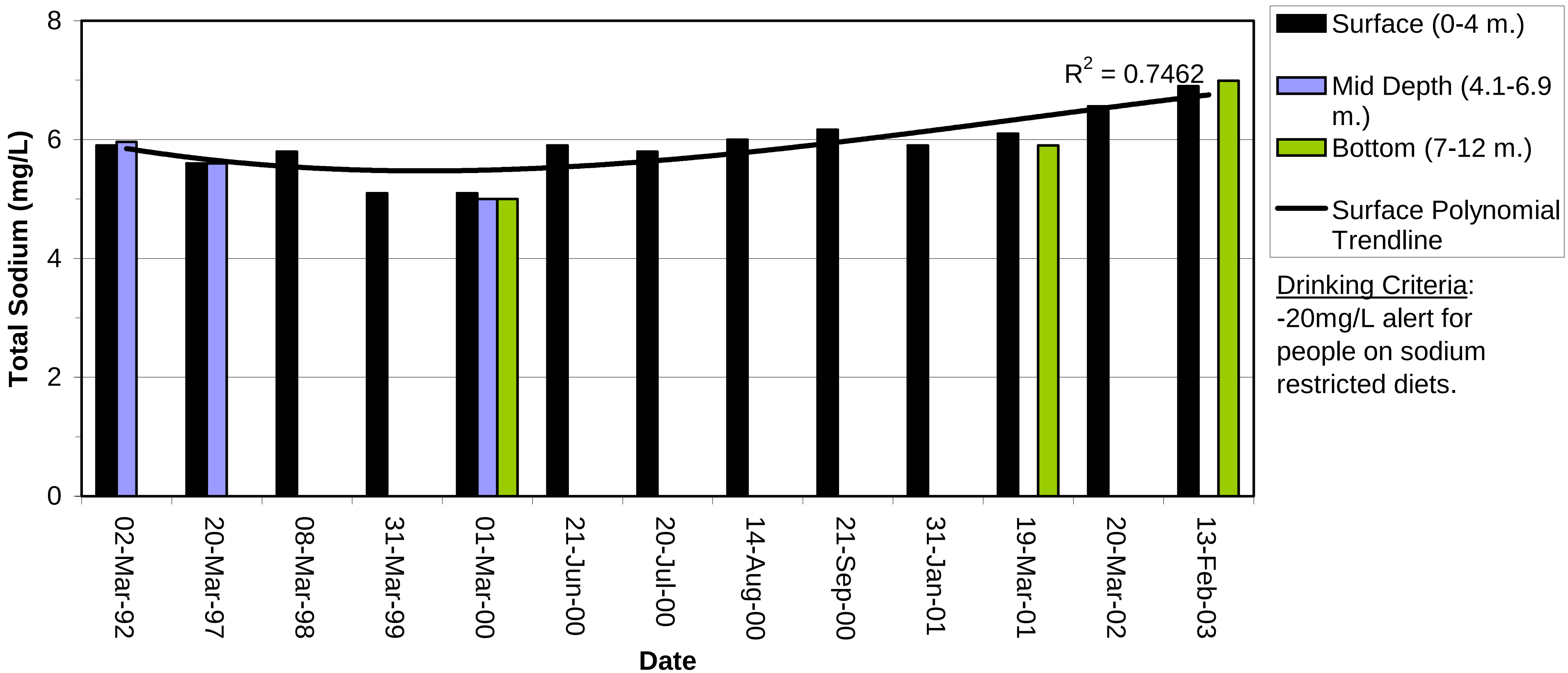
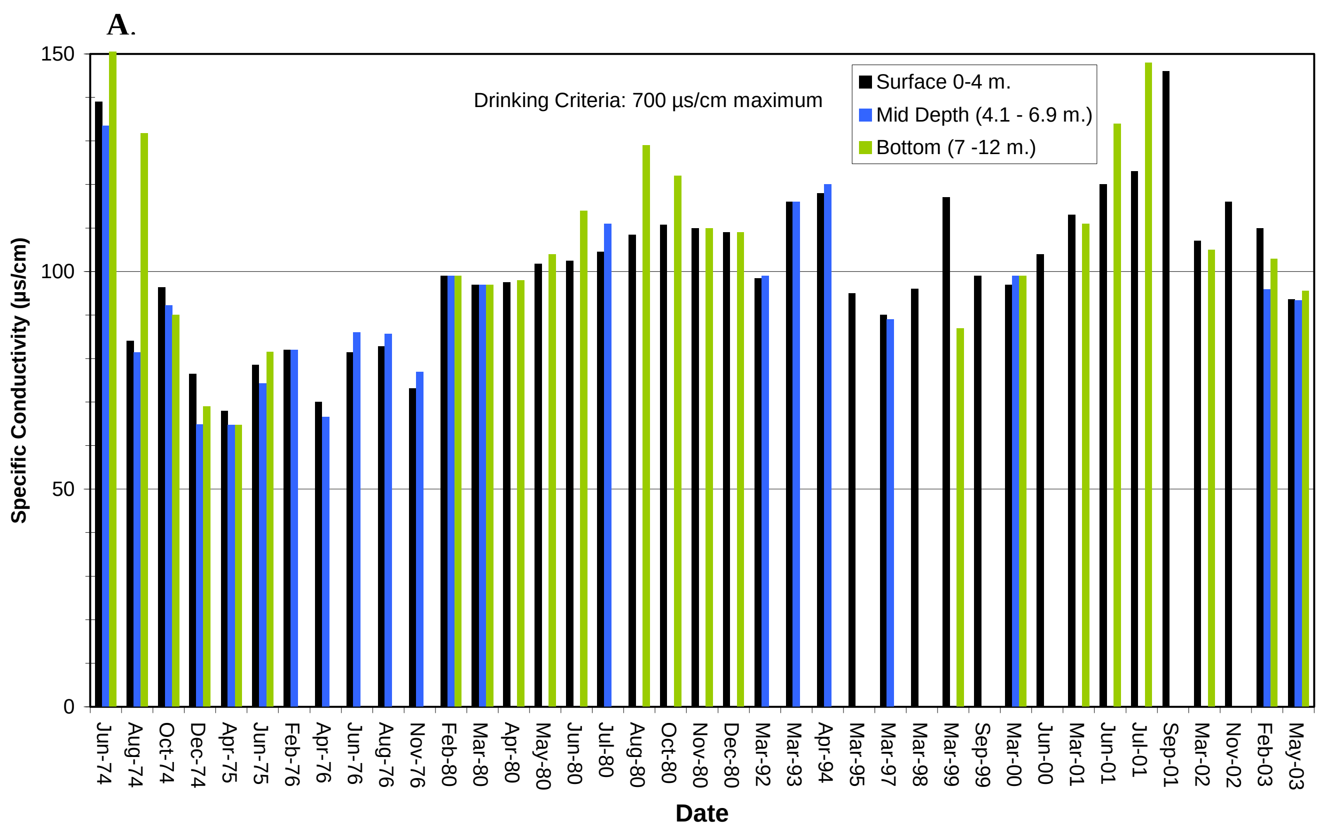


Figure 16. Total Sodium with Depth at the Cusheon Mid Lake Site



Drinking Criteria:
-20mg/L alert for people on sodium restricted diets.

Figure 17. Specific Conductivity at the Cusheon Mid Lake Site Portrayed as A. Sampled Values With Depth, and B. Column Averages During the Summer



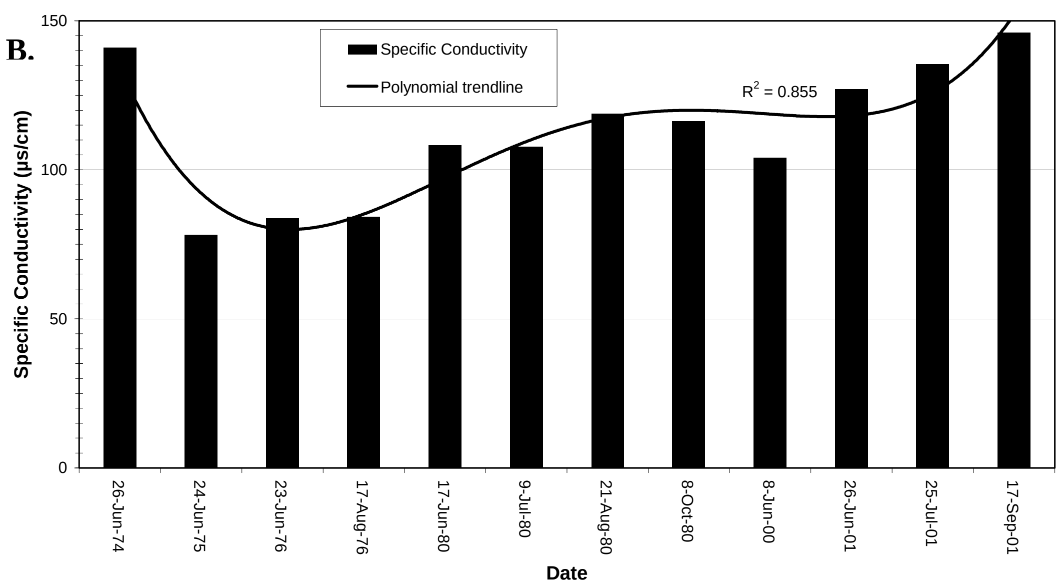


Figure 18. Monthly Average Turbidity, with Depth at the Cusheon Mid Lake Site

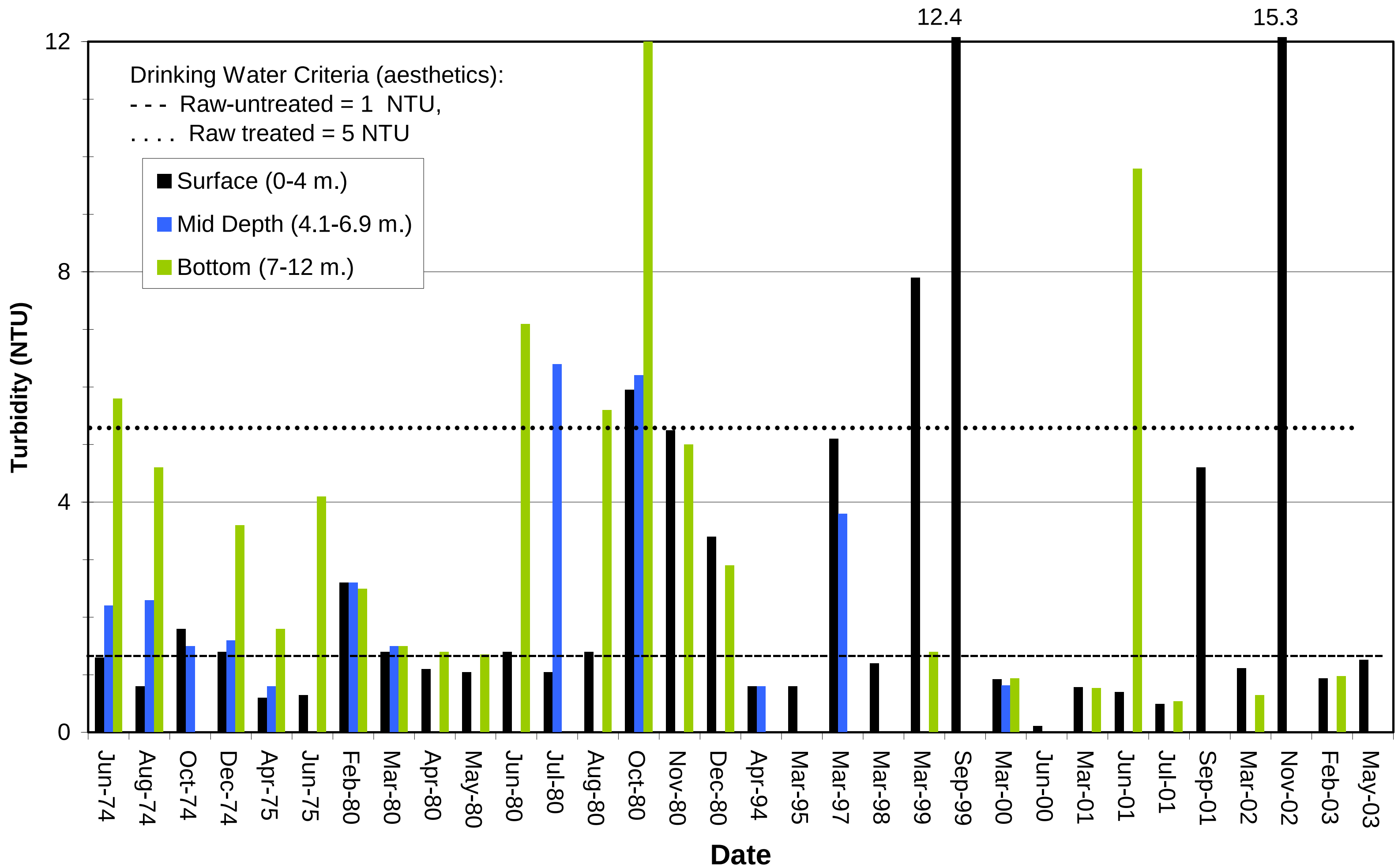


Figure 19. Total Nitrogen:Total Phosphorus Ratio, For The Cusheon Mid Lake Site As Monthly and Water Column Averages

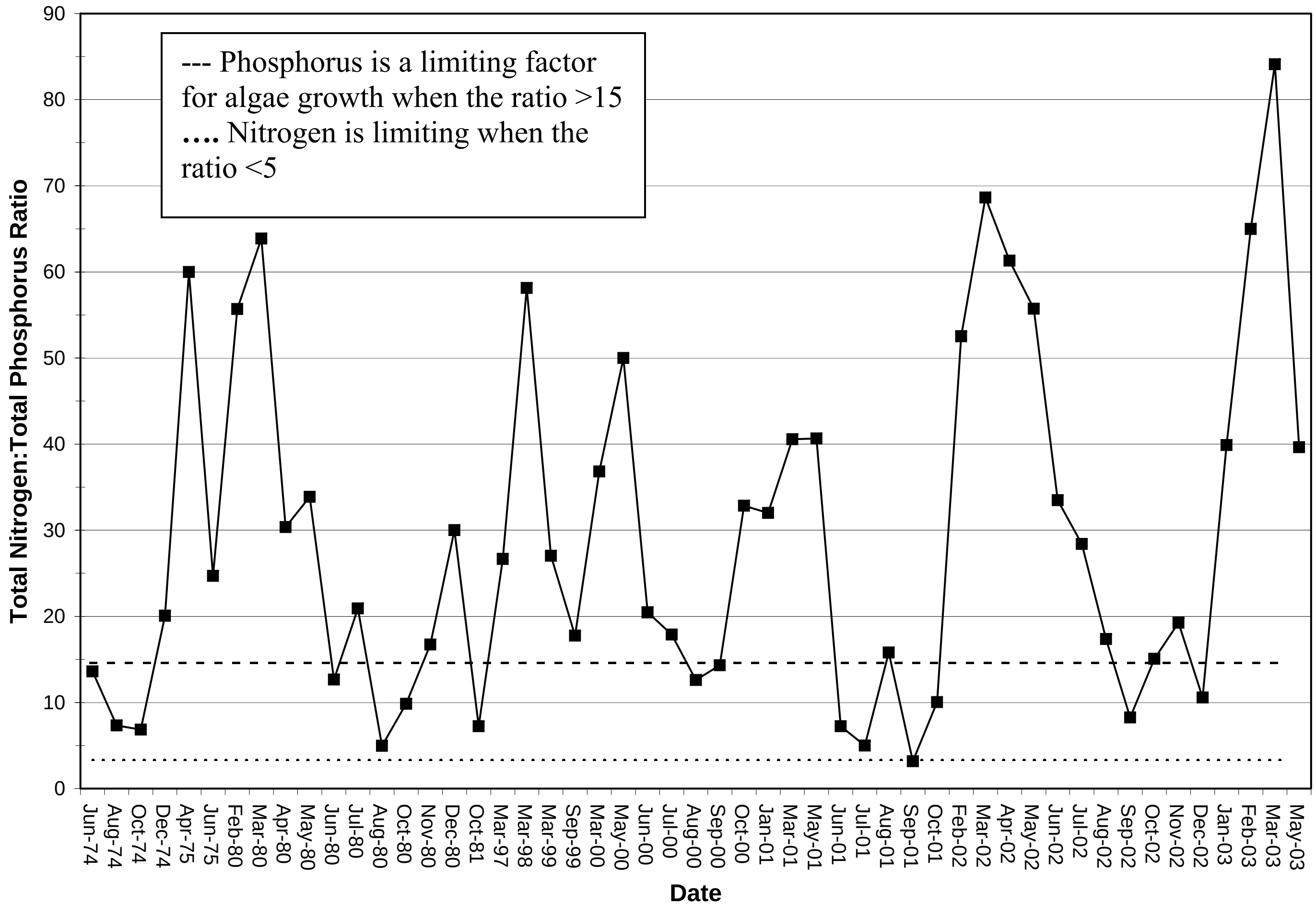


Figure 20. Total Phosphorus Influences on Cusheon Lake from the Perimeter and Tributary Sites

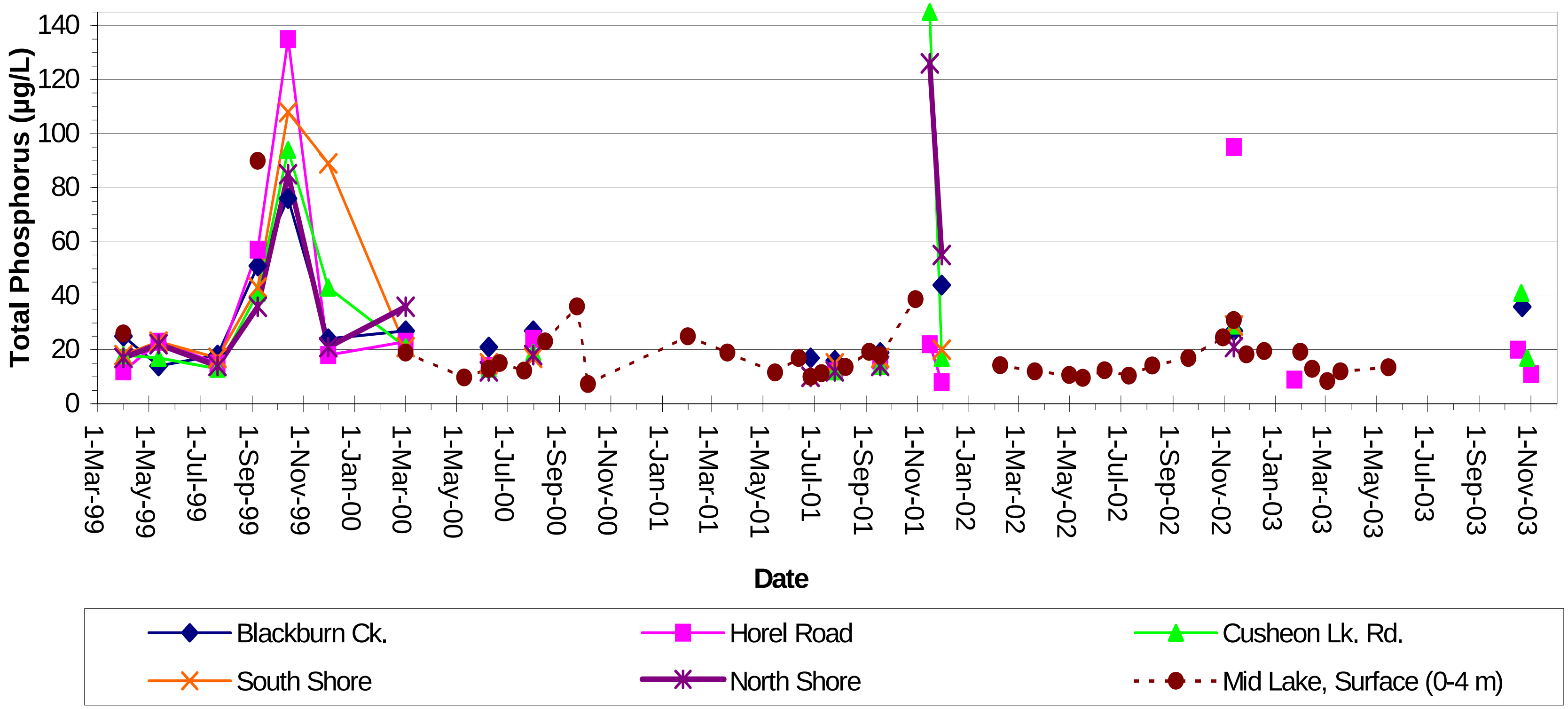


Figure 21. Dissolved Nitrate + Nitrite Influences on the Mid Lake Site From the Perimeter and Tributary Sites

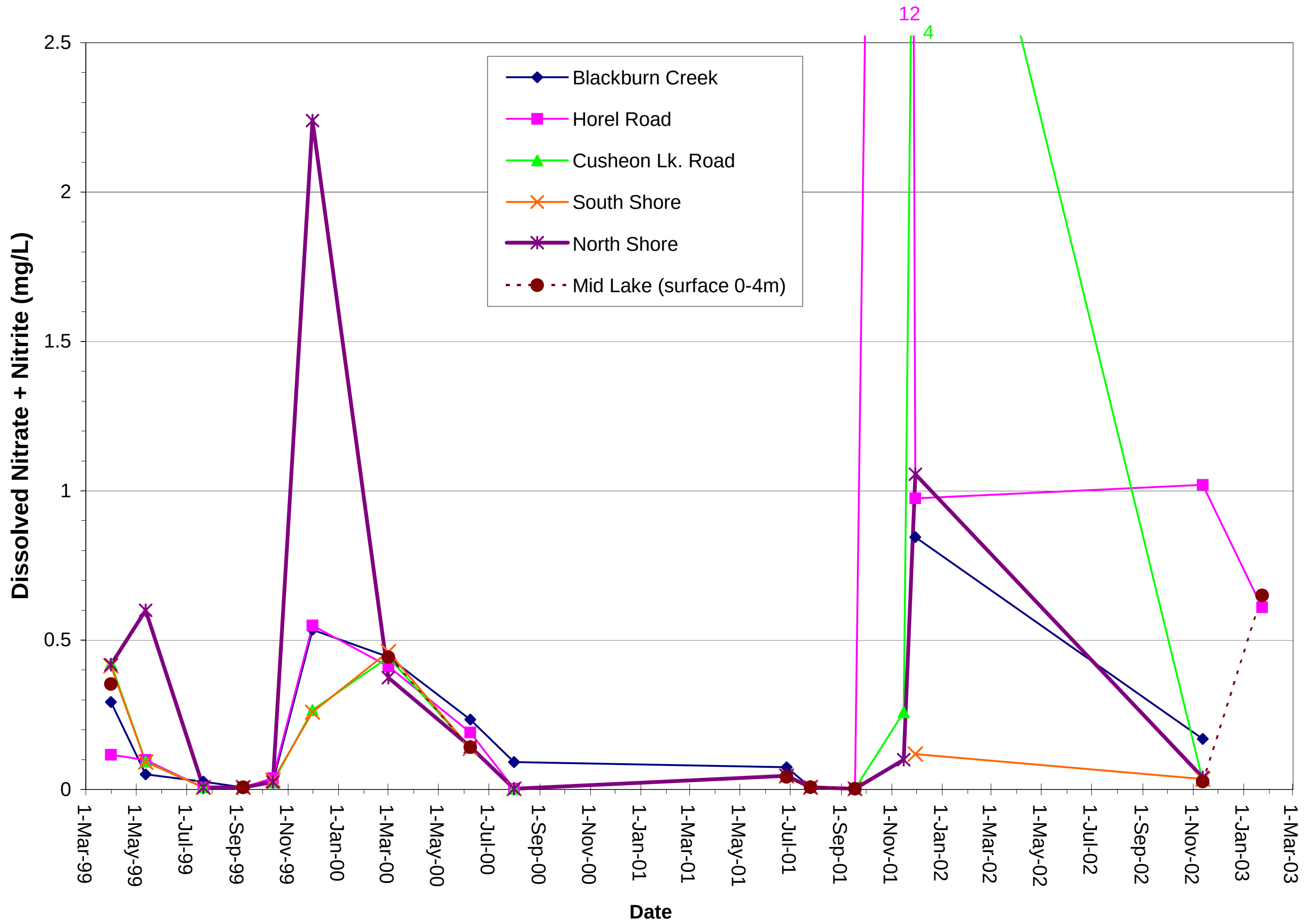


Figure 22. Average Dissolved Nitrate + Nitrite with Depth at the Mid Lake Site

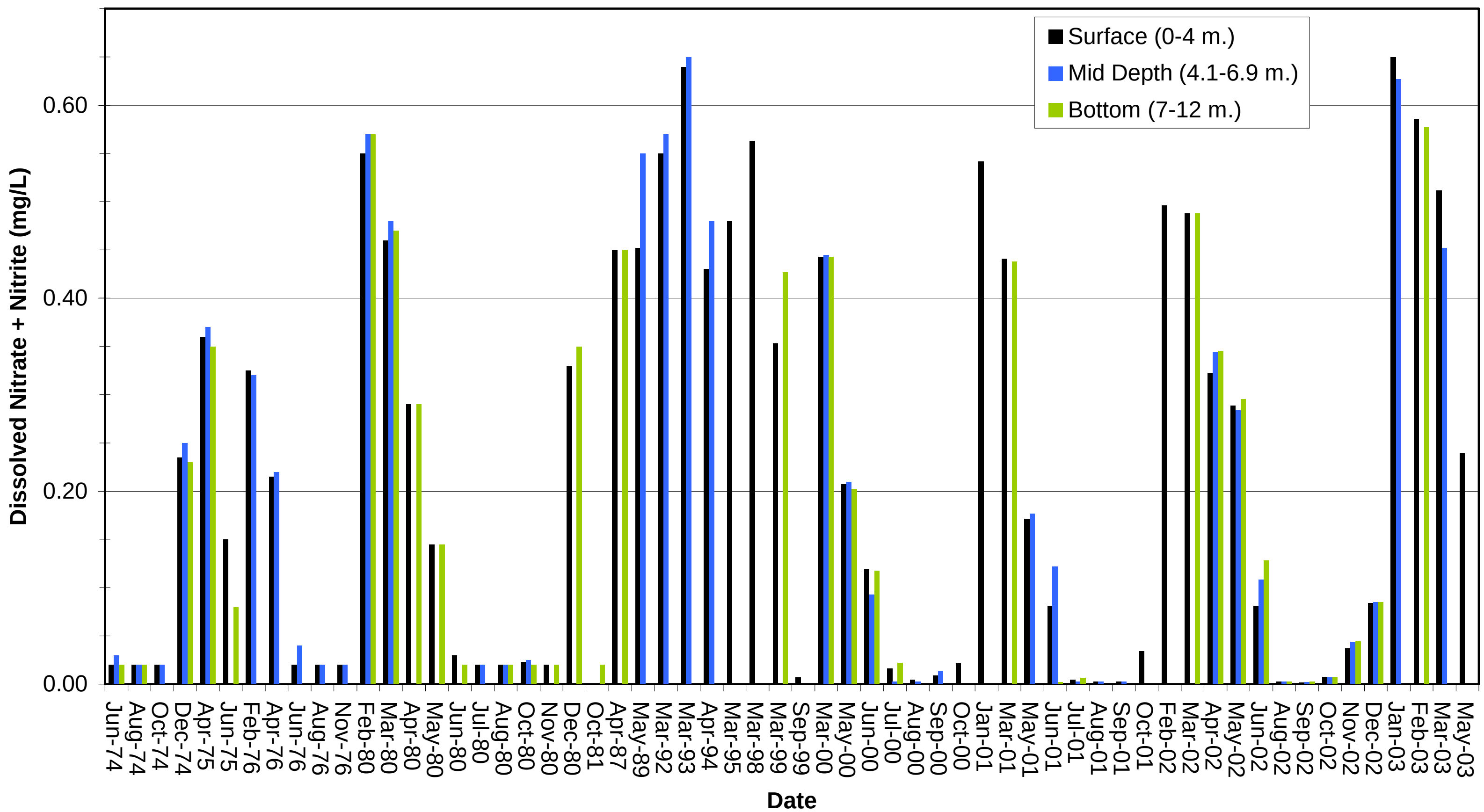


Figure 23. Turbidity Influences on the Cusheon Mid Lake Site From the Perimeter and Tributary Sites

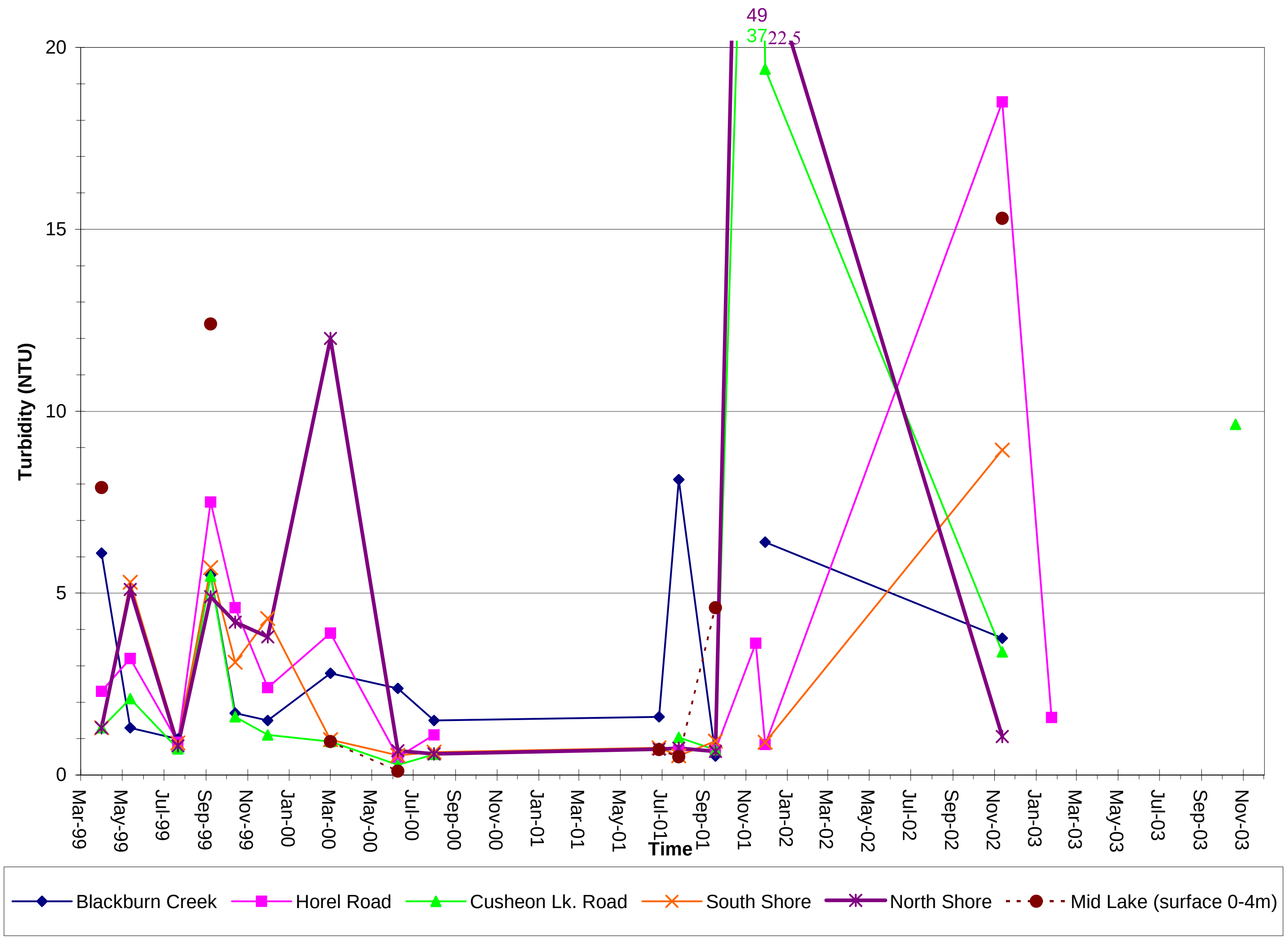


Figure 24. Fecal Coliform Contributions to Cusheon Lake From the Perimeter and Tributary Sites