FRASER RIVER ACTION PLAN

Water Quality, Lake Sensitivity Ratings, And Septic Seepage Surveys Of Six Lakes In The Bridge Creek Basin

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Water Quality, Lake Sensitivity Ratings, and Septic Seepage Surveys of Six Lakes in the Bridge Creek Basin

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Ministry of Environment, Lands and Parks
Williams Lake, B.C.

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ABSTRACT

Six lakes in the Bridge Creek Basin, considered by Ministry of Environment, Lands & Parks (MELP) to be high priority for water quality assessment (Bridge, Deka, Horse, Otter, Sheridan, and Sulphurous), were sampled at spring overturn in 1996. This data was compared to data from the early 1980s collected by the Cariboo Regional District (CRD) and other agencies.

An analysis of the data concluded that only Horse Lake appeared to have increased phosphorus levels and therefore is suggested to have undergone a change in water quality. The analysis of historical data suggests that the early 1980's data provides only an indication of baseline conditions, however adequate baseline for future reference will require data to be collected in at least 1997 and 1998 at spring overturn. Three years data collection with quality assurance built into sampling programs is considered by MELP to be a minimum to adequately reflect baseline conditions.

The CRD lake sensitivity ratings were updated for each lake by reviewing the primary factors that contribute to lake trophic status and sensitivity. It was found that overall water quality has not been impaired in any substantive way over the last 13-15 years, for any of the six lakes. This conclusion is supported by the relatively clear water found in the lakes. The sensitivity of Horse Lake has been upgraded from moderate to high.

A fluorometer survey was conducted on each of the six lakes to address the concern about the potential for septic systems to affect water quality. These surveys did not indicate significant sewage contamination from residences that would suggest the need for futher study, following a protocol developed by MELP. The fluorometer surveys, combined with establishing the number of seasonal versus permanent residences has provided a baseline for future reference concerning potential residential sewage impacts.

ACKNOWLEDGMENTS

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1.0 INTRODUCTION

The Bridge Creek watershed lies in the Fraser River Plateau area, and has a gently rolling topography with steeper slopes in the eastern headwaters. 100 Mile House, the largest urban centre in the basin, has recorded ranges in temperature from minus 46 ^{o}C to plus 36 ^{o}C and has a mean annual precipitation of 442 mm (Atmospheric Environment Service; 1970-95 unpublished data). The southeastern portion of the watershed includes numerous large lakes such as Deka, Sheridan, Bridge and Sulphurous, and is drained in a westerly direction by Bridge Creek. Bridge Creek, which flows through Horse Lake, joins with Little Bridge Creek at 100 Mile House, and then flows northeastward to its confluence with Buffalo Creek and eventually Canim Lake. Buffalo Creek drains such lakes as Drewry, Edwards and Buffalo (Petch and Zirnhelt, 1996).

The watershed is a popular recreation area containing many interconnected lakes and is under significant human pressure in the way of logging, lakefront residential development and recreational pursuits. Effective integrated management of future watershed development is essential to the preservation of water quality. Management needs, with recommendations to prevent water quality degradation in the Bridge Creek Basin, were outlined in a study by the Ministry of Environment, Lands and Parks (MELP) and Environment Canada, entitled Landuse and Water Quality Management in the Bridge Creek Basin (Hart, 1995). One recommendation was to:

> "monitor water quality to evaluate trophic status and sensitivity of the more developed lakes including Horse, Sulphurous, Deka, Bridge, and Sheridan Lakes"

The Bridge Creek Watershed Lake Monitoring Program was established by MELP to address the above recommendation made by Hart (1995); specifically to identify and prioritize lakes for monitoring and assessment, and update lake sensitivity ratings. A report by Petch and Zirnhelt (1996) prioritized the lakes for further monitoring and assessment, with six lakes being ranked high priority: Bridge, Deka, Horse, Otter, Sheridan and Sulphurous Lakes (Figure 1).

The six high priority lakes were sampled by MELP at spring overturn in 1996 as recommended by Petch and Zirnhelt (1996). Spring overturn was chosen because at that time most lakes are the same temperature top to bottom and are circulating freely, providing the best opportunity for a representative sample. Samples were also taken in the winter of 1996, through the ice. During the summer of 1996, the six high priority lakes were surveyed by MELP with a fluorometer, designed to detect septic inflows from lakeshore residences.

The objectives of this report are to:

1) summarize all available water quality data on the six lakes,
2) compare 1996 water quality data with data collected in the early 1980s by the Cariboo Regional District and other agencies.
3) report on the findings of the fluorometer surveys of septic seepage into the six lakes and,
4) evaluate the trophic status and sensitivity to water quality degradation of the six lakes, and update the Cariboo Regional District Lake Evaluation Summaries for these lakes.

2.0 METHODS

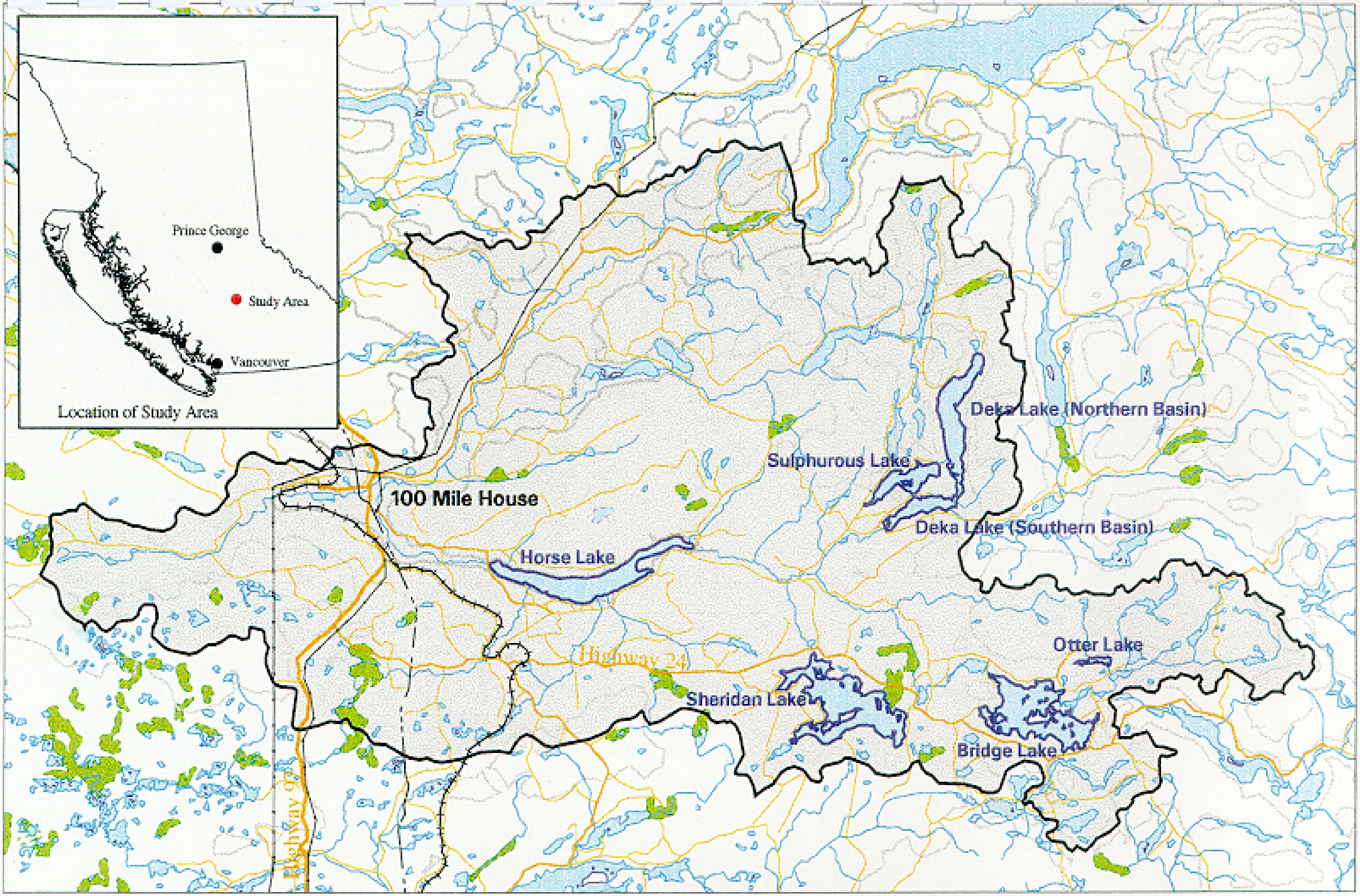
Water Quality Data

Until the mid 1980s water samples collected by MELP were composites, using a 15 m tygon tube (1" diameter). Samples taken by consultants to the Cariboo Regional District (CRD) and the Aquatic Studies Branch (ASB) were likely surface samples. From the mid 1980s on, MELP samples were taken at multiple depths using a Kemmerer sampler, and these are presented as an average for the site. An Orion Model 840 dissolved oxygen(DO) meter was used to take DO/Temperature profiles in 1996. In the early 1980's, a Yellow Springs Instrument Co. Model 54 DO/Temperature meter was used. A Hydrolab Corporation Datasonde 3 measuring dissolved oxygen, turbidity, temperature, conductivity, pH and depth was used in 1996 to support the findings of laboratory analyses. Hydrolab data is presented in Appendix III. DO and temperature profiles were taken in the winter to determine potential hypolimnetic oxygen deficits, in the spring to verify the occurrence of overturn, and in the summer to show stratification and hypolimnetic oxygen levels.

Water quality data collected in 1996 was used to update 1983 Cariboo Regional District (CRD) lake sensitivity ratings as described in Section 3.1. Refer to the CRD's Lake Management Strategy For Lake Shoreland Development (CRD, 1983) for further information on how the Lake Evaluation Summary ratings were developed.

Laboratory Analysis

With the exception of CRD samples in 1982, all water chemistry and taxonomic samples were analyzed at MELP Environmental Laboratories or Zenon Laboratories prior to 1996. Commencing in 1996, water chemistry samples were analyzed at Pacific Environmental Centre Laboratories, and taxonomic samples were analyzed at Fraser Environmental Laboratories.



Scale 1:300 000 - Échelle 1/300 000

Kilometres 5 0 5 10 15 20 25 Kilomètres

Produced by Stacy Meech
Ministry of Environment, Lands & Parks

Figure 1. High Priority Lakes of the Bridge Creek Basin

Bacteriology samples were analyzed by JR Laboratories.

Septic Surveys

The Turner Designs Ltd. model 10-AU-005 Field Fluorometer was used in conjunction with secondary sampling methods (as described in 5.3.1.6) to indicate septic leachate presence in shoreline areas (Petch, 1996). Data is presented from 1996 fluorometer surveys.

Quality Assurance/Quality Control (QA/QC)

The data from the early 1980s did not have any QA/QC samples, however in 1996, blanks of deionized water were submitted with samples, as well as deionized samples from the Kemmerer multi-depth sampler. Duplicate samples were taken from 0.5 m to assess sampling/laboratory precision. Also, on occasion, MELP staff submit blind spiked samples and blanks to the laboratories to evaluate method performance. QA/QC is reported and discussed in Appendix IV and Table 1 provides a summary.

3.0 RESULTS AND DISCUSSION

3.1 Study Parameters

There are a number of parameters that affect water quality. These are described in detail in the subsections below, and applied to the evaluation of the individual lakes in Sections 3.2 to 3.7. Some of the following discussion is taken from a report prepared by Urban Systems Ltd. (CRD, 1983).

3.1.1 Morphometric/Watershed Characteristics

Within the Bridge Creek basin there are many lakes, each of which exhibit unique characteristics that influence water quality.

Lake mean depth is given special consideration. As the mean depth of a lake increases in relation to its volume, the capacity to assimilate nutrients such as phosphorus (P), without suffering a loss in water quality, increases. Lake depths with corresponding nutrient assimilation capabilities are shown in Table 2. The table is subjective in nature and is meant only to illustrate the effects of lake depth on nutrient assimilation capabilities of a lake (CRD, 1983).

Table 1. Quality Assurance Summary

Sampling Site (Date: 96/05/22)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Bridge Lake @ North End (E222871)	Colour / True		(Rel.U.)	< 5	< 5	7	5
	Conductivity		(uS/cm)	2	2	219	219
	Nitrogen	Ammonia	(mg/L)	0.005	0.009	0.014	0.006
		Nitrite	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Nitrite + Nitrate	(mg/L)	0.004	< 0.002	<0.002	< 0.002
		Total	(mg/L)	0.07	0.06	0.48	0.5
	pH		(Rel. U.)	5.41	5.31	8.16	8.26
	Phosphorus	Orthophosphate	(mg/L)	< 0.002	< 0.002	0.002	0.002
		Total	(mg/L)	0.002	0.003	0.022	0.022
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.016	0.016
	Residue	Filterable	(mg/L)	< 10	< 10	140	120
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	<0.2	5.7	5.7
	Turbidity		(FTU)	< 0.05	0.1	0.3	0.3

Sampling Site (Date: 96/05/23)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Deka Lake @ Deepest Pt (E222866)	Colour / True		(Rel.U.)	< 5	< 5	5	5
	Conductivity		(uS/cm)	2	2	180	181
	Nitrogen	Ammonia	(mg/L)	0.004	0.002	0.008	0.006
		Nitrite	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Nitrite + Nitrate	(mg/L)	< 0.002	< 0.002	0.007	< 0.002
		Total	(mg/L)	0.02	< 0.02	0.29	0.24
	pH		(Rel. U.)	5.34	5.34	8.23	8.23
	Phosphorus	Orthophosphate	(mg/L)	< 0.002	< 0.002	0.004	0.004
		Total	(mg/L)	< 0.002	< 0.002	0.015	0.015
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.008	0.008
	Residue	Filterable	(mg/L)	< 10	10	110	100
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	< 0.2	1.5	1.5
	Turbidity		(FTU)	0.06	0.08	0.33	0.32

Sampling Site (Date: 96/05/01)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Horse Lake @ Deepest Pt (0603100)	Colour / True		(Rel.U.)	< 5	< 5	7.5	7.5
	Conductivity		(uS/cm)	< 2	3	288	287
	Nitrogen	Ammonia	(mg/L)	< 0.002	< 0.002	0.011	0.014
		Nitrite	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Nitrite + Nitrate	(mg/L)	< 0.002	< 0.002	0.013	0.006
		Total	(mg/L)	< 0.02	< 0.02	0.43	0.36
	pH		(Rel. U.)	5.48	5.89	8.1	8.11
	Phosphorus	Orthophosphate	(mg/L)	< 0.002	< 0.002	0.006	0.006
		Total	(mg/L)	< 0.002	< 0.002	0.034	0.036
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.015	0.016
	Residue	Filterable	(mg/L)	< 10	< 10	190	180
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	< 0.2	9.8	9.6
	Turbidity		(FTU)	< 0.05	0.08	0.88	0.75

Sampling Site (Date: 96/05/28)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Otter Lake @ Deep End (0803012)	Colour / True		(Rel.U.)	< 5	< 5	45	45
	Conductivity		(uS/cm)	2	2	144	145
	Nitrogen	Ammonia	(mg/L)	< 0.002	< 0.002	0.011	0.02
		Nitrite	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Nitrite + Nitrate	(mg/L)	0.221	0.014	< 0.002	0.002
		Total	(mg/L)	0.37	< 0.02	0.42	0.43
	pH		(Rel. U.)	5.7	5.92	7.96	7.96
	Phosphorus	Orthophosphate	(mg/L)	< 0.001	< 0.001	0.002	0.002
		Total	(mg/L)	< 0.002	< 0.002	0.023	0.024
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.022	0.02
	Residue	Filterable	(mg/L)	< 10	< 10	110	100
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	< 0.2	13	14
	Turbidity		(FTU)	< 0.05	< 0.05	0.75	0.75

Sampling Site (Date: 96/05/15)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Sheridan Lake @ Center (E216929)	Colour / True		(Rel.U.)	< 5	< 5	< 5	< 5
	Conductivity		(uS/cm)	3	3	450	450
	Nitrogen	Ammonia	(mg/L)	< 0.002	< 0.002	0.036	0.055
		Nitrite	(mg/L)	< 0.002	< 0.002	0.003	0.003
		Nitrite + Nitrate	(mg/L)	0.003	0.004	0.037	0.039
		Total	(mg/L)	0.22	0.05	0.68	0.72
	pH		(Rel. U.)	5.27	5.12	8.55	8.56
	Phosphorus	Orthophosphate	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Total	(mg/L)	< 0.002	< 0.002	0.024	0.023
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.024	0.023
	Residue	Filterable	(mg/L)	< 10	< 10	270	260
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	< 0.2	14.3	14.4
	Turbidity		(FTU)	0.2	0.08	0.22	0.19

Sampling Site (Date: 96/05/23)	Parameter Analyzed			Blanks DI	Blanks Kem	Replicates I	Replicates II
Selpharous Lake @ Deepest Pt (E222874)	Colour / True		(Rel.U.)	< 5	< 5	< 5	< 5
	Conductivity		(uS/cm)	< 2	2	252	254
	Nitrogen	Ammonia	(mg/L)	0.003	0.003	0.011	0.01
		Nitrite	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Nitrite + Nitrate	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Total	(mg/L)	< 0.02	< 0.02	0.26	0.29
	pH		(Rel. U.)	5.2	5.88	8.23	8.25
	Phosphorus	Orthophosphate	(mg/L)	< 0.002	< 0.002	< 0.002	< 0.002
		Total	(mg/L)	< 0.002	< 0.002	0.007	0.007
		Total Dissolved	(mg/L)	< 0.002	< 0.002	0.004	0.006
	Residue	Filterable	(mg/L)	< 10	< 10	140	130
		Non-Filterable	(mg/L)	< 5	< 5	< 5	< 5
	Silica (Reactive)		(mg/L)	< 0.2	< 0.2	1.3	1.3
	Turbidity		(FTU)	< 0.05	0.14	0.26	0.26

*Note: Kem = Kemmerer

The information for morphometric characteristics in the tables referred to in the following sections was obtained from a comparison of those figures in the Cariboo Regional District Management Strategy for Lake Shoreland Development report (CRD, 1983) and those figures on the bathymetric map for Bridge Lake (MELP files). In 1996, the Ministry used bathymetric maps on file and Geographical Information Systems (GIS) to recalculate some morphometric characteristics. Where the two differ, figures from the bathymetric map were used for assessment purposes.

Table 2. Nutrient Assimilation Capabilities Associated with Mean Depths.

Mean Depth	Additional Nutrient Assimilation Rating
< 5 m	low
5m - 15 m	moderate
>15m	high

Source: CRD, 1983

3.1.2 Temperature and Dissolved Oxygen

Dissolved oxygen (DO)/temperature profiles are useful for several reasons. They may indicate if a lake is mixed at spring overturn, or if a lake is vulnerable to hypolimnetic oxygen deficiencies in the winter and late summer. Low hypolimnetic oxygen concentrations are often undesirable because they can initiate the release of phosphorus (P) from the sediments, and begin a general acceleration of the eutrophication process (Nordin, 1985). Episodes of extremely depressed DO can also cause fish kills or kills of invertebrates (EPA 1990).

Winter DO levels are usually low under ice conditions when mixing is prevented. Temperate Cariboo lakes usually become inversely stratified in winter whereby DO decreases with depth and temperature increases with depth.

A lake mixed at overturn is evident as an isothermal body of water which permits nutrients to mix over all strata. This is a good time to sample since data collected is more likely to be, at any given depth, representative of the entire lake body than when the lake is stratified in summer and winter.

Summer profiles will generally show stratification into three layers whereby the epilimnion (upper layer) is warmed by the sun and maintains relatively high oxygen levels due to wind mixing and photosynthetic activity in the euphotic zone. The euphotic zone is the upper layer receiving enough light for green plants to grow. By late summer, there may be nutrient depletion in the epilimnion, since nutrients are not mixed into the upper waters as long as stratification persists (Horne and Goldman, 1994). This decreased productivity often increases clarity. In the hypolimnion (bottom layer), there is minimal replenishment of oxygen, and oxidation/reduction reactions and decomposition deplete the oxygen levels.

Lastly, DO/temperature profiles will verify which Bridge Creek basin lakes are dimictic. Dimictic lakes mix freely twice a year in the spring and fall (at overturn), and are directly stratified in the summer and inversely stratified in the winter. There may be some lakes that remain stratified all year and which are termed meromictic.

Note:1996 DO/temperature profiles require correction. Depths in the profile must be multiplied by 0.9144 to change the readings, currently in yards, to meters. This is because the probe cable used was marked off in yards.

3.1.3 Phosphorus and Nitrogen

In most freshwater bodies, phosphorus (P) is the growth-limiting nutrient for phytoplankton (Horne and Goldman, 1994). It is essential that P loading be minimized to slow the process of eutrophication. Eutrophication is the natural state of aging in lakes whereby nutrients accumulate in the lake and support further biological growth of aquatic plants and animals. The eutrophication of lakes is often associated with a loss in clarity. In rare cases, it is possible for nitrogen (N) to limit growth in lakes. Both P and N are discussed in terms of their importance as growth-limiting nutrients. Lakes can be classified in terms of the N concentration at spring overturn (Table 3).

Table 3. Trophic State Based on Total Nitrogen Concentration at Spring Overturn*.

Total N (mg/L)	**Trophic State**
<0.1	oligotrophic
0.1-0.5	mesotrophic
0.5-1	eutrophic

*adapted from Nordin (1985)

Lakes can be classified in terms of the P concentration at spring overturn (Table 4).

Table 4. Trophic State Based on Total Phosphorus Concentration at Spring Overturn*.

Total P (mg/L)	**Trophic State**
0.001-0.010	oligotrophic
0.010-0.030	mesotrophic
>0.03	eutrophic

*adapted from Nordin (1985)

Spring P can be used as a predictor of summer chlorophyll *a* levels from which a lake trophic status can be derived (Table 5).

Table 5. CRD Criteria for Trophic State Based on Summer Chlorophyll *a*.

Chlorophyll *a*	**Trophic State**
0-3 mg/m^3	oligotrophic
3-7 mg/m^3	mesotrophic
>7 mg/m^3	eutrophic

Lastly, the total N:total P ratio can be used to determine if N or P is the main limiting nutrient (Table 6).

Table 6. Nitrogen:Phosphorus (N:P) Ratios and Nutrient Limitation.

N:P Ratio	**Nutrient Limitation**
<5:1	nitrogen
5-15:1	co-limitation or no limitation
>15:1	phosphorus

*adapted from Nordin (1985)

P and N data were summarized for all lakes to categorize the lakes in terms of trophic status and nutrient limitation.

3.1.4 Water Clarity

Transparency or water clarity data can be used as a long term indicator of lake water quality and is a good relative measure between lakes. Lake transparency is measured using a Secchi disk.

Liebe and Zirnhelt (1996) note that as a sampling tool, the Secchi disk is inexpensive, low maintenance, easy to use, and yet provides very useful information. The Secchi disk is also a more precise measure of lake transparency than the often substituted test of water turbidity. In most lakes, Secchi depth relates to the concentration of algae (Carlson, 1995), but it may also be affected by suspended sediment. A complete background on the Secchi disk and its uses can be found in Carlson (1995).

Lake transparencies for all six lakes were presented for 1997 and taken from a report by Liebe and Zirnhelt (1996) Trends in lake clarity become apparent after several years of Secchi data have been collected.

3.1.5 Flushing Rate and Nutrient Assimilation Capability

Flushing period is generally expressed in years and is a measure of the time that natural runoff (inflow) takes to replace the lake water volume. The CRD (1983) states that lakes with a short retention time have a higher capacity to assimilate additional phosphorus without a change in trophic state because a large percentage of the added phosphorus or nitrogen is flushed out of the lake each year. Conversely, lakes with a long flushing period have a higher sensitivity to added nutrients because of the typical retention and accumulation of added nutrients.

Flushing rate values in relation to the capability of a lake to assimilate additional phosphorus or nitrogen are given in Table 7 which is taken from CRD (1983).

Table 7. The Effects of Flushing Rate on Additional Nutrient Assimilation Capabilities.

Flushing Period	Additional Nutrient Assimilation Rating
0 - 2 years	high
2 - 8 years	average
greater than 8 years	low

Source: CRD, 1983

Flushing rate alone may determine a high sensitivity rating, however, it is usually a combination of factors that determine overall lake sensitivity (CRD, 1983).

3.1.6 Fluorometer Survey

Hart (1995) recommended that septic systems having the greatest potential to threaten water quality be identified and that the actual potential for contamination be quantified.

To follow this up, MELP, Cariboo Region, launched an investigation using a fluorometer to detect septic leachate in lakes. The fluorometer indicates sewage presence by detecting optical brighteners from detergents which fluoresce and are found in septic system wastewater. For a thorough description of this instrument and its operation, the reader is referred to Petch (1996).

The investigation began with a pilot study on Bridge Lake in 1995. The initial study was intended for staff to become familiar with the instrument, test it, and develop a protocol for assessing septic leachate in lakes using a fluorometer as an initial survey tool (Appendix I). Subsequently in the summer of 1996, the six Bridge Creek basin high priority lakes (Petch and Zirnhelt, 1996) were surveyed with the fluorometer. The results of the fluorometer surveys indicated whether or not residential septic systems were substantially affecting water quality, and this was used to determine if further assessment was necessary.

Secondary water chemistry and bacteriology samples were collected at sites having high readings to help confirm that seepages detected by the fluorometer were sewage related. The assessment methodology categorized lakes into two broad categories, those having few or those having many peaks. Lakes with many peaks were to be investigated (using a worst case analysis) for residential P loading as a percentage of the total P loading to the lake. Where residents are contributing > 5% of the total phosphorus loading to the lake, then the lake would become a high priority for a water quality assessment and soil P adsorption assessment (taking into account soil transmission coefficients).

The number of permanent and seasonal residents for each lake were determined based on surveys from Hart (1995) and Petch and Zirnhelt (1996).

3.1.7 Lake Evaluation Summaries (Lake Sensitivity)

The following section summarizes factors described in the previous sections which combine to determine a final sensitivity rating for each lake. For each lake, trophic state, water clarity, flushing rate, mean depth and other water quality data are considered. The sensitivity ratings in 1996 were then compared to those for the same lakes in the early 1980s (CRD, 1983).

3.2 Bridge Lake

3.2.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

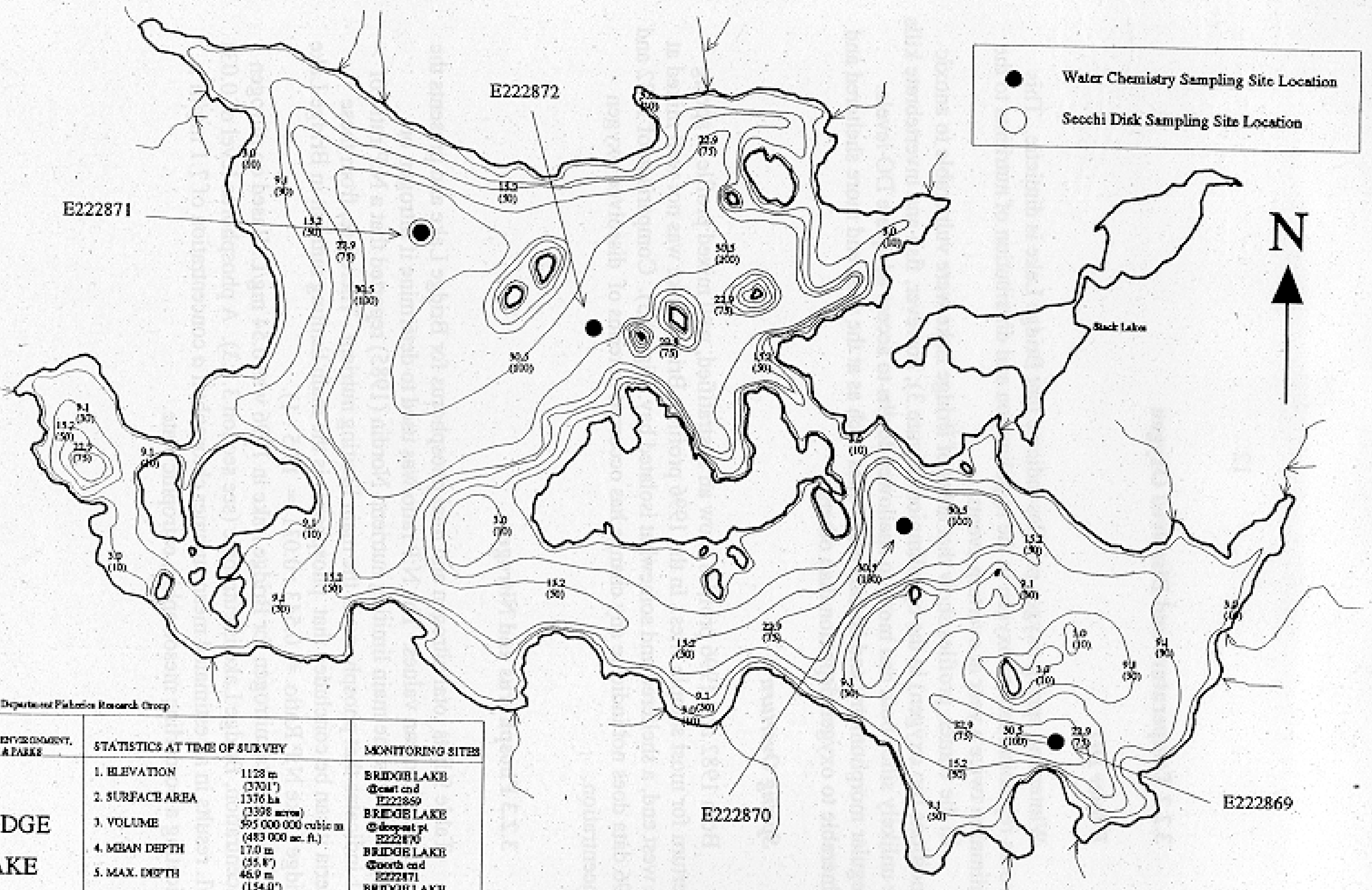
Table 8. Bridge Lake Morphometric Characteristics.

Parameter	CRD (1983)	Bathymetric Map (1996)
Size (km^2)	35.0	13.76
Perimeter (km)	47.0	47.0
Elevation (m)	1128	1128
Volume (million m^3)	595	595
Mean depth (m)	17.0	17.0

Bridge Lake has an irregular shoreline, and several bays and islands which may inhibit lake mixing by sheltering bays from the wind (Figure 2). The irregular morphology may also contribute to site variability across the lake by separating basins. Although the lake has several basins of variable depths, the mean depth is relatively high. The mean depth of Bridge Lake is 17 m (Table 8), therefore this lake ranks high in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

Watershed Characteristics

The Bridge Lake watershed is 159 km^2 in area. The lake is surrounded by low lying, poorly drained forests of Interior Douglas fir that have been subjected to some logging and clearing. The south and west shores contain most of the housing development, and new subdivision development occurs along the south shore. Agricultural development occurs on the north and west shores.



Source: BC Game Department Fisheries Research Group

MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
BRIDGE LAKE	1. ELEVATION	1128 m (3701')	BRIDGE LAKE @east end E222869
	2. SURFACE AREA	1376 ha (3398 acres)	BRIDGE LAKE @deepest pt E222870
	3. VOLUME	595 000 000 cubic m (483 000 ac. ft.)	BRIDGE LAKE @north end E222871
	4. MEAN DEPTH	17.0 m (55.8')	BRIDGE LAKE @west end E222872
	5. MAX. DEPTH	46.9 m (154.0')	
	6. PERIMETER	47 000 m (154 200')	

Figure 2. Bathymetric Map of Bridge Lake Showing Monitoring Sites

Scale: 1 cm = 300 m

3.2.2 Temperature and Dissolved Oxygen

Winter DO

Winter and spring oxygen profiles indicate that Bridge Lake is dimictic. This favours replenishment of oxygen in the hypolimnion and distribution of nutrients to the epilimnion twice a year at overturn events.

In the winter, profiles show that areas of Bridge Lake were vulnerable to anoxic conditions (no oxygen) in the hypolimnion (Figure 3); however, fish and invertebrate kills are unlikely since both can move to shallower depths to access adequate DO levels. Irregular morphometry and islands make sites such as at the west end more sheltered and vulnerable to oxygen depletion than others.

Spring Overturn

Both 1982 and 1996 profiles show an unstratified, well mixed profile at spring overturn for most sample sites. In the 1996 profiles, Bridge Lake was not well mixed at the west end, a sheltered and somewhat isolated bay (Figure 3). Comparison of 1982 and 1996 data does not indicate any change has occurred in terms of dissolved oxygen concentration.

3.2.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Bridge Lake and presents the information in mean values. The N:P ratio was used to determine if nitrogen or phosphorus was the main limiting nutrient. Nordin (1985) reported that a N:P ratio of > 15:1 indicates that phosphorus is the main limiting nutrient. Therefore, from these criteria it can be concluded that phosphorus is the main limiting nutrient in Bridge Lake (Bridge Lake N:P Ratio = 0.543 : 0.031 = 17.5 : 1).

Mean total nitrogen for Bridge Lake in 1996 was 0.54 mg/L. Based on nitrogen concentration, Bridge Lake is eutrophic (see section 3.1.3). A phosphorus level of 0.031 mg/L results in an estimated mean summer chlorophyll *a* concentration of 7.1 mg/m^3, indicating a borderline mesotrophic, eutrophic state.

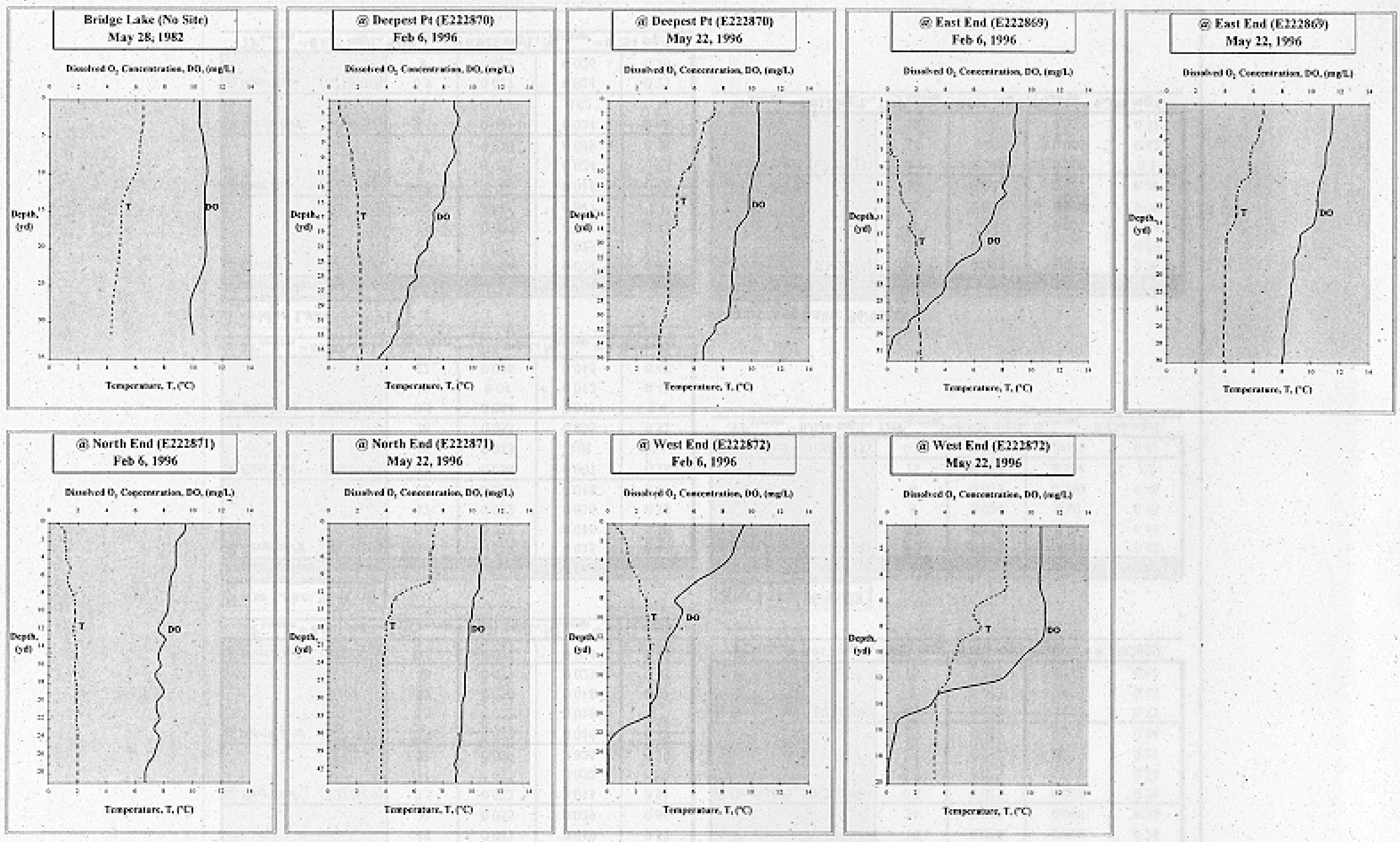


Figure 3. Bridge Lake Dissolved Oxygen and Temperature Profiles

Table 9. Total Phosphorus (TP), Total Dissolved Phosphorus (TDP), and Total Nitrogen (N) for the Six High Priority Lakes - 1996

Bridge Lake: 96/05/22

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Deepest Pt (E222870)	0.5	0.025	0.017	0.52
	16	0.033	0.019	0.57
	32	0.055	0.039	0.66
@ East End (E222869)	0.5	0.022	0.013	0.51
	14	0.033	0.022	0.57
	28	0.039	0.025	0.59
@ North End (E222871)	0.5	0.022	0.016	0.48
	0.5	0.022	0.016	0.5
	20	0.029	0.018	0.51
	40	0.033	0.023	0.53
@ West End (E222872)	0.5	0.021	0.014	0.48

$TP_{Average}$ = 0.031 mg/L, $TDP_{Average}$ = 0.021 mg/L, $N_{Average}$ = 0.543 mg/L

Deka Lake: 96/05/23

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Center (E222867)	0.5	0.014	0.007	0.24
	17	0.018	0.008	0.24
	34	0.018	0.008	0.25
@ Deepest Pt (E222866)	0.5	0.015	0.008	0.29
	0.5	0.015	0.008	0.24
	20	0.017	0.007	0.21
	39	0.021	0.009	0.24
@ South End (E222868)	0.5	0.012	0.007	0.35
	8	0.017	0.009	0.43
	16	***0.037***	***0.013***	***0.62***

$TP_{Average}$ = 0.017 mg/L, $TDP_{Average}$ = 0.008 mg/L, $N_{Average}$ = 0.278 mg/L

Horse Lake: 96/05/01

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Deepest Pt (0603100)	0.5	0.034	0.015	0.43
	0.5	0.036	0.016	0.36
	17	0.032	0.016	0.39
	32	0.037	0.018	0.41
@ East End (0603106)	0.5	0.034	0.007	0.38
	14	0.033	0.01	0.4
	26	0.055	0.035	0.52
@ West End (0603099)	0.5	0.034	0.015	0.4
	10	0.04	0.012	0.41
	22	0.036	0.015	0.42

$TP_{Average}$ = 0.037 mg/L, $TDP_{Average}$ = 0.016 mg/L, $N_{Average}$ = 0.414 mg/L

Otter Lake: 96/05/28

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Deep End (0803012)	0.5	0.023	0.022	0.42
	0.5	0.024	0.02	0.43
	3	0.024	0.02	0.45
	6	0.032	0.019	0.46
	15	***0.588***	***0.354***	***1.7***
@ West End (0803013)	0.5	0.023	0.021	0.41

$TP_{Average}$ = 0.026 mg/L, $TDP_{Average}$ = 0.020 mg/L, $N_{Average}$ = 0.436 mg/L

Sheridan Lake: 96/05/15

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Center (E216929)	0.5	0.024	0.024	0.68
	0.5	0.023	0.023	0.72
	15	0.027	0.022	0.72
	30	***0.041***	***0.047***	***1.1***
@ East Bay (E216932)	0.5	0.02	0.018	0.75
	5	0.023	0.024	0.77
	15	0.039	0.039	0.88
@ South Bay (E216931)	0.5	0.021	0.024	0.68
	7	0.023	0.02	0.78
@ West Bay (E216930)	0.5	0.027	0.024	0.75
	8	0.025	0.026	0.76

$TP_{Average}$ = 0.025 mg/L, $TDP_{Average}$ = 0.025 mg/L, $N_{Average}$ = 0.754 mg/L

Sulphurous Lake: 96/05/23

Sampling Site	Depth (m)	TP (mg/L)	TDP (mg/L)	N (mg/L)
@ Deepest Pt (E222874)	0.5	0.007	0.004	0.26
	0.5	0.007	0.006	0.29
	5	0.01	0.006	0.34
	15	0.018	0.005	0.39
	30	***0.025***	***0.011***	***0.46***
@ West End (E222873)	0.5	0.006	0.006	0.3
	15	0.02	0.006	0.42
	30	0.01	0.007	0.31

$TP_{Average}$ = 0.012 mg/L, $TDP_{Average}$ = 0.006 mg/L, $N_{Average}$ = 0.339 mg/L

*Note: ***Bold italicised*** values excluded from mean TP, TDP, and N calculations.

3.2.4 Water Clarity

Secchi disk readings were collected by volunteers on Bridge Lake from May 24, 1996 to Sept 20, 1996 to show trends in lake clarity. The maximum recorded depth was 9.40 m, the minimum was 5.9 m and the average was 7.17 m (Liebe and Zirnhelt, 1996).

3.2.5 Flushing Rate and Nutrient Assimilation Capability

The following were used to calculate the flushing rate.

(Step 1) ***Horse Lake Drainage***

- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995 stn 08LA020)
- Drainage area = 830 km^2
- Mean annual flow/drainage area = 1.584/830 = 0.0019 c.m.s./km^2 for the outlet of Horse Lake

(Step 2) ***Bridge Lake Drainage***

- Drainage area = 159 km^2
- Mean flow at outlet of Bridge Lake: 0.0019 c.m.s./km^2 * 159 km^2 = 0.30 c.m.s. (1 c.m.s. = 31.536 * 10^6 m^3/yr)
- Mean annual flow at outlet of Bridge lake
  0.30 c.m.s. * 31.536 * 10^6 m^3/yr = 9.57 * 10^6 m^3/yr
- Flushing rate = volume of lake / volume of flow at outlet
  = 595 * 10^6 m^3 / 9.57 * 10^6 m^3/yr.
  = 62.5 yrs. is the estimated flushing rate for Bridge Lake

Based on the criteria in the CRD report (section 3.1), Bridge Lake has a low ability to assimilate nutrients with an estimated flushing rate of 62.5 yrs.

3.2.6 Fluorometer Survey

The developed shoreline on Bridge Lake was surveyed in 1996 with the fluorometer. Bridge Lake has approximately 55 permanent residences and 140 temporary residences (Petch and Zirnhelt, 1996). One high reading was detected at an unnamed creek mouth site (Appendix II). Secondary sampling was conducted at the high reading site as well as at an unimpacted background site in an effort to separate septic seepage effects. The chloride ion, conductivity, ammonia, total dissolved phosphorus (TDP), total phosphorus (TP), ortho-phosphorus (ortho-P), total inorganic and total organic carbon were noticeably elevated relative to background. It is possible that creek mouths on lakes, which receive much natural nutrient loading through runoff, may also exhibit contamination from adjacent sewage systems, livestock or waterfowl. This may provide a rich supply of organics to the shoreline water, causing elevated readings. Bridge Lake was also investigated in a 1995 pilot study (Petch, 1996).

According to the assessment methodology in Appendix I, one peak did not warrant further investigation of the lake’s residential lakeshore septic systems. Bridge Lake is likely not suffering detectable water quality degradation from septic systems.

3.2.7 Lake Evaluation Summary for Bridge Lake

Base Information

Size: 13.76 km^2
Perimeter: 47.0 km
Elevation: 1128 m
Shoreline Ownership: private - 95%, crown - 5%
Other: very irregular shoreline, heavily utilised for fishing

Lake Classification Factors - Water Quality

1. Trophic State: borderline mesotrophic to slightly eutrophic

- calculated chlorophyll *a* = 7.1 mg/m^3

2. Flushing Period: 62.5 years (based on limited data)

3. Mean Depth: 17.0 m

4. Volume: 595 million m^3

5. Water Quality Indicators:

- dissolved oxygen - well mixed at spring overturn
  - winter profile - anoxic in some areas
- $[nitrogen]_{total}$ = 0.543 mg/L (eutrophic)
- $[phosphorus]_{total}$ = 0.031 mg/L
- nitrogen:phosphorus ratio = 17.5:1 (phosphorus limiting)
- pH = 8.18
- Secchi disk = 7.17 m

6. Watershed Characteristics:

- watershed area = 159 km^2

- Low lying, poorly drained surrounding forests of Interior Douglas fir have been subject to logging and clearing. South and west shores contain most of the housing development. New development occurring along south shore. Agricultural activity on north and west shores.

Rating: High Sensitivity

Summary:

Borderline mesotrophic to slightly eutrophic state, but water clarity relatively high. Has relatively long flushing period, but mean depth is quite high allowing for moderate assimilation of additional nutrients. High sensitivity, particularly in localised areas along shoreline, such as in isolated bays.

3.3 Deka Lake

3.3.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

Table 10. Deka Lake Morphometric Characteristics.

Parameter	CRD (1983)	Bathymetric Map (1996)
Size (km^2)	11.5	11.5
Perimeter (km)	34.1	34.1
Elevation (m)	1113	1113
Volume (million m^3)	250	250
Mean depth (m)	21.6	21.6

Deka Lake is divided into two sub-basins separated by a narrow, shallow channel. Both basins are simple and relatively deep but the northern basin is larger and deeper (Figures 4a and 4b). As noted previously in this report, as the mean depth of a lake increases in relation to its volume its ability to assimilate additional nutrients increases. In calculating the mean depth of Deka Lake, depths from both basins were averaged. The mean depth is 21.6 m (Table 10), therefore this lake ranks high in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

Watershed Characteristics

The Deka Lake watershed is 92 km^2. Deka is surrounded by a heavily forested watershed where there has been some logging activity, and which slopes steeply into the lake. Residential development occurs almost exclusively in the shallower south basin which may be more immediately sensitive to increasing development and losses in water quality.

MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
DEKA LAKE Northern Basin	1. ELEVATION	1113.43 m (3653')	DEKA LAKE @centre E222867
	2. SURFACE AREA	1153.78 ha (2851 acres)	DEKA LAKE @deepest point E222866
	3. VOLUME	250 000 000 cubic m (202 414 ac. ft.)	DEKA LAKE @south end E222868
	4. MEAN DEPTH	21.64 m (71.0')	
	5. MAX. DEPTH	101.19 m (332')	
	6. PERIMETER	34 094 m (111 860')	

* Note - Statistics are for both northern and southern basins

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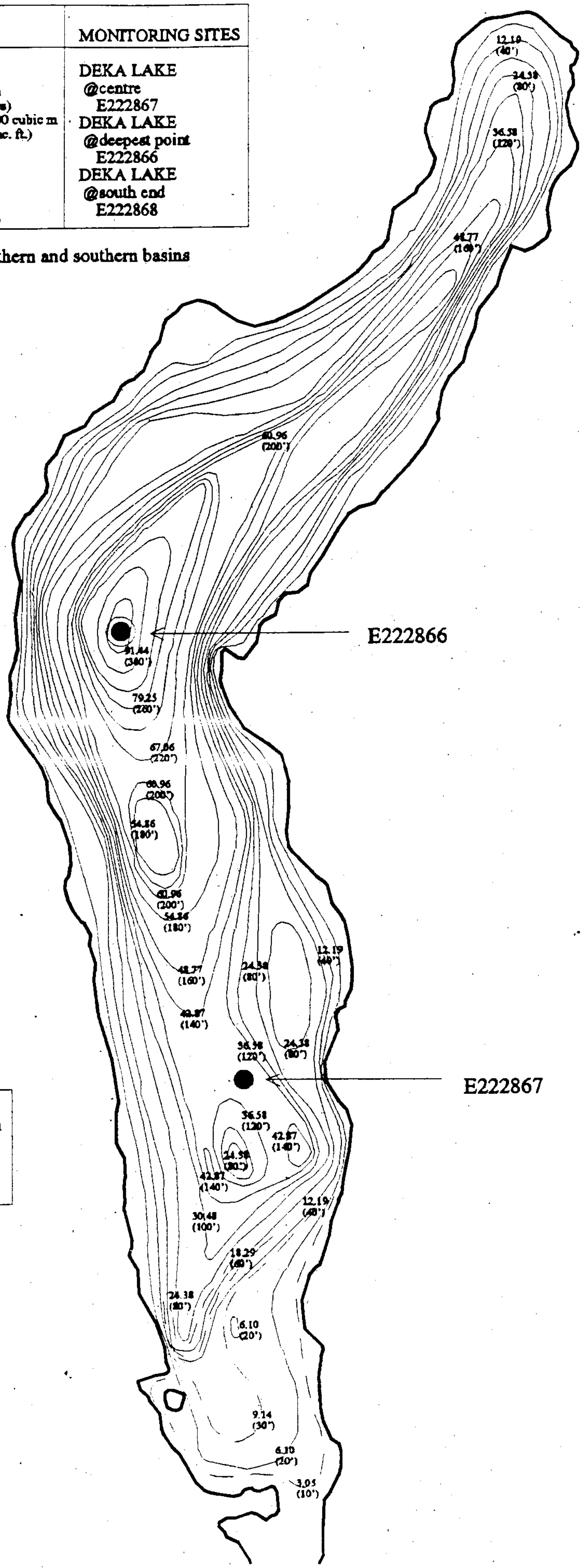

● Water Chemistry Sampling Site Location

○ Secchi Disk Sampling Site Location

Scale: 1 cm = 300 m

Figure 4a. Bathymetric Map of Deka Lake Northern Basin Showing Monitoring Sites

MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
DEKA LAKE Southern Basin	1. ELEVATION	1113.43 m (3653')	DEKA LAKE @centre E222867
	2. SURFACE AREA	1153.78 ha (2851 acres)	DEKA LAKE @deepest point E222866
	3. VOLUME	250 000 000 cubic m (202 414 ac. ft.)	DEKA LAKE @south end E222868
	4. MEAN DEPTH	21.64 m (71.0')	
	5. MAX. DEPTH	101.19 m (332')	
	6. PERIMETER	34 094 m (111 860')	

* Note - Statistics are for both northern and southern basins

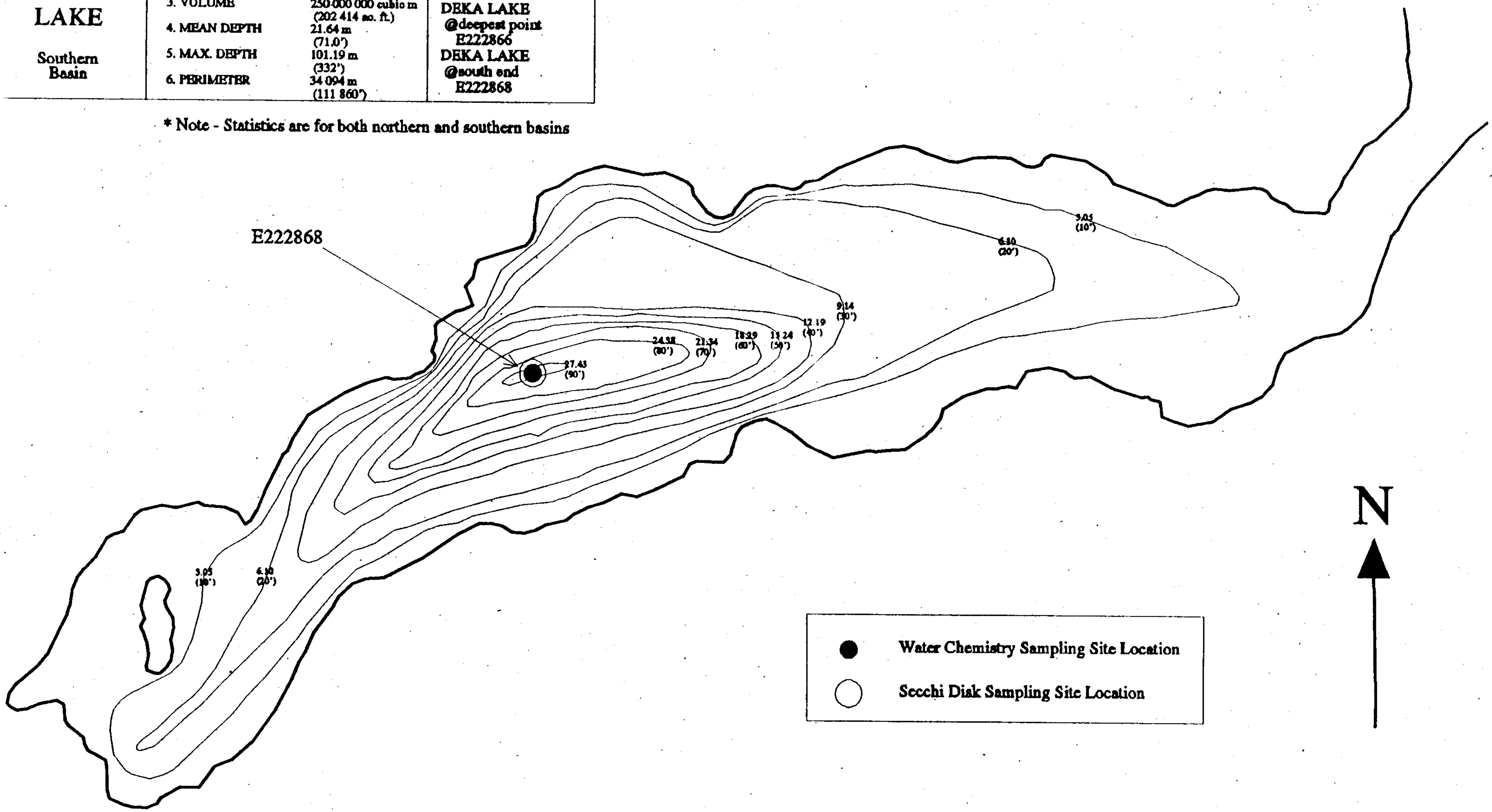

Figure 4b. Bathymetric Map of Deka Lake Southern Basin Showing Monitoring Sites

Scale: 1 cm = 180 m

3.3.2 Temperature and Dissolved Oxygen

Winter DO

Winter and spring oxygen profiles indicate that Deka Lake (north and south basins) is dimictic, which favours replenishment of oxygen in the hypolimnion and distribution of nutrients to the epilimnion twice a year at overturn events.

In the winter, there were anoxic conditions in the hypolimnion (below 16 m) in the south basin while in the north basin DO levels are relatively high (Figure 5).

Spring Overturn

In 1982 at spring overturn, Deka Lake was well mixed and showed no stratification or thermoclines, however the location of this profile is not known. In 1996, the north basin was again unstratified and isothermal at overturn. However, the south basin site profile (E222868) was stratified significantly between 10 and 15 m in spring causing poor mixing and low hypolimnetic oxygen levels. The south basin runs lengthwise east to west, and likely does not receive the strong overturn winds predominant on the north basin that promote mixing.

3.3.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Deka Lake and presents the information in mean values. From Nordin's (1985) criteria, it can be concluded that phosphorus is the main limiting nutrient, and that based on nitrogen concentration, Deka Lake is mesotrophic (Deka Lake N:P Ratio = 0.278 : 0.017 = 16: 1). A phosphorus level of 0.017 mg/L results in an estimated mean summer chlorophyll *a* of 3.9 mg/m^3 suggesting Deka Lake may be mesotrophic.

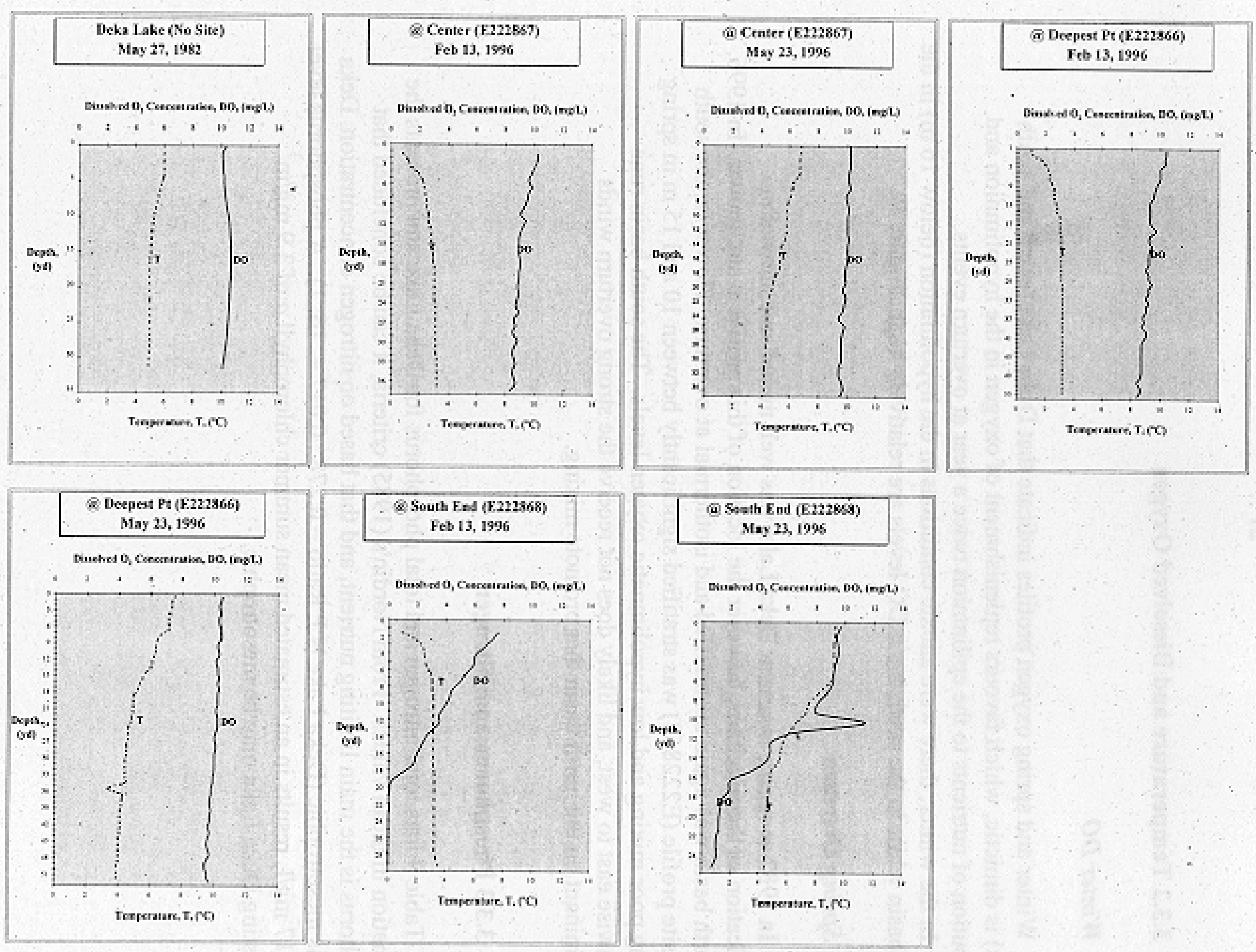

Figure 5. Deka Lake Dissolved Oxygen and Temperature Profiles

3.3.4 Water Clarity

Secchi disk readings were collected on Deka Lake in the north basin and in the south basin to show trends in lake clarity. In the north basin, readings were collected from July 25, 1996 to October 3, 1996. The maximum recorded depth was 11.88 m, the minimum was 8.60 m and the average was 10.41 m (Liebe and Zirnhelt, 1996). The north basin had the clearest water (greatest mean transparency) of all the lakes monitored. In the south basin, readings were collected from May 16, 1996 to October 25, 1996. The maximum recorded depth was 8.50 m, the minimum was 3.60 m, and the mean depth for 1996 was 6.19 m. It is interesting to note that most development and recreational use occurs in the south basin which is also shallower than the north basin and more vulnerable to disturbance and resuspension of sediments and nutrients.

3.3.5 Flushing Rate and Nutrient Assimilation Capability

The following were used to calculate the flushing rate.

(Step 1) ***Horse Lake Drainage***

- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995, stn 08LA020)
- Drainage area = 830 km^2
- Mean annual flow/drainage area = 1.584/830 = 0.0019 c.m.s./km^2 for the outlet of Horse Lake

(Step 2) ***Deka Lake Drainage***

- Drainage area = 92 km^2
- Mean flow at outlet of Deka Lake: 0.0019 c.m.s./km^2 * 92 km^2 = 0.18 c.m.s.
  1 c.m.s = 31.536 * 10^6 m^3/yr.
- Mean annual flow at outlet of Deka Lake
  0.18 c.m.s. * 31.536 *10^6 m^3/yr = 5.54 *10^6 m^3/yr.
- Flushing rate = volume of lake / volume of flow at outlet
  = 250 *10^6 m^3 / 5.54 *10^6 m^3/yr.
  = 45.2 yrs. is the estimated flushing rate for Deka Lake

Based on the criteria in the CRD report (section 3.1), Deka Lake has a low ability to assimilate nutrients with an estimated flushing rate of 45.2 years.

3.3.6 Fluorometer Survey

The developed shoreline in the south basin of Deka was surveyed with the fluorometer on June 24 and 25, 1996. The south basin contains almost all of the residential development and has approximately 42 permanent residences and 99 temporary residences (Petch and Zirnhelt, 1996). There were no high readings detected on Deka Lake suggesting no significant discharges of septic effluent into the adjacent lake water. The north basin, which has little shoreline development, was not surveyed.

According to the assessment methodology in Appendix I, the absence of elevated readings suggests no further investigation of the lake's residential lakeshore septic systems is necessary at this time. Deka Lake is likely not suffering detectable water quality degradation from septic systems.

3.3.7 Lake Evaluation Summary for Deka Lake

Base Information

Size: 11.5 km^2
Perimeter: 34.1 km
Elevation: 1113 m
Shoreline Ownership: private - 23%, crown - 77%
Other: heavily concentrated development on north and west shores of south arm.

Lake Classification Factors - Water Quality

1. Trophic State: borderline oligotrophic - mesotrophic

- calculated chlorophyll a = 3.9 mg/m^3

2. Flushing Period: 45.2 years

3. Mean Depth: 21.6 m

4. Volume: 250 million m^3

5. Water Quality Indicators:

- dissolved oxygen - spring overturn - well mixed at north basin, stratification at south basin
  - winter profile - well mixed at north basin, slight anoxia in south basin
- $[nitrogen]_{total}$ = 0.278 mg/L (mesotrophic)
- $[phosphorus]_{total}$ = 0.017 mg/L
- nitrogen:phosphorus ratio = 16:1 (phosphorus limiting)
- pH = 8.12
- Secchi disk = 10.41 m (north basin), 6.19 m (south basin)

6. Watershed Characteristics:

- watershed area = 92 km^2

- Deka Lake is divided into two basins seperated by a shallow, narrow channel. Heavily forested watershed, sloping steeply into the lake; some logging activity. Most housing development is in south basin.

Rating: High Sensitivity

Summary:

All water quality indicators support borderline oligotrophic - mesotrophic state. Concentrated development in south basin increases sensitivity in this area. Logging activity in watershed also increases sensitivity.

3.4 Horse Lake

It should be noted that a detailed assessment of Horse Lake water quality is the subject of a separate MELP report entitled Horse Lake-Bridge Cr. Water Quality Assessment (Zirnhelt et.al., *in prep*.). Data discussed in this report is intended as a summary of 1996 data collected as part of a program to monitor six high priority lakes in the Bridge Creek Basin.

3.4.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

The information for morphometric characteristics in Table 11 was obtained from a comparison of those figures in the Cariboo Regional District (CRD) Management Strategy for Lake Shoreland Development report (1983), and those figures on the bathymetric map for Horse Lake (MELP, 1996). In 1996, the Ministry used bathymetric maps on file and Geographical Information Systems (GIS) to recalculate some morphometric characteristics. Where the two differ, figures from the bathymetric map were used.

Table 11. Horse Lake Morphometric Characteristics.

Parameter	CRD (1983)	Bathymetric Map (1996)
Size (km^2)	11.5	11.6
Perimeter (km)	30.1	31
Elevation (m)	991	991
Volume (million m^3)	174.6	174.6
Mean depth (m)	15.2	15.2

Horse Lake has a single basin and is a large lake (Figure 6). At the east end, a peninsula separates the lake into two arms. There is a sampling site in one of these arms. This can result in variability from the more central sampling stations. The mean depth of Horse Lake is 15.2 m, therefore this lake ranks moderate to high in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
HORSE LAKE	1. ELEVATION	991 m (3251')	HORSE LAKE @east end 0603106
	2. SURFACE AREA	1160 ha (2866 acres)	HORSE LAKE @deepest pt 0603100
	3. VOLUME	174 600 000 cubic m (142 000 ac. ft.)	HORSE LAKE @west end 0603099
	4. MEAN DEPTH	15.2 m (49.9')	
	5. MAX. DEPTH	34.0 m (111.5')	
	6. PERIMETER	31 000 m (101 700')	

Source: BC Game Department Fisheries Research Group

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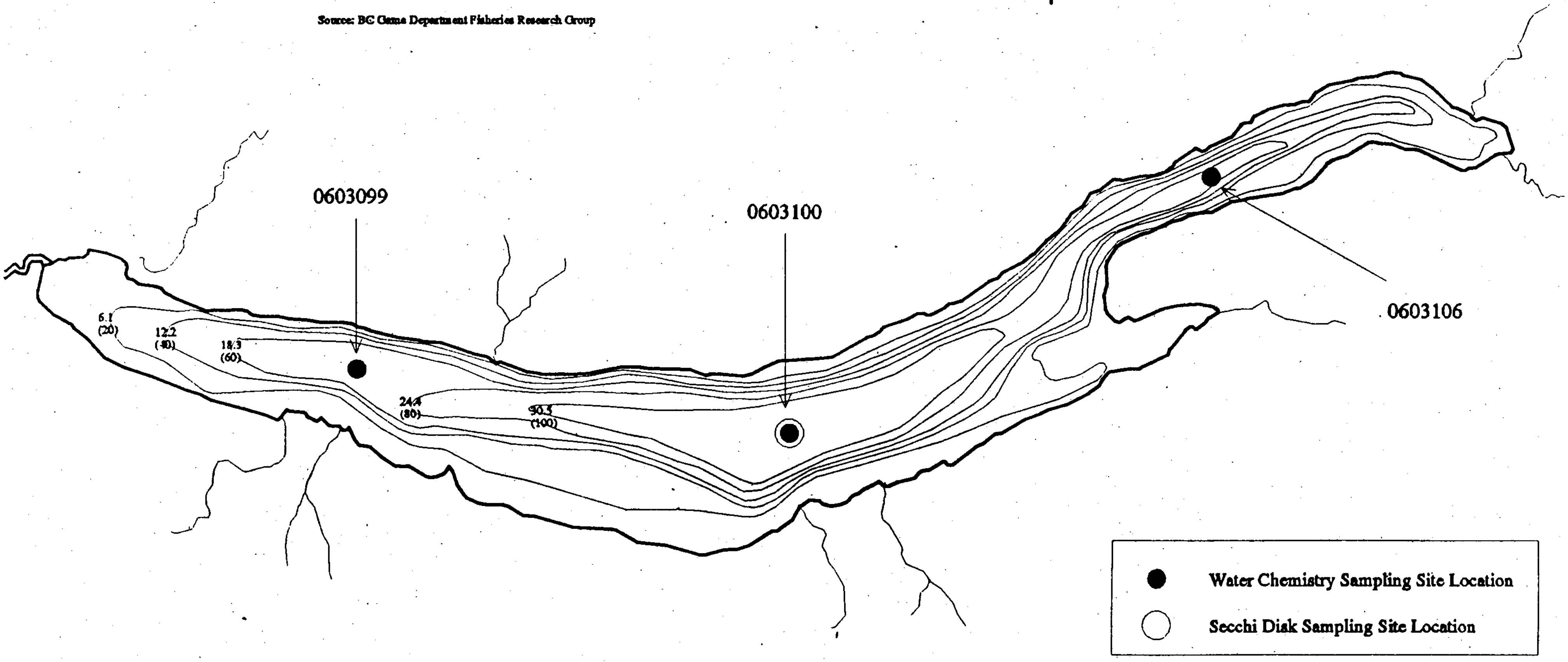


Figure 6. Bathymetric Map of Horse Lake Showing Monitoring Sites

Scale: 1 cm = 500 m

Watershed Characteristics

The Horse Lake watershed is 830 km^2. There are six main inflowing creeks and one major outflow, Bridge Creek. Horse Lake is quite close to 100 Mile House and has considerable residential development. Development is concentrated along the south shore, and with the exception of the west end, the north shore has little development.

3.4.2 Temperature and Dissolved Oxygen

Winter DO

In the winter 1996 profile, Horse Lake was unstratified and exhibited a constant thermal gradient (Figure 7). There was a slight oxygen deficit in the hypolimnion in deep sites such as at the deepest point and at the east end where there were limited mechanisms of replenishment. However, complete hypolimnetic anoxia may be unlikely since overturn events often replenish oxygen levels. Furthermore, productivity is only moderate in Horse Lake reducing demand on oxygen levels.

Spring Overturn

On April 28, 1983, Horse Lake was unstratified at the deepest point (Figure 7) and in 1996 was also isothermal and unstratified. Both years indicated a well mixed body of water at overturn. Comparison of 1983 and 1996 data indicates little change has occurred in terms of dissolved oxygen concentration.

3.4.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Horse Lake and presents the information as mean values. The N:P ratio was used to determine if nitrogen or phosphorus was the main limiting nutrient. It can be concluded that Horse Lake borderlines between phosphorus limitation and limitation by both nitrogen and phosphorus (Horse Lake N:P Ratio = 0.414 : 0.037 = 11.2 : 1).

Based on nitrogen concentration, Horse Lake is mesotrophic. Phosphorus levels of 0.037 mg/L result in an estimated mean summer chlorophyll *a* concentration of 8.4 mg/m^3, indicating a borderline mesotrophic state.

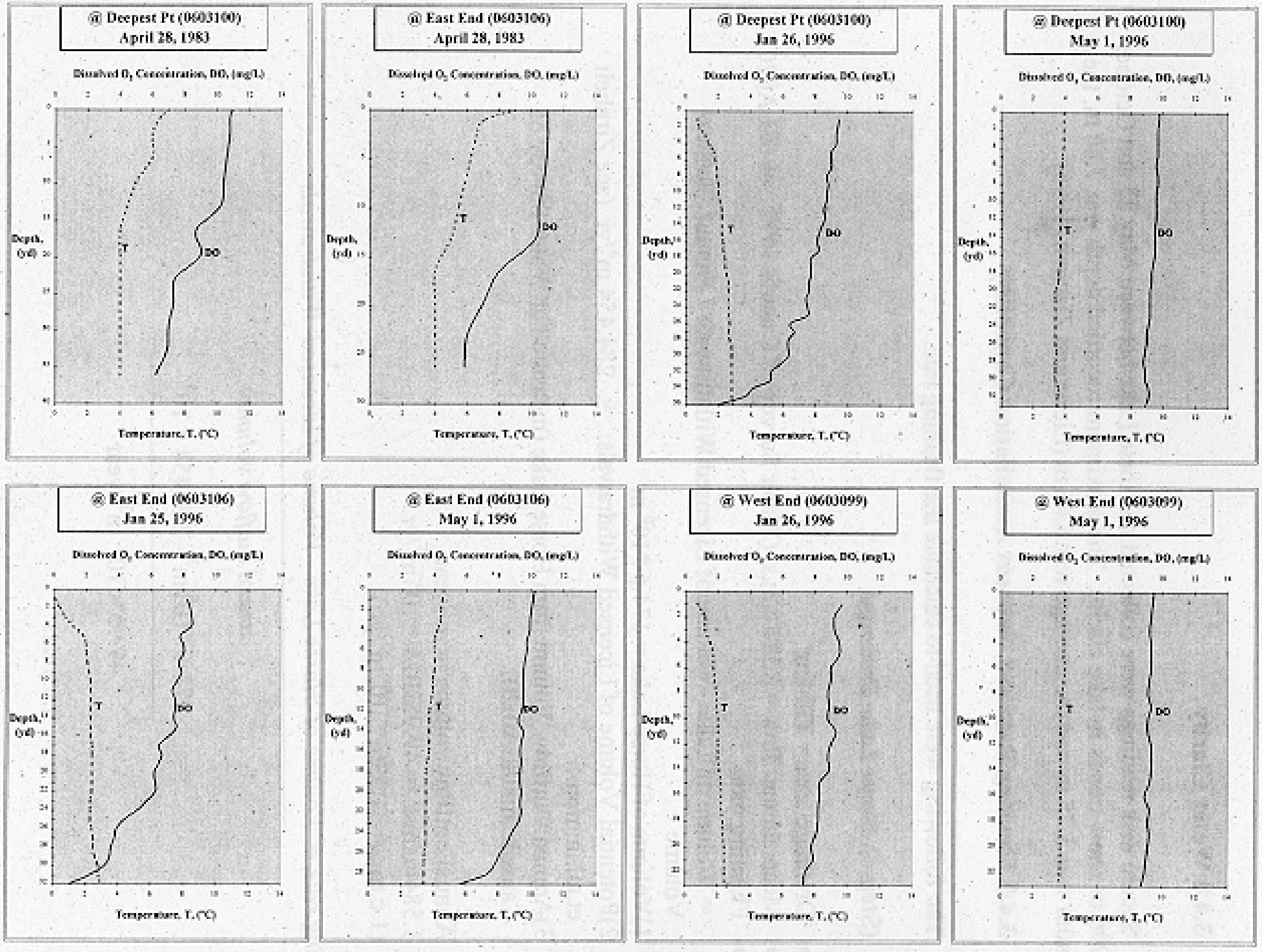


Figure 7. Horse Lake Dissolved Oxygen and Temperature Profiles

3.4.4 Water Clarity

Secchi disk readings were collected on Horse Lake between May 23 and October 11, 1996 to show trends in lake clarity. The maximum recorded depth was 7.80 m, the minimum was 5.75 m and the average was 6.66 m (Liebe and Zirnhelt, 1996).

3.4.5 Flushing Rate and Nutrient Assimilation Capability

The following were used to calculate the flushing rate.

(Step 1) ***Horse Lake Drainage***

- Drainage area = 830 km^2
- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995, stn 08LA020)
- Flushing rate
  = Volume of Lake - Volume of Licensed Withdrawals / Annual Outflow Volume

1)Volume of Horse Lake = 174.6 $*10^6$ m^3
2)Potential Volume of Licensed Withdrawals: = 284,454 m^3/yr (see Zirnhelt et.al.,in prep.)
3)Annual Outflow Volume from Horse Lake (measured at Water Survey of Canada stn 08LA020).

Annual outflow volume in m^3/year,
1.584 c.m.s. = 49.953024 * 10^6 m^3/yr.
(1 c.m.s = 31.536 * 10^6 m^3/yr.)

$$\textit{Flushing rate} = \frac{\textit{Volume of Horse Lake} - \textit{Volume of Licensed Withdrawals}}{\textit{annual outflow volume}}$$

$$= \frac{174.6 * 10^6\ m^3 - 2.84454 * 10^5}{49.95 \times 10^6\ m^3\ /year}$$

$$= 3.5\ years$$

Based on the criteria in the CRD report, Horse Lake has an average ability to assimilate nutrients with an estimated flushing rate of 3.5 yrs.

3.4.6 Fluorometer Survey

The developed shoreline on Horse Lake was surveyed with the fluorometer from June 26 to 28 and from July 8 to 9, 1996. Horse Lake has approximately 260 permanent residences (88%) and 35 temporary residences (Petch and Zirnhelt, 1996). There were three high readings located on Horse Lake - the highest number of readings recorded on any of the six lakes investigated in the Bridge Creek Basin. All high reading sites were located at the outlets of creeks. Creeks often deliver a high level of organics (Wetzel, 1983), and high levels of naturally fluorescing organics in the creek may have caused readings that could be misinterpreted as sewage effluent. However, as noted in Section 3.2.6 it is possible that creek mouths on lakes, which receive much natural nutrient loading through runoff, may also exhibit some contamination from adjacent sewage systems, livestock or waterfowl. This may provide a rich supply of organics to the shoreline water, causing elevated readings.

Water chemistry and bacteriology samples were collected at the high reading creek mouths as well as from an unimpacted background lake site in order to separate sewage effects at high reading sites (Appendix II).

There was a high reading at Fawn Creek outlet. Chloride ion, *E. coli*, phosphorus and ammonia were not elevated suggesting sewage wasn't a factor.

93 Mile Creek outlet (recorded as Horse Lake at South Central at Boat Launch in Appendix II) also showed elevated readings, however, this site exhibited conflicting indicators of sewage presence. Coliforms, *E. coli*, chloride ion, conductivity, TP, TDP, and ortho-P were elevated above background. However, ammonia, which is a component of animal excretory products, was lower than background. Although the fluorometer's high reading is likely attributed to naturally occurring fluorescing organics, it is possible that there is some contamination from livestock, water fowl or a septic system further up the creek.

The third and final high reading on Horse Lake occurred at the Attwood Creek outlet. There was conflicting support for sewage presence. Coliforms and *E. coli* were extremely elevated. Chloride ion, conductivity, phosphorus forms (TDP, TP and ortho-P), and turbidity were also elevated. This data supports a heavy presence of nutrients and organics at the creek mouth, but ammonia was lower than the unimpacted background lake levels suggesting a lack of sewage presence.

Although there was supporting evidence against sewage presence at all high reading sites, it is possible that a small degree of sewage, livestock or water fowl fecal contamination was present at each site.

The assessment methodology in Appendix I suggests that three peaks did not warrant further investigation of the lake's residential lakeshore septic systems. Horse Lake is likely not suffering detectable water quality degradation from septic systems. As noted previously, Horse Lake water quality is discussed in more detail in a separate report (Zirnhelt et. al., *in prep.*).

3.4.7 Lake Evaluation Summary for Horse Lake

Base Information

Size: 11.6 km^2
Perimeter: 31 km
Elevation: 991 m
Shoreline Ownership: private - 79%, crown - 21%

Lake Classification Factors - Water Quality

1. Trophic State: mesotrophic

- calculated chlorophyll *a* = 8.4 mg/m^3

2. Flushing Period: 3.5 years

3. Mean Depth: 15.2 m

4. Volume: 174.6 million m^3

5. Water Quality Indicators:

- dissolved oxygen - well mixed at spring overturn
  - winter profile - slight oxygen deficit
- $[nitrogen]_{total}$ = 0.414 mg/L (mesotrophic)
- $[phosphorus]_{total}$ = 0.037 mg/L
- nitrogen:phosphorus ratio = 11.2:1 (borderline between phosphorus limitation and co-limitation)
- pH = 8.09
- Secchi disk = 6.66 m

6. Watershed Characteristics:

- watershed area = 830 km^2

- Horse Lake is quite close to 100 Mile House and approximately 88% of the residents are permanent (Petch and Zirnhelt, 1996). There are six inflow creeks and one major outflow, Bridge Creek. The south shore contains most of the housing development, and except for at the west end, the north shore has little development.

Rating: High Sensitivity

Summary:

Mesotrophic state, but water clarity is relatively high. Has an average flushing period, a high mean depth, and a moderate ability to assimilate additional nutrients. The lake is rated as high priority for further monitoring largely because of its high recreational value and the large degree of permanent residents. As well, due to it's downstream position in the watershed, Horse Lake receives runoff from many land-uses upstream. These factors combined with data indicating phosphorus levels may be increasing, makes the lake high sensitivity.

3.5 Otter Lake

3.5.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

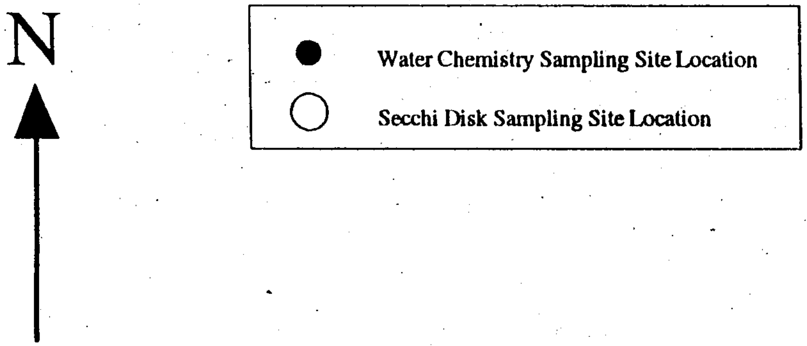
Table 12. Otter Lake Morphometric Characteristics.

Parameter	CRD (1983)	Bathymetric Map (1996)
Size (km^2)	0.5	0.5
Perimeter (km)	5.0	5.0
Elevation (m)	1158	1158
Volume (million m^3)	2.3	2.3
Mean depth (m)	4.3	4.3

Otter Lake is a very small lake. The west end of the lake is very shallow with considerable aquatic plant growth along the shoreline. The east end contains the deepest hole of the lake (Figure 8). The mean depth of Otter Lake is 4.3 m, therefore this lake ranks low in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

Watershed Characteristics

The Otter Lake watershed has an area of 8.46 km^2. It is a small, gently sloping watershed with surrounding forests of Interior Douglas fir. The west end has a large swamp.



MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
OTTER LAKE	1. ELEVATION	1158.24 m (3800')	OTTER LAKE @deep end 0803012
	2. SURFACE AREA	53.18 ha (131.4 acres)	OTTER LAKE @west end 0803013
	3. VOLUME	2 278 000 cubic m (1848 ac. ft.)	
	4. MEAN DEPTH	4.30 m (14.1')	
	5. MAX. DEPTH	16.46 m (64')	
	6. PERIMETER	5029 m (16 500')	

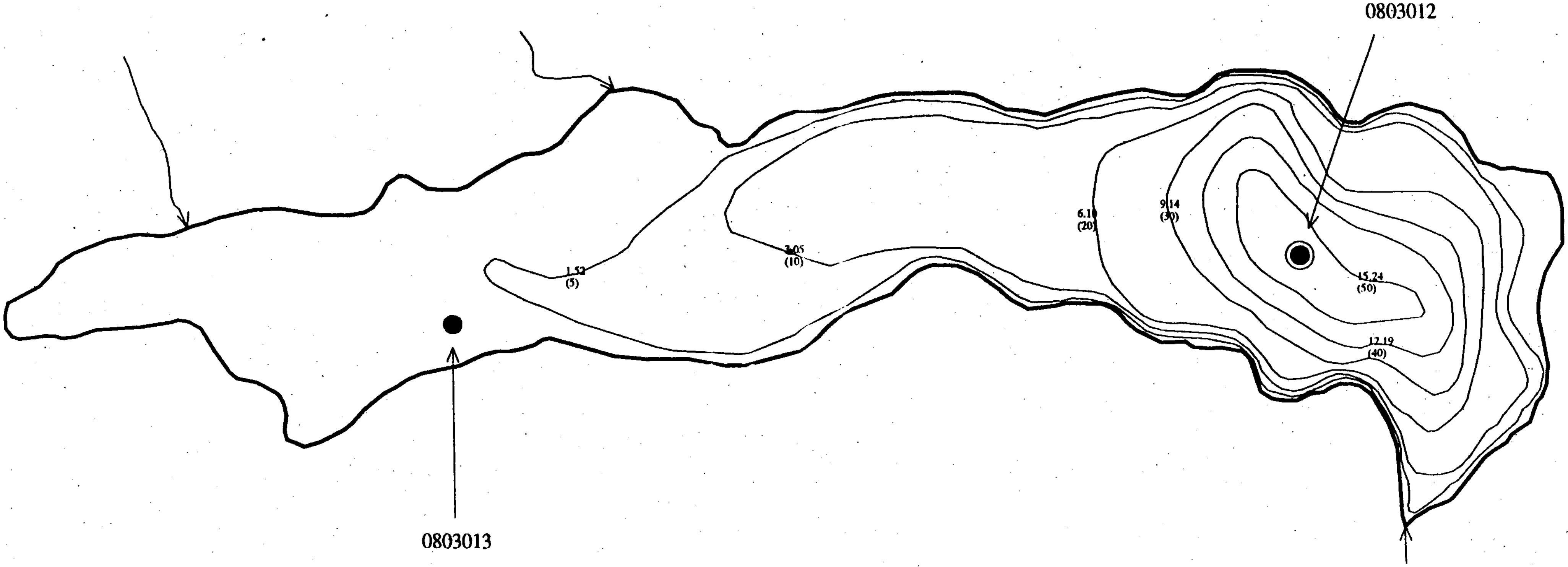


Figure 8. Bathymetric Map of Otter Lake Showing Monitoring Sites

Scale: 1 cm = 80 m

3.5.2 Temperature and Dissolved Oxygen

Winter DO

Winter and spring oxygen profiles indicate that Otter behaves somewhat like a meromictic lake but is likely dimictic (Figure 9). In the winter 1996 profile, the west end site, measuring only 3 m deep, had low DO levels overall, and the deep end site exhibited a large hypolimnetic oxygen deficit with anoxic conditions below 8 m. Low DO levels can increase internal phosphorus loading resulting in algae blooms that reduce clarity.

Spring Overturn

In both 1983 and 1996, spring profiles, with the exception of the west end, appear poorly mixed, exhibiting stratification and thermoclines. In 1996, DO profiles were collected twice on Otter Lake to determine when overturn was occurring. One sampling event occurred on May 14, and the second occurred on May 28. Both days exhibited a stratified oxygen profile indicating little evidence of mixing. The 1996 data indicated that Otter Lake did not turnover completely after ice break up and was restricted by thermoclines and likely density gradients. The west end is shallow, and had fairly high DO levels due to wind mixing.

Several factors may explain Otter Lake's low hypolimnetic oxygen levels at the deep end. Aside from regular processes of oxygen depletion, there is a large littoral zone and a large quantity of aquatic plants which could deplete oxygen levels when they decompose. Otter Lake is a small lake sheltered by surrounding trees. In addition, the lake’s fetch (length for wind to accumulate speed and enhance mixing) is small and may prevent thorough mixing of the lake at overturn.

The incomplete spring mixing seems to suggest that Otter Lake may be meromictic (i.e. the lake does not undergo complete circulation at overturn). However, it is likely that replenishment of hypolimnetic oxygen levels occurs in years when winds are strong enough to cause overturn. Otter Lake is therefore likely a dimictic lake that doesn't always turn over.

3.5.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Otter Lake and presents the information as mean values.

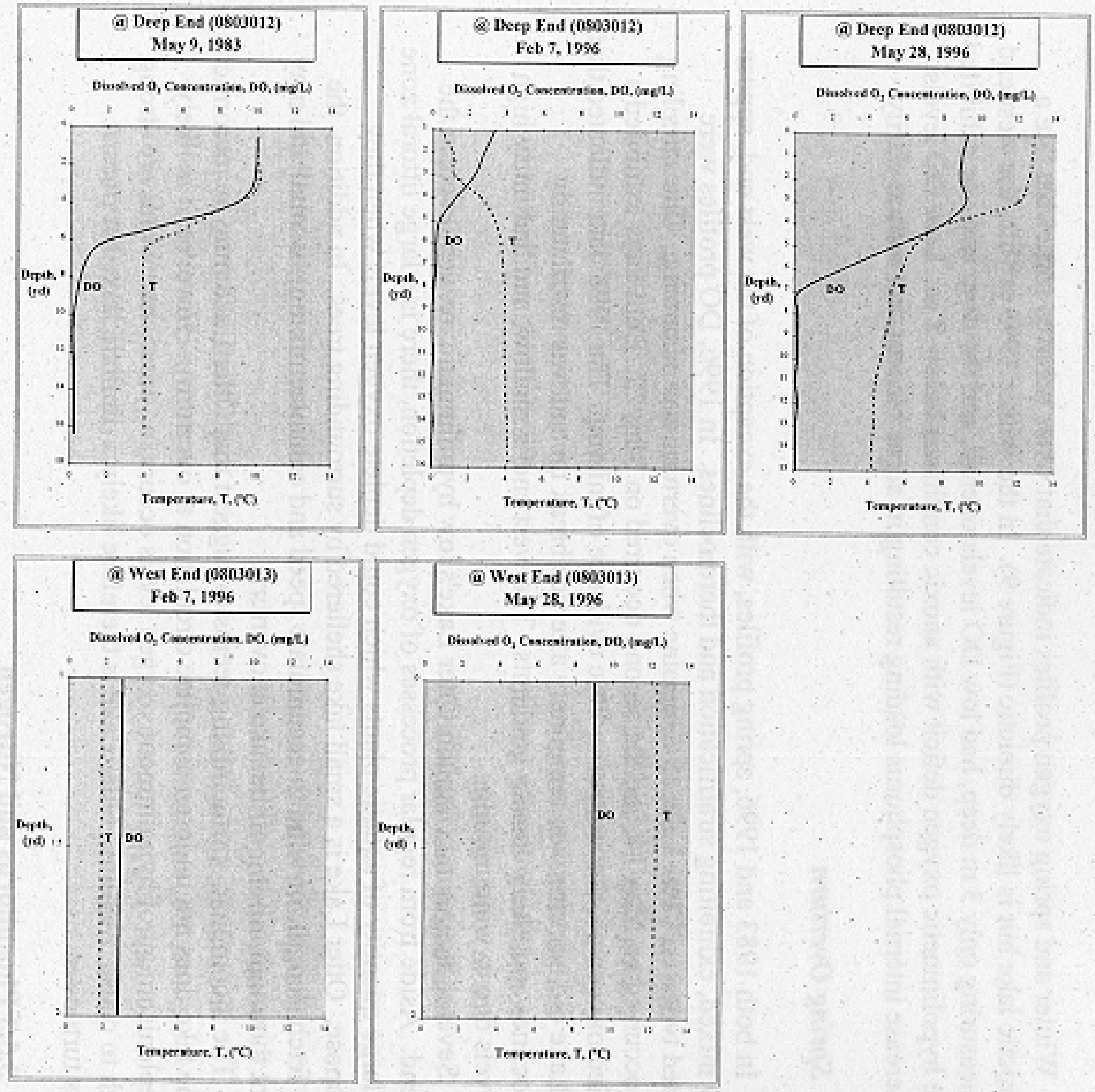


Figure 9. Otter Lake Dissolved Oxygen and Temperature Profiles

From Nordin's (1985) criteria it can be concluded that phosphorus is likely the main limiting nutrient in Otter Lake (Otter Lake N:P Ratio = 0.436: 0.026 = 16.8 : 1). Based on nitrogen concentration, Otter Lake is mesotrophic. A phosphorus level of 0.026 mg/L results in an estimated mean summer chlorophyll *a* level of 5.9 mg/m^3, suggesting a mesotrophic classification.

It should be noted however that Otter Lake is highly tannic coloured due to dissolved humic compounds and may not exhibit typical phosphorus - chlorophyll relationships (Wetzel, 1983). These lakes tend to be light limited, rather than phosphorus limited. This would require further investigation

3.5.4 Water Clarity

Secchi disk readings were collected on Otter Lake in 1996 between May 20 and October 14. The maximum recorded depth was 4.17 m, the minimum was 2.20 m and the mean depth was 3.90 m (Liebe and Zirnhelt, 1996). It appears that Otter Lake lacks the clarity evident in the other lakes studied in this report due to the tannic colour discussed above.

3.5.5 Flushing Rate and Nutrient Assimilation Capability

The following were used to calculate flushing rate.

(Step 1) *Horse Lake Drainage*

- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995 station 08LA020)
- Drainage area = 830 km^2
- Mean annual flow/drainage area = 1.584/830 = 0.0019 c.m.s./km^2 for the outlet of Horse Lake

(Step 2) *Otter Lake Drainage*

- Drainage area = 8.46 km^2
- Mean flow at outlet of Otter Lake: 0.0019 c.m.s./km^2 * 8.46km^2 = 0.0161 c.m.s.
  1 c.m.s = 31.536 * 10^6 m^3/yr.
- Mean annual flow at outlet of Otter Lake
  (0.0161 c.m.s. * 31.536 *10^6 m^3/yr = 5.07729 *10^5 m^3/yr.)

- Flushing rate = volume of lake / volume of flow at outlet
  = $2.3 * 10^6\ m^3$ / $5.07729 * 10^5\ m^3$/yr.
  = 4.5 yrs. is the estimated flushing rate for Otter Lake

Based on the criteria in the CRD report Otter Lake has an average ability to assimilate nutrients with an estimated flushing rate of 4.5 yrs.

3.5.6 Fluorometer Survey

The developed shoreline on Otter Lake was surveyed using the fluorometer on July 18, 1996. Otter lake has approximately 5 residences, all of which are permanent (Petch and Zirnhelt, 1996). Fluorometer sampling on the lake was ineffective and in the future, Otter Lake should not be surveyed with the fluorometer for the following reasons: the houses are situated directly across from very shallow areas which make boat maneuvering difficult, and secondly, the lake has large patches of aquatic macrophytes occurring in shallow areas that make effective sampling of shoreline very difficult. No conclusions can be made regarding residential lakeshore septic systems on Otter Lake.

3.5.7 Lake Evaluation Summary for Otter Lake

Base Information

Size: 0.5 km^2
Perimeter: 5.0 km
Elevation: 1158 m
Shoreline Ownership: n/a
Other: relatively little development on lake at present.

Lake Classification Factors - Water Quality

1. Trophic State: mesotrophic

- calculated chlorophyll *a* = 5.9 mg/m^3

2. Flushing Period: 4.5 years

3. Mean Depth: 4.3 m

4. Volume: 2.3 million m^3

5. Water Quality Indicators:

- dissolved oxygen - spring overturn - stratification and considerable oxygen depletion at deep end, well mixed at west end
  - winter profile - major oxygen deficit at deep end, well mixed and moderate oxygen depletion at west end
- $[\text{nitrogen}]_{total}$ = 0.436 mg/L (mesotrophic)
- $[\text{phosphorus}]_{total}$ = 0.026 mg/L
- nitrogen:phosphorus ratio = 16.8:1 (phosphorus limiting)
- pH = 7.8
- Secchi disk = 3.9 m

6. Watershed Characteristics:

- watershed area = 8.5 km^2

- Small, gently sloping watershed with surrounding forests of Interior Douglas fir. Lake is small and sheltered with large swamp at one end.

Rating: High Sensitivity

Summary:

Small mesotrophic lake. West end of lake is very shallow with aquatic plant growth, especially along the shoreline.

3.6 Sheridan Lake

3.6.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

Table 13. Sheridan Lake Morphometric Characteristics.

Parameter	CRD	Bathymetric
Size (km^2)	16.4	16.6
Perimeter (km)	51.5	39.6
Elevation (m)	1115	1115
Volume (million m^3)	115	121
Mean depth (m)	7	7.3

Sheridan Lake is similar to Bridge Lake in that it has an irregular shoreline and a few islands which contribute to site variability. It has a large volume and a large surface area (Figure 10). The mean depth of Sheridan Lake is 7.3 m, and therefore ranks moderate in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

Watershed Characteristics

The Sheridan Lake watershed has an area of approximately 81 km^2. The lake is surrounded by gentle rolling terrain with low volumes of water entering and leaving the lake. Water levels may fluctuate especially if the one outlet is clogged by trees or beaver dams sometimes reported to be a problem by local residents. Considerable logging and clearing has occurred, and there is some agriculture at the east end of the lake. Lakeshore development is considerable and scattered along the entire shoreline, however, the south side is largely made up of temporary residents. There are 4 resorts on the lake (Petch and Zirnhelt, 1996).

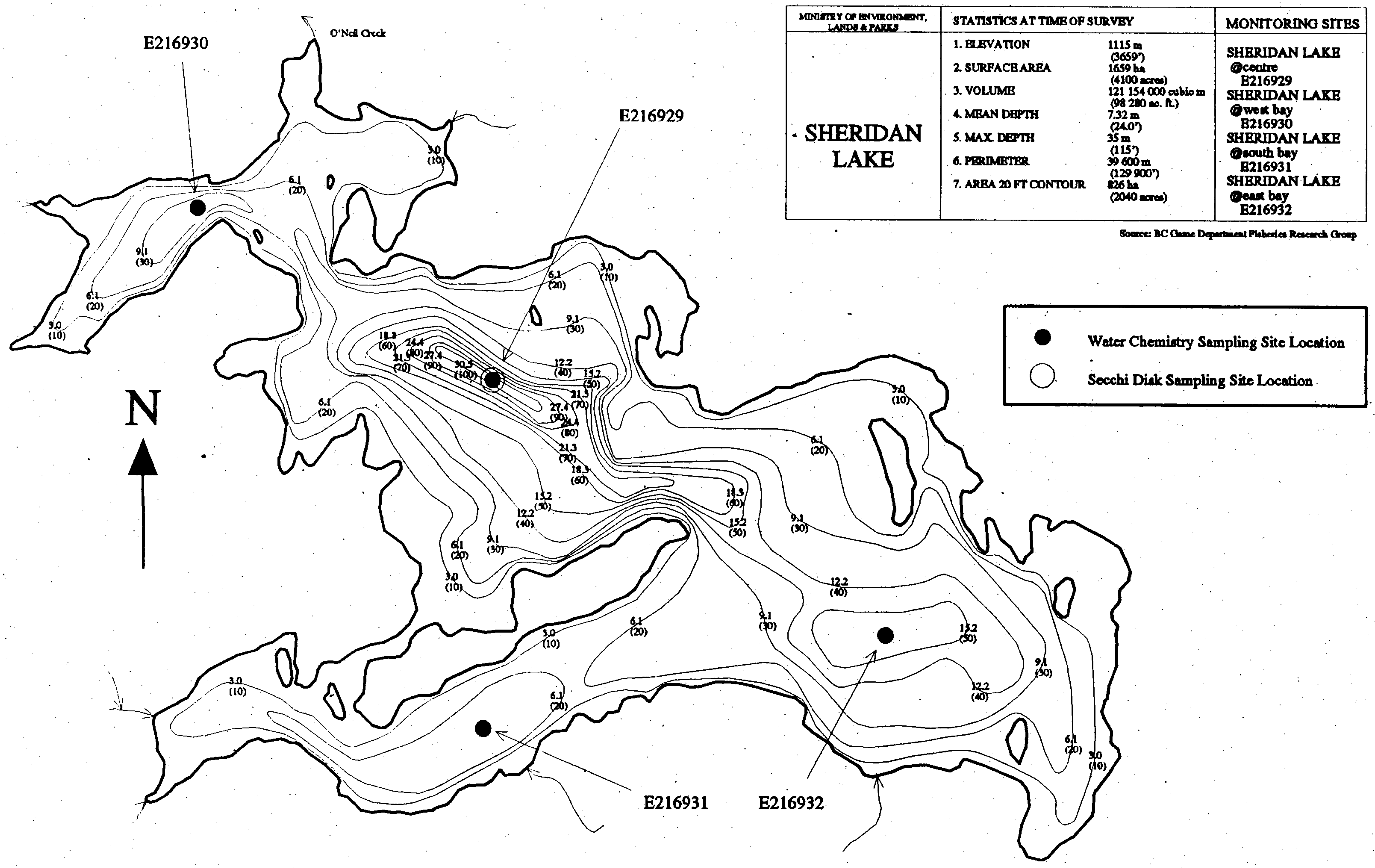


Figure 10. Bathymetric Map of Sheridan Lake Showing Monitoring Sites

Scale: 1 cm = 350 m

3.6.2 Temperature and Dissolved Oxygen

Winter DO

Winter and spring oxygen profiles indicate that Sheridan is a dimictic lake. In the 1996 winter profile, there was an oxygen deficit with depth and near anoxic conditions at the bottom in the hypolimnion, at deep sites such as at center where there are limited mechanisms of replenishment (Figure 11). Complete hypolimnetic anoxia may be unlikely since productivity is only moderate in Sheridan and demands on oxygen levels are lower. Sheridan Lake has an irregular shoreline and several islands which may enhance site profile variability.

Spring Overturn

1992 and 1996 data indicated that Sheridan Lake was well mixed at overturn as relatively uniform, unstratified profiles were observed (Figure 11). The 1982 overturn data also indicated the lake was mixed. Lower hypolimnetic DO levels in 1982 may be attributed to less wind mixing. Sheridan Lake has only moderate productivity and with adequate mixing at overturn is unlikely to experience extreme oxygen depletion in the hypoliminion during summer stratification.

3.6.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Sheridan Lake and presents the information in mean values. The N:P ratio indicates that phosphorus is likely the main limiting nutrient in Sheridan Lake (Sheridan N:P Ratio = 0.754 : 0.025 = 30.2 : 1). Based on nitrogen concentration, Sheridan Lake is eutrophic. A phosphorus level of 0.025 mg/L results in an estimated mean summer chlorophyll *a* of 5.72 mg/m^3, suggesting a mesotrophic classification.

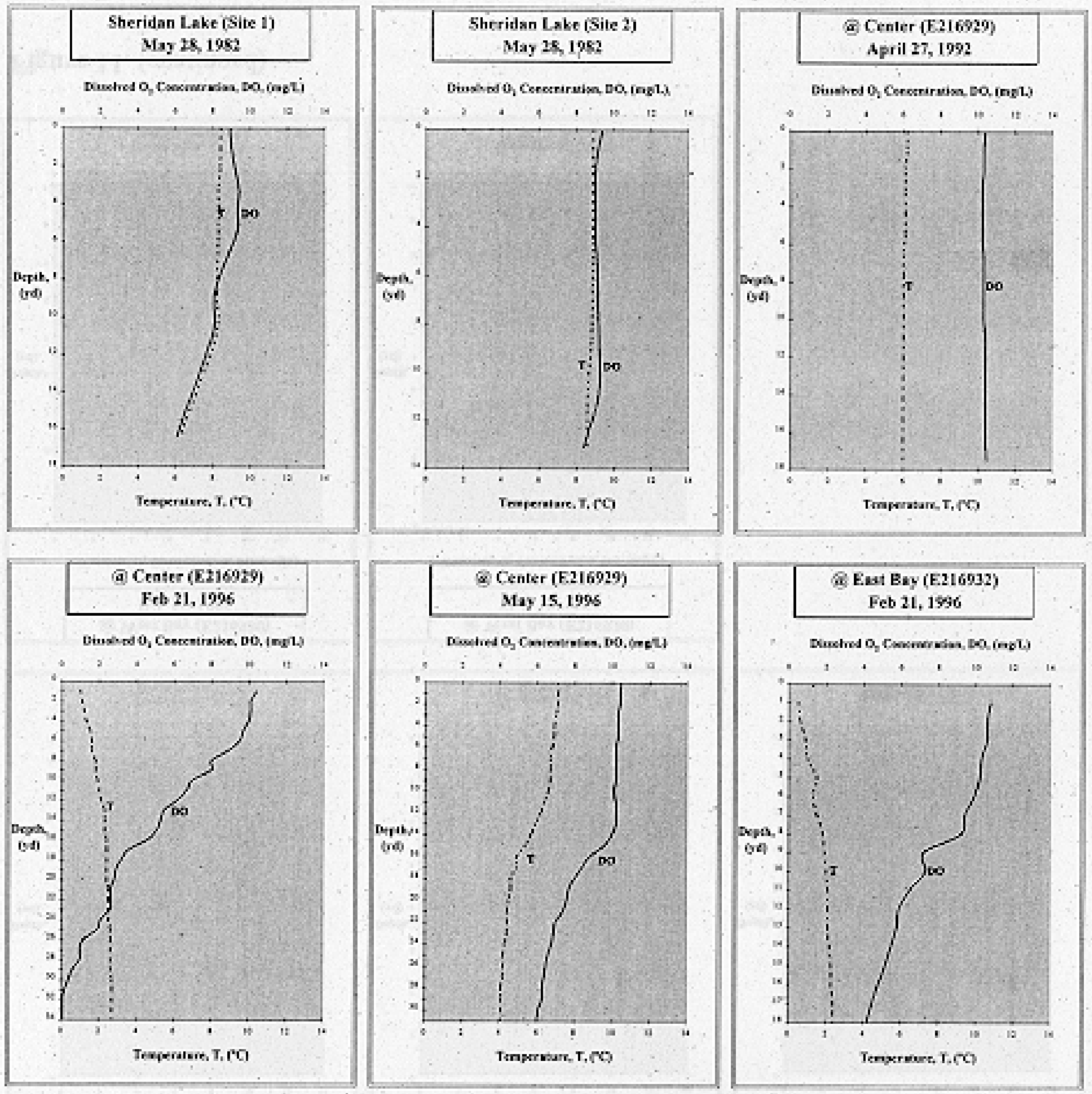


Figure 11. Sheridan Lake Dissolved Oxygen and Temperature Profiles (over...)

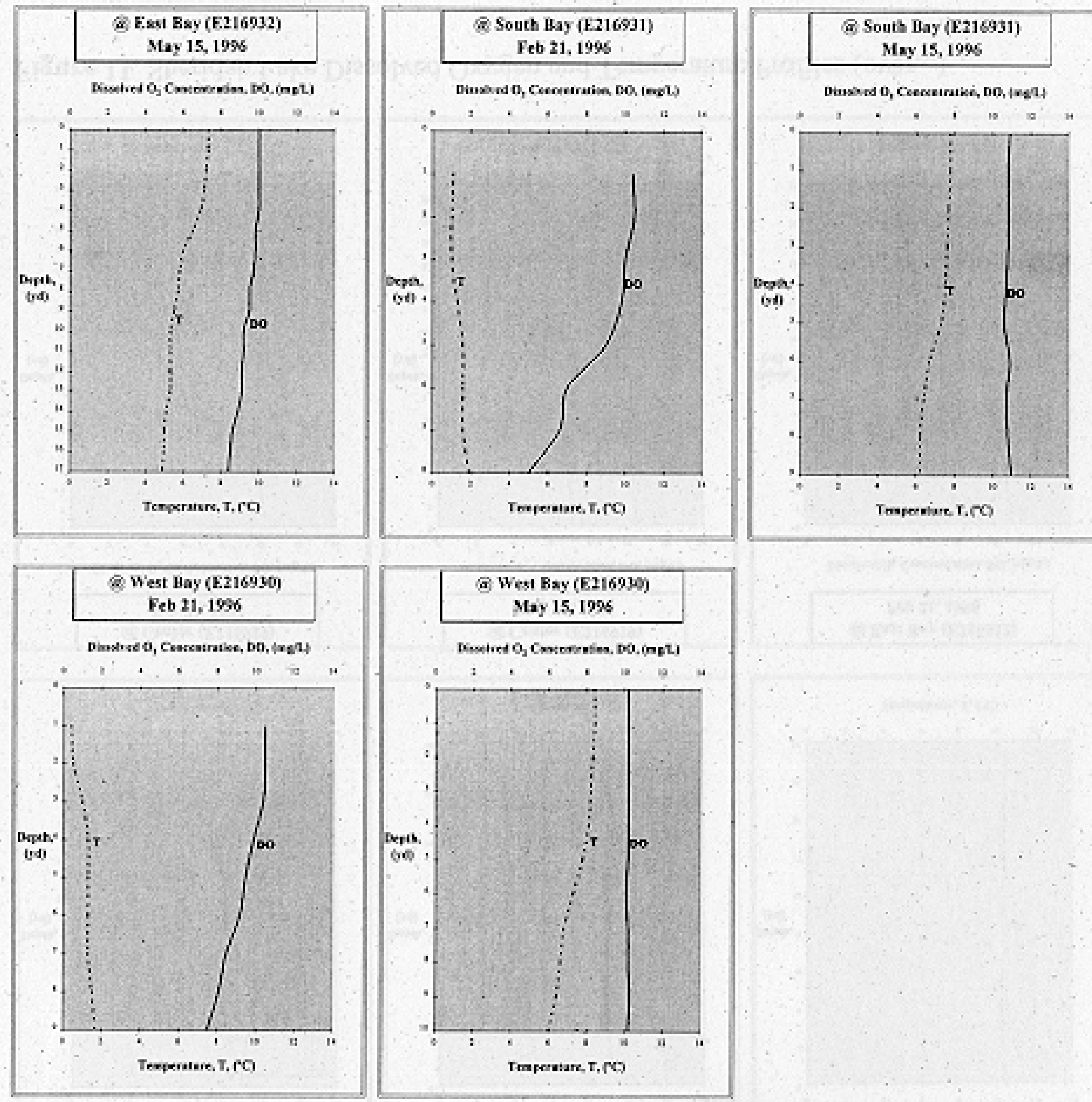


Figure 11. (continued)

3.6.4 Water Clarity

Secchi disk readings were collected on Sheridan Lake from May 15 to October 19, 1996 to show trends in lake clarity. The maximum recorded depth was 12.80 m, the minimum was 7.40 m and the average was 9.66 m (Liebe and Zirnhelt, 1996).

3.6.5 Flushing Rate and Nutrient Assimilation Capability

The following were used calculate the flushing rate.

(Step 1) Horse Lake Drainage

- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995, stn 08LA020)
- Drainage area = 830 km^2
- Mean annual flow/drainage area = 1.584/830 = 0.0019 c.m.s./km^2 for the outlet of Horse Lake

(Step 2) Sheridan Lake Drainage

- Drainage area = 81 km^2
- Mean flow at outlet of Sheridan Lake: 0.0019 c.m.s./km^2 * 81 km^2 = 0.15 c.m.s.
  (1 c.m.s. = 31.536 * 10^6 m^3/yr)

- Mean annual flow at outlet of Sheridan Lake

  0.15 c.m.s. * 31.536 * 10^6 m^3/yr = 4.87 * 10^6 m^3/yr

- Flushing rate = volume of lake / volume of flow at outlet
  = 121 * 10^6 m^3 / 4.87 * 10^6 m^3/yr
  = 24.9 yrs is the estimated flushing rate of Sheridan Lake

Based on the criteria in the CRD report (section 3.1), Sheridan Lake has a low ability to assimilate nutrients with an estimated flushing rate of 24.9 yrs.

3.6.6 Fluorometer Survey

The developed shoreline on Sheridan was surveyed using the fluorometer on July 10, 11 and 16, 1996. Sheridan lake has approximately 160 permanent residences (33%), and 319 seasonal residences. There were no high readings detected on Sheridan Lake (despite unusually high water levels) suggesting no significant discharges of sewage effluent to the lake.

According to the assessment methodology in Appendix I, the absence of elevated readings suggests no further investigation of the lake’s residential lakeshore septic systems is necessary at present. Sheridan Lake is likely not suffering detectable water quality degradation from septic systems.

3.6.7 Lake Evaluation Summary for Sheridan Lake

Base Information

Size: 16.6 km^2
Perimeter: 39.6 km
Elevation: 1115 m
Shoreline Ownership: private - 68%, crown - 32%
Other: very irregular shoreline, heavily utilised for fishing.

Lake Classification Factors - Water Quality

1. Trophic State: mesotrophic

- estimated summer chlorophyll *a* = 5.7 mg/m^3

2. Flushing Period: 24.9 years

3. Mean Depth: 7.3 m

4. Volume: 121 million m^3

5. Water Quality Indicators:

- dissolved oxygen - well mixed at spring overturn
- $[\text{nitrogen}]_{total}$ = 0.754 mg/L (eutrophic)
- $[\text{phosphorus}]_{total}$ = 0.025 mg/L
- nitrogen:phosphorus ratio = 30.2:1 (phosphorus limiting)
- pH = 8.5 (1992)
- Secchi disk = 9.66 m

6. Watershed Characteristics:

- watershed area = 81 km^2

- Gentle rolling terrain with low levels of water flow entering and leaving the lake. Considerable logging and clearing, some agriculture, scattered lakeshore development - potential high impact on water quality.

Rating: High Sensitivity

Summary:

Mesotrophic lake with very long flushing period. Relatively shallow depth. High sensitivity, particularily in localised areas.

3.7 Sulphurous Lake

3.7.1 Morphometric/Watershed Characteristics

Morphometric Characteristics

Table 14. Sulphurous Lake Morphometric Characteristics.

Parameter	CRD (1983)	Bathymetric Map (1996)
Size (km^2)	3.8	3.8
Perimeter (km)	13.2	14.2
Elevation (m)	1116	1116
Volume (million m^3)	57.8	58.4
Mean depth (m)	15.2	15.4

Sulphurous Lake contains an island but is otherwise a single basin (Figure 12). It has the second smallest area of the six lakes investigated, but has a relatively large volume because the mean depth is high. As the mean depth of a lake increases in relation to its volume its ability to assimilate additional nutrients increases. The mean depth of Sulphurous Lake is 15.2m and therefore ranks moderate to high in terms of its ability to assimilate additional nutrients such as phosphorus, without suffering a loss in water quality.

Watershed Characteristics

Sulphurous Lake has a small watershed area of 25.3 km^2. It is surrounded by forests of Interior Douglas fir and residential development is concentrated on the north shore of lake. The outlet flows into Deka Lake.

3.7.2 Temperature and Dissolved Oxygen

Winter DO

Winter and spring oxygen profiles (Figure 13) indicate that Sulphurous Lake may not mix entirely but it is likely a dimictic lake. In the winter, both sample sites on the

MINISTRY OF ENVIRONMENT, LANDS & PARKS	STATISTICS AT TIME OF SURVEY		MONITORING SITES
SULPHUROUS LAKE	1. ELEVATION	1116 m (3660 ')	SULPHUROUS LAKE @west end E222873 SULPHUROUS LAKE @deepest pt E222874
	2. SURFACE AREA	380.8 ha (941 acres)	
	3. VOLUME	58 442 000 cubic m (47 408 ac. ft.)	
	4. MEAN DEPTH	15.36 m (50.4')	
	5. MAX. DEPTH	46.93 m (154')	
	6. PERIMETER	14 198 m (46 580')	

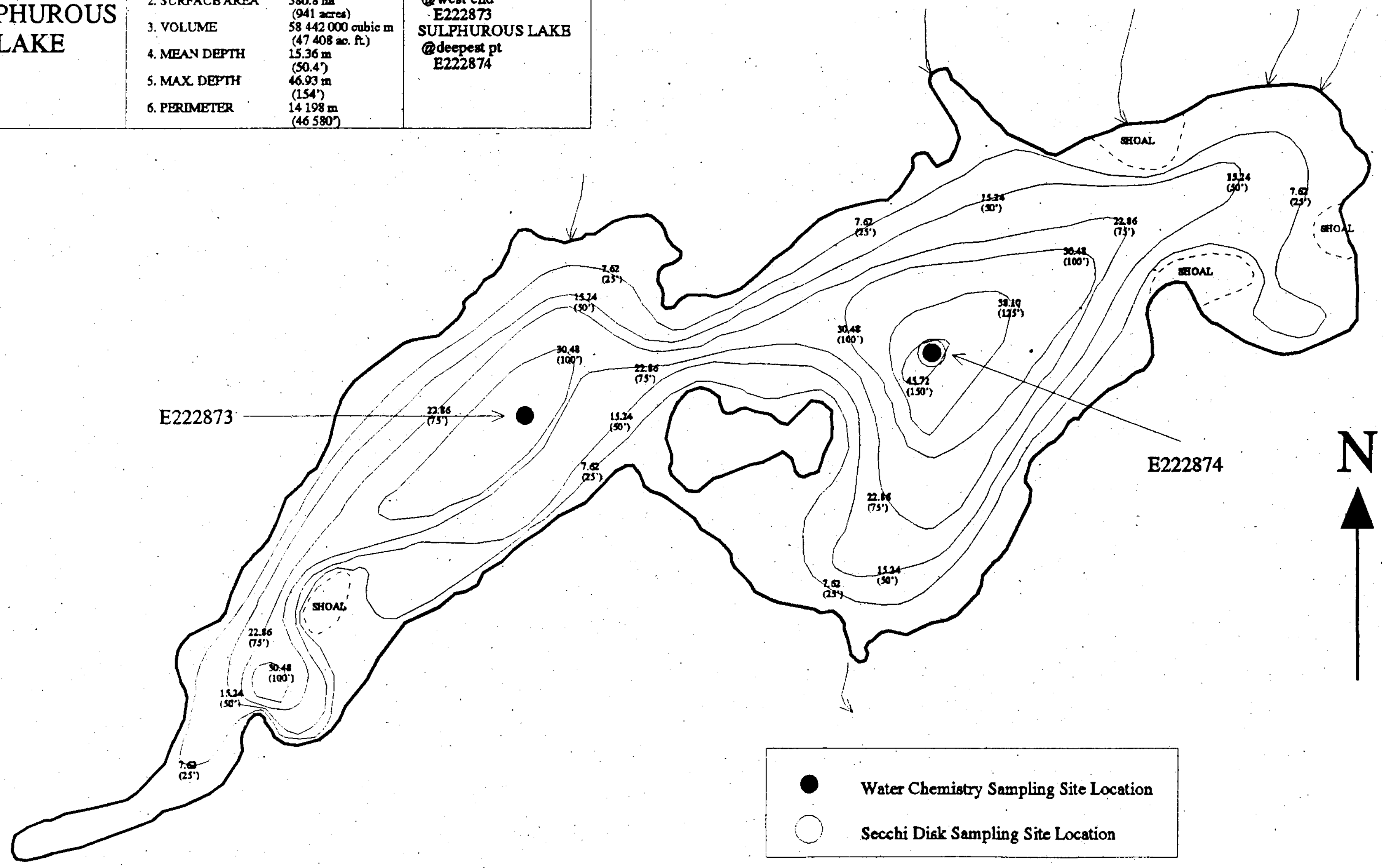


Figure 12. Bathymetric Map of Sulphurous Lake Showing Monitoring Sites Scale: 1 cm = 200 m

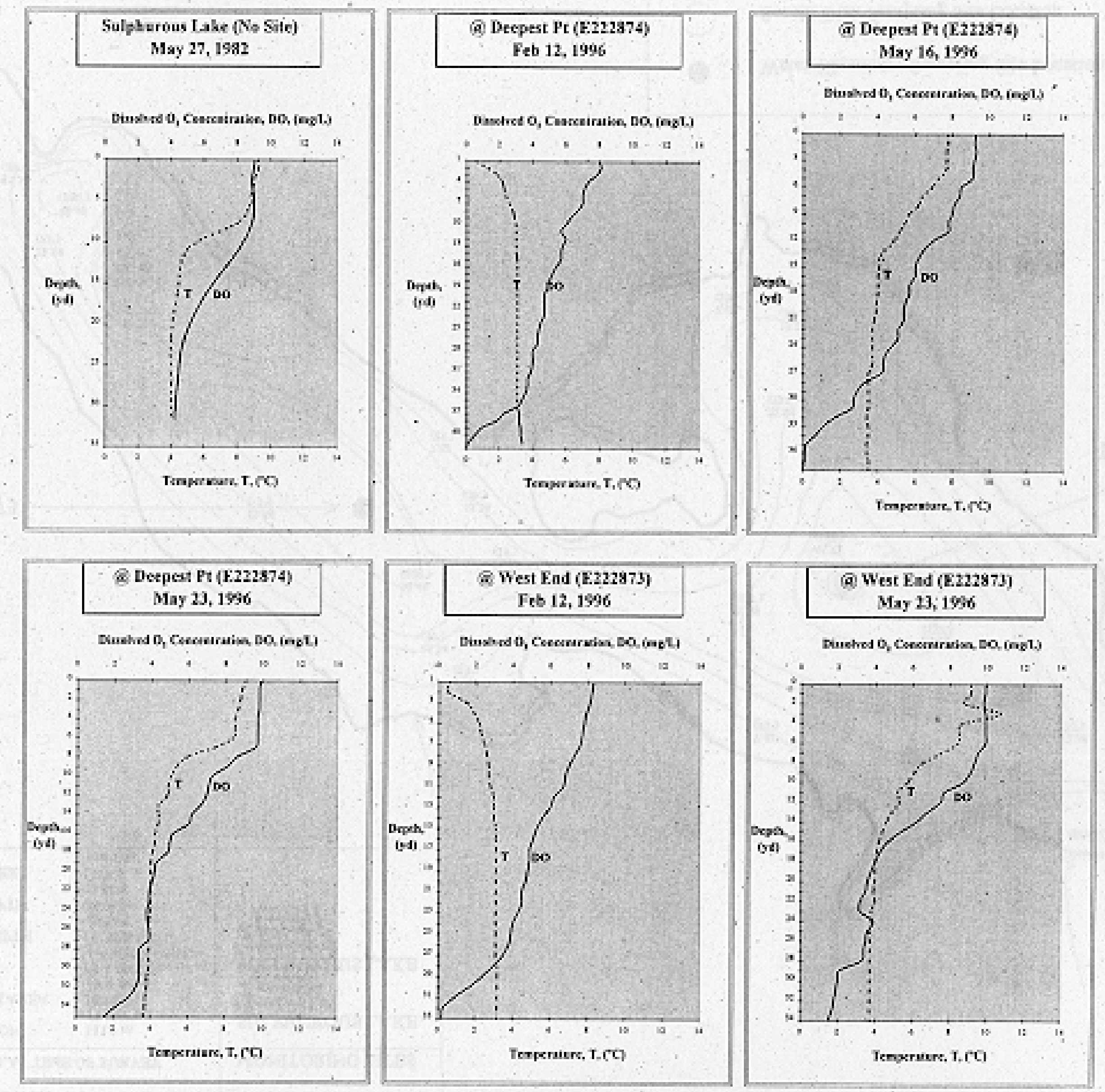


Figure 13. Sulphurous Lake Dissolved Oxygen and Temperature Profiles

lake showed similar profiles. Sulphurous Lake had low hypolimnetic oxygen levels in the winter suggesting limited mechanisms of replenishment (i.e. inadequate mixing at overturn). The 1996 winter DO profiles appeared to be unstratified but exhibited a constant gradient decreasing gradually with depth, except near the sediments where the DO dropped significantly (Figure 13).

Spring Overturn

In 1982 and 1996, overturn mixing was weak. DO profiles were collected twice in the spring of 1996 on Sulphurous Lake to determine when overturn was occurring. One sampling event was a few days post ice-off and one was a week later. Both days exhibited stratification suggesting poor mixing at overturn. At deep depths, oxygen levels were not zero and therefore it is likely that replenishment of hypolimnetic oxygen levels occurs in years when overturn winds are strong.

Although Sulphurous Lake seemed to behave like a meromictic lake in 1996 it is more likely dimictic, where the degree of mixing and lake circulation each varies depending on the strength of the winds at overturn.

3.7.3 Phosphorus and Nitrogen

Table 9 lists total nitrogen and total phosphorus for Sulphurous Lake and presents the information in mean values. It can be concluded that phosphorus is likely the main limiting nutrient in Sulphurous Lake (Sulphurous N:P Ratio = 0.339 : 0.012 = 28.2 : 1). Based nitrogen concentration, Sulphurous Lake is mesotrophic. A phosphorus level of 0.012 mg/L results in an estimated mean summer chlorophyll *a* of 2.77 mg/m^3, suggesting an oligotrophic status.

3.7.4 Water Clarity

Secchi disk readings were collected on Sulphurous Lake in 1996 from May 16 to October 17, 1996 to show trends in lake clarity. The maximum recorded depth was 11.20 m, the minimum was 4.90 m and the mean depth was 8.66 m (Liebe and Zirnhelt, 1996) which is relatively high compared to other Bridge Creek Basin lakes.

3.7.5 Flushing Rate and Nutrient Assimilation Capability

The following were used to calculate lake flushing rate.

(Step 1) ***Horse Lake Drainage***

- Mean annual flow = 1.584 c.m.s. (Water Survey of Canada 1995, stn 08LA020)
- Drainage area = 830 km^2
- Mean annual flow/drainage area = 1.584/830 = 0.0019 c.m.s./km^2 for the outlet of Horse Lake

(Step 2) ***Sulphurous Lake Drainage***

- Drainage area = 25.3 km^2
- Mean flow at outlet of Sulphurous Lake: 0.0019 c.m.s./km^2 * 25.3 km^2 = 0.048 c.m.s.
  (1 c.m.s = 31.536 * 10^6 m^3/yr.)

- Mean annual flow at outlet of Sulphurous Lake

  0.048 c.m.s. * 31.536 *10^6 m^3/yr = 1.52 * 10^6 m^3/yr.

- Flushing rate = volume of lake / volume of flow at outlet
  = 58.44 *10^6 m^3 / 1.52 *10^6 m^3/yr.
  = 38.4 yrs. is the estimated flushing rate for Sulphurous Lake

Based on the criteria in the CRD report, Sulphurous Lake has a low ability to assimilate nutrients with an estimated flushing rate of 38.4 yrs.

3.7.6 Fluorometer Survey

The developed shoreline on Sulphurous Lake, largely the north side, was surveyed using the fluorometer on July 18, 1996. Sulphurous Lake has approximately 40 permanent residences and 129 seasonal residences (Petch and Zirnhelt, 1996). There were no high readings detected suggesting no significant discharges of septic effluent to the lake.

According to the assessment methodology in Appendix I, the absence of elevated readings suggests no further investigation of the lake's residential lakeshore septic systems is necessary at present. Sulphurous Lake is likely not suffering detectable water quality degradation from septic systems.

3.7.7 Lake Evaluation Summary for Sulphurous Lake

Base Information

Size: 3.8 km^2
Perimeter: 14.2 km
Elevation: 1116 m
Shoreline Ownership: private - 38%, crown - 62%
Other: heavily concentrated development on north shore, one commercial resort.

Lake Classification Factors - Water Quality

1. Trophic State:

- estimated summer chlorophyll *a* = 2.8 mg/m^3 (oligotrophic)

2. Flushing Period: 38.4 years (based on limited data)

3. Mean Depth: 15.4 m

4. Volume: 58.4 million m^3

5. Water Quality Indicators:

- dissolved oxygen - spring overturn - stratification
  - winter profile - slight oxygen depletion at greater depths
- $[nitrogen]_{total}$ = 0.339 mg/L (mesotrophic)
- $[phosphorus]_{total}$ = 0.012 mg/L
- nitrogen:phosphorus ratio = 28.2:1 (phosphorus limiting)
- pH = 8.12
- Secchi disk = 8.66 m

6. Watershed Characteristics:

- watershed area = 25.3 km^2

- Small watershed with surrounding forests of Interior Douglas fir. Outlet flows into Deka Lake. Concentrated development on north shore of lake.

Rating: High Sensitivity

Summary:

Medium-sized, oligotrophic lake. Relatively high Secchi disk readings with low estimated chlorophyll *a* concentration. Potential for localised problems in concentrated development area.

4.0 SUMMARY

This section provides a summary of each lake's current water quality status. The trophic status of each lake is shown on Table 14 and Table 15 compares the 1983 lake sensitivity rating with the updated 1996 lake sensitivity rating.

Table 15. Trophic Status Comparison of Six High Priority Lakes in the Bridge Creek Basin.

Lake	Trophic Status
Bridge	mesotrophic, borderline eutrophic
Deka	oligotrophic, borderline mesotrophic
Horse	mesotrophic
Otter	mesotrophic
Sheridan	mesotrophic
Sulphurous	oligotrophic

Table 16. The 1983 CRD Lake Sensitivity Rating vs. the Updated 1996 Lake Sensitivity Rating for Six High Priority Lakes.

Lake	1983 CRD Water Quality Sensitivity Rating	1996 Water Quality Sensitivity Rating
Bridge	High	High
Deka	High	High
Horse	Moderate	High
Otter	High	High
Sheridan	High	High
Sulphurous	High	High

All lake sensitivity ratings remain the same in 1996 with the exception of Horse Lake which has been upgraded from moderate to high. This is because there is some indication phosphorus levels are increasing, and because of the lake's downstream position which makes it subject to runoff from many upstream land-uses. A comparison of phosphorus data between 1982/83 and 1996 for the six lakes is presented in Figure 14 and Table 17.

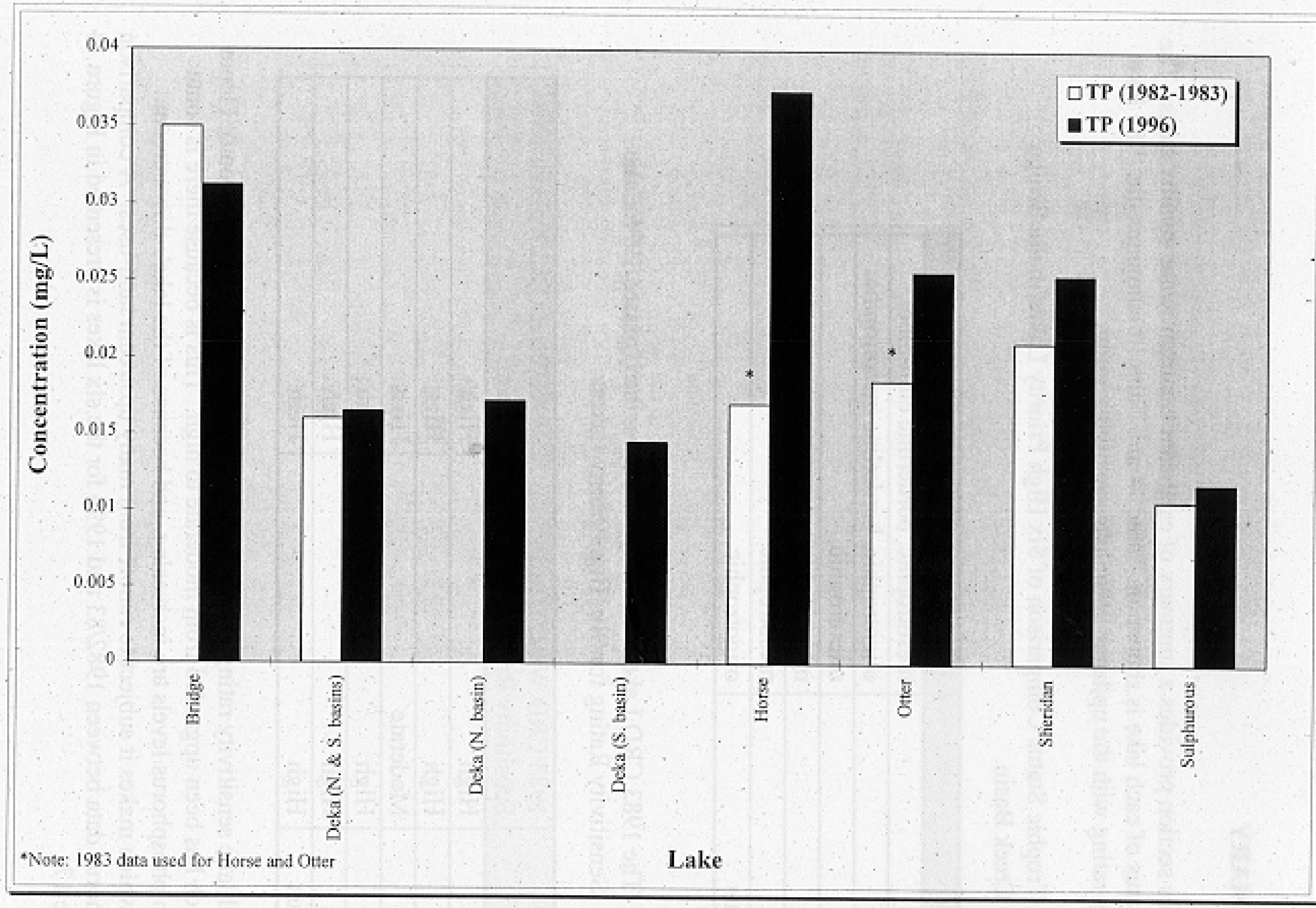


Figure 14. Spring Overturn Total Phosphorus (TP) Concentrations for Bridge Creek Basin High Priority Lakes (1982 -1996).

Table 17. Total Phosphorus (TP) and Total Dissolved Phosphorus (TDP) Concentrations for the Six High Priority Lakes - 1982 & 1983*

Bridge Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Site 1	CRD (82/05/28)	---	0.03	---
@ Site 2	CRD (82/05/28)	---	0.053	---
(No Site)	ASB (82/05/31)	0	0.022	0.011

$TP_{Average}$ = 0.035 mg/L

Horse Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Deepest Pt (0603100)	WMB(83/04/28)	0-15	0.016	0.007
@ East End (0603106)	WMB (83/04/28)	0-15	0.018	0.008

$TP_{Average}$ = 0.017 mg/L, $TDP_{Average}$ = 0.008 mg/L

Sheridan Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Site 1	CRD (82/05/28)	---	0.029	---
@ Site 2	CRD (82/05/28)	---	0.029	---
@ Site 3	CRD (82/05/28)	---	0.011	---
(No Site)	ASB (82/05/31)	0	0.015	0.008
@ Center (E216929)	F&W (92/04/27)	0.5	0.01	0.004
		10	0.012	0.005
		20	0.009	0.004
		33	0.012	0.005
@ East Bay (E216932)	F&W (92/04/27)	0.5	0.01	0.004
@ South Bay (E216931)	F&W (92/04/27)	0.5	0.01	0.003
@ West Bay (E216930)	F&W (92/04/27)	0.5	0.008	0.005

$TP_{Average}$ = 0.021 mg/L

Deka Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Site 1	CRD (82/05/27)	---	0.011	---
@ Site 2	CRD (82/05/27)	---	0.013	---
@ Site 3	CRD (82/05/27)	---	0.016	---
(No Site)	ASB (82/05/27)	0	0.024	0.013

$TP_{Average}$ = 0.016 mg/L

Otter Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Deep End (0803012)	WMB(83/05/09)	0	0.016	0.008
@ West End (0803013)	WMB (83/05/09)	0	0.021	0.01

$TP_{Average}$ = 0.019 mg/L, $TDP_{Average}$ = 0.009 mg/L

Sulphurous Lake

Sampling Site	Agency & Date	Depth (m)	TP (mg/L)	TDP (mg/L)
@ Site 1	CRD (82/05/27)	---	0.005	---
@ Site 2	CRD (82/05/27)	---	0.006	---
(No Site)	ASB (82/05/27)	0	0.021	0.008

$TP_{Average}$ = 0.011 mg/L

ASB = Aquatic Studies Branch (MELP)
CRD = Cariboo Regional District (Eco-Tech Laboratories)
F&W = Fish and Wildlife (MELP)
WMB = Waste Management Branch (MELP)

*Note: 1992 data included for Sheridan

Figure 14 shows that some lakes appear to have increased total phosphorus levels (Horse, Otter, and Sheridan), while others appear to have remained the same or decreased (Deka, Sulphurous, Bridge).

In interpreting this data a number of things must be kept in mind. First, natural variability, associated with annual climatic variation is to be expected and could explain a certain increase or decrease (Reckhow and Stow, 1990; Zirnhelt, unpublished data), and each lake will respond differently. Secondly, there was no quality assurance (checks on field and lab) or replication involved in the early 1980s data, rendering this data somewhat suspect in terms of absolute reliability.

With the forgoing in mind, only Horse Lake appears to have increased substantially from the early 1980s to the mid-1990s. As mentioned previously, Horse Lake water quality is the subject of a separate and more detailed report (Zirnhelt et.al., *in prep*.). While phosphorus levels may have increased in Horse Lake, its clarity has not decreased (Liebe and Zirnhelt, 1996) leading to the conclusion that water quality has not substantially declined (Zirnhelt, et.al., *in prep.*) Other Cariboo lakes (ie. outside of the Bridge Creek Basin) are illustrated in Figure 15 and show differing trends. Bouchie, Chimney and Felker Lakes appear to be increasing, Lac La Hache has remained the same, while Williams Lake has fluctuated quite dramatically.

The trophic status has not changed in any of the lakes since 1983 (Table 14). As discussed in Section 5.3.1, a number of factors contribute to determining lake trophic status and lake sensitivity, therefore it can be stated with confidence that overall, water quality has not been impaired in any substantive way over the last 13-15 years, for any of the six lakes. This conclusion is supported by the relatively clear water found in the lakes (Figure 16).

Fluorometer surveys did not indicate significant sewage contamination from residences that would suggest the need for further study, following the protocol developed by MELP (see Appendix I). The fluorometer surveys, combined with establishing the number of seasonal vs. permanent residences (Petch and Zirnhelt, 1996) has provided a baseline for future reference concerning residential sewage impacts.

Summaries of existing water quality data suggest that the 1983 data provides an ***indication*** of baseline conditions, however adequate baseline for future reference will require data to be collected in at least 1997 and 1998 at spring overturn. Three years data collection with quality assurance built into sampling programs is considered a minimum to adequately reflect baseline conditions.

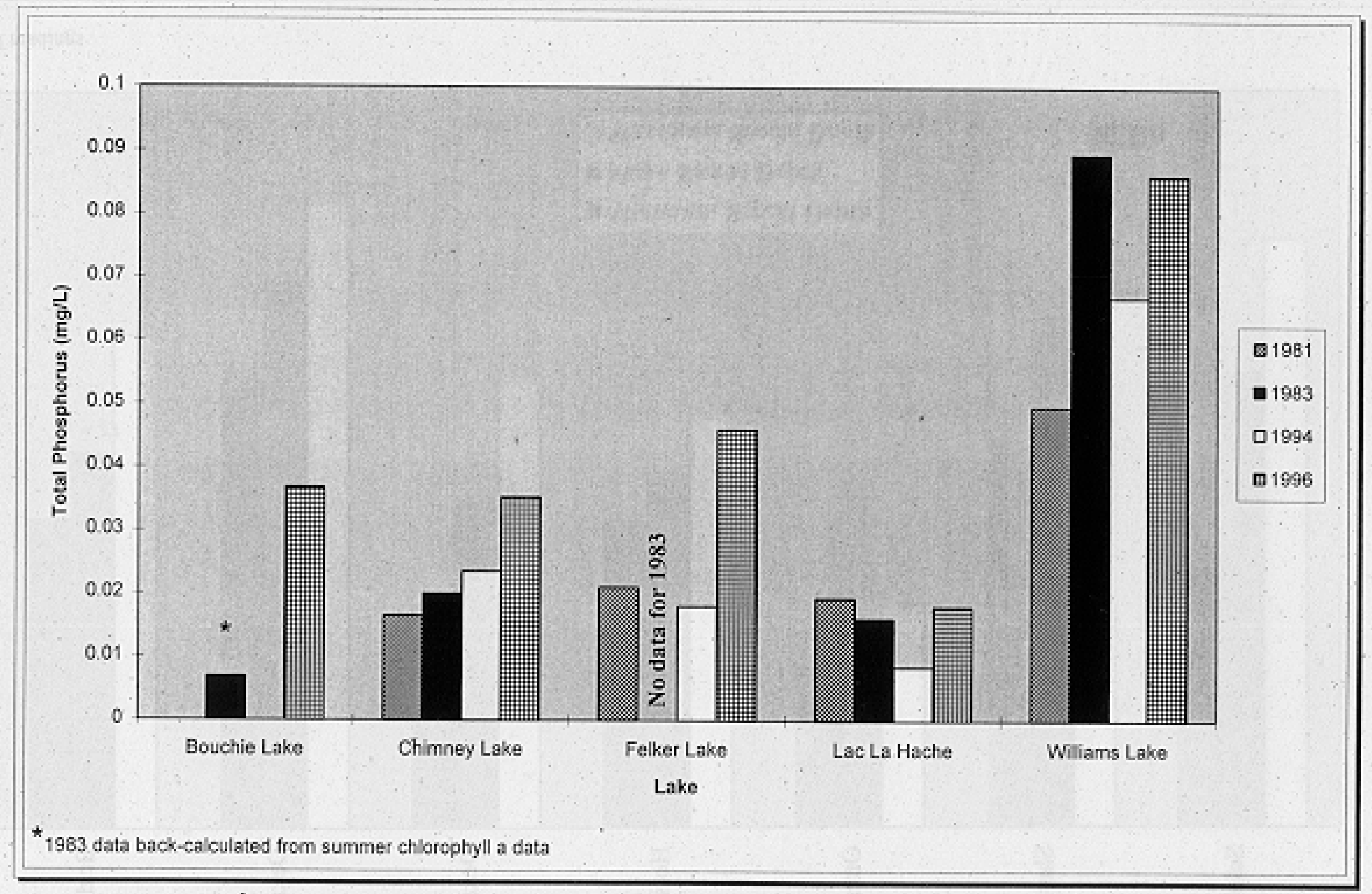


Figure 15: Spring Overturn Total Phosphorus Concentrations for Cariboo lakes.

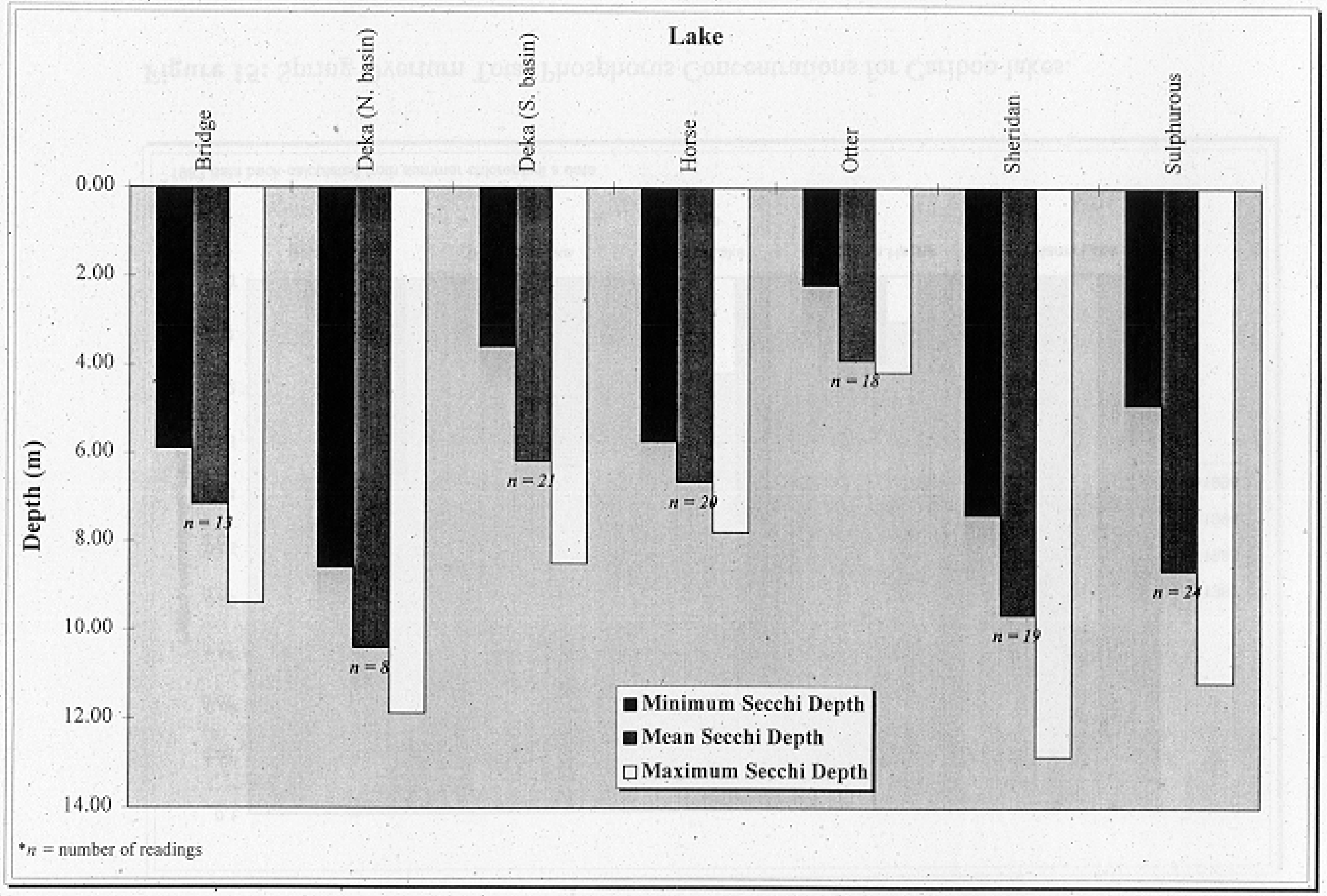


Figure 16. Minimum, Mean, and Maximum Secchi Depths for Bridge Creek Basin High Priority Lakes - 1996

Expansion of the volunteer monitoring program has been suggested by others (Michener, 1996) and the costs/logistics discussed in depth by Liebe and Zirnhelt (1996). This report has demonstrated the utility of overturn monitoring and lake sensitivity ratings. This is a less expensive way to assess lake water quality than regular sampling through the summer months. The addition of spring overturn water chemistry monitoring to the volunteer Secchi disk program is suggested for a minimum of three years.

5.0 CONCLUSIONS AND RECOMMENDATIONS

1. With the exception of Horse Lake which is the subject of another report, all available water quality data up to 1996 for the six lakes was summarized in this report.

2. The trophic status and water quality sensitivity ratings were reviewed and updated where required for each of the six lakes. Lake sensitivity ratings derived by the Cariboo Regional District in 1983 have not changed after re-evaluation with 1996 water quality data, with the exception of Horse Lake which has been upgraded from moderate to high.

3. Water quality does not seem to have deteriorated over the period 1982 to 1996. However it is recommended that additional monitoring be done at spring overturn in 1997 and 1998 to ensure an adequate assessment of present water quality conditions for future comparisons. This includes better representation of samples from anoxic strata at overturn.

4. For the lakes in the Bridge Creek Basin that have volunteers collecting Secchi (clarity) data, consideration should be given to sampling them during spring overturn for two or three years for baseline purposes.

5. Fluorometer surveys of the six lakes did not indicate that further assessment of residential septic systems is warranted, however a baseline has been established for assessment of potential residential impacts in the future.

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APPENDICES

APPENDIX I - Assessment Methodology

Assessment Methodology

Suspect Septic Seepage into Lake[1]

Synoptic Fluorometer Survey of Lakeshore[2]

Few Peaks

Lower Priority Lake

Go to Next Lake

Many Peaks

Conduct "Worst Case" Analysis[3] of Phosphorus Contribution Potential from Residences

Residences Contribute ≤ 5% of Total P Loading

Low Priority for Further Assessment

Residences Contribute > 5% of Total P Loading

High Priority for Water Quality Assessment and Soil P Adsorption Capability Assessment

Schematic of Staged Approach to Assessing Septic Seepage in Lakes using a Fluorometer for Initial Survey (From Petch, 1996).

[1] Possible triggers of a seepage investigation might be increases in localized shoreline algae, an increase in foreshore development or an inquiry.

[2] Synoptic survey includes inspecting local land use practices, secondary water chemistry and bacteriology sampling where a high reading is located. As well, a sample must be taken from an unimpacted background site to show site variability.

[3] "Worst Case" Analysis: septic system loading to a lake is considered relative to the total phosphorus (TP) loading to the lake by assuming that all septic systems within 200 m of the lake are discharging directly (obviously not the case). If this analysis results in an estimate of ≤ 5% of TP loading, then the lake will be low priority for further assessment. If estimates suggest that residences contribute > 5% of TP loading to the lake, then the lake will assume high priority for water quality assessment and a soil P adsorption capability assessment. Five percent is an arbitrary number which is suggested to indicate the difference between a significant and insignificant contribution to the lake's TP loading by lakeshore residences. It arises from the necessity to prioritize lakes for assessment.

APPENDIX II - 1996 Fluorometer Data Results

1996 Fluorometer Data Results

1996 Fluorometer Sampling - Secondary Sampling Results
File: 77500-20/Bridge Lk

1. 96/07/23 High Reading at Bridge Lake @ Creek Outlet [NOSITE] (creek is unnamed)

Variable	High Reading Sites		Background	DI Blank
	Rep 1	Rep 2		
Field Depth (m)	0.5	0.5	0.5	0.5
Total Coliform (cfu/100 mL)	2900	2800	34	
Fecal Coliform (cfu/100 mL)	48	24	<1	
E. Coli (cfu/100 mL)	1	4	<1	
Bromide Ion (mg/L)	<0.05	<0.05	<0.05	<0.05
Chloride Ion (mg/L)	4	4	2	0.1
Fluoride Ion (mg/L)	0.09	0.4	0.05	<0.01
Conductivity (*uS*/cm)	329	338	214	3
NH_3 (mg/L)	0.005	0.045	0.007	<0.002
NO_2 (nitrite) (mg/L)	<0.005	<0.005	<0.005	<0.005
NO_3 (nitrate) (mg/L)	0.056	0.055	0.056	<0.002
TN (mg/L)	0.62	0.62	0.36	0.07
Ortho-P (mg/L)	0.023	0.026	<0.001	0.002
TDP (mg/L)	0.056	0.053	0.012	<0.002
TP (mg/L)	0.061	0.057	0.01	0.003
SO_4 (mg/L)	2	2	4	<0.5
Total Inorganic Carbon (mg/L)	38.2	39.4	24.9	
Total Organic Carbon (mg/L)	8.2	8.8	4.7	

1996 Fluorometer Sampling - Secondary Sampling Results
File: 77500-20/Horse Lk

2. 96/07/09 High Reading at Horse Lake @ Attwood Cr. Outlet [NOSITE]

Variable	High Reading Site		Background	DI Blank
	Rep 1	Rep 2		
Field Depth (m)	0.5	0.5	0.5	n/a
Total Coliform (cfu/100 mL)	7600	11000	4	
Fecal Coliform (cfu/100 mL)	6700	13000	<1	
E. Coli (cfu/100 mL)	1700	7600	<1	
Bromide Ion (mg/L)	<0.05	<0.05	<0.05	<0.05
Chloride Ion (mg/L)	8.37	8.13	4.08	<0.1
Fluoride Ion (mg/L)	0.22	0.2	0.16	<0.01
Conductivity (uS/cm)	530	516	279	2
NH_3 (mg/L)	0.019	0.018	0.071	0.018
NO_2 (nitrite) (mg/L)	<0.005	<0.005	<0.005	<0.005
NO_3 (nitrate) (mg/L)	0.028	0.024	0.03	0.002
TN (mg/L)	0.89	0.91	0.39	<.02
Ortho-P (mg/L)	0.005	0.006	0.002	0.001
TDP (mg/L)	0.039	0.041	0.018	<0.002
TP (mg/L)	0.054	0.047	0.023	<0.002
SO_4 (mg/L)	0.95	0.96	2.5	<0.50
Turbidity (FTU)	2.2	2.4	0.85	0.2
Total Inorganic Carbon (mg/L)	67.3	67.3		
Total Organic Carbon (mg/L)	16.4	16.8		

1996 Fluorometer Sampling - Secondary Sampling Results
File: 77500-20/Horse Lk

3. 96/07/09 Horse Lake @ Fawn Cr. Outlet [NOSITE]

Variable	**High Reading Sites**		**Background**	**DI Blank**
	Rep 1	Rep 2		
Field Depth (m)	0.5	0.5	0.5	n/a
Total Coliform (cfu/100 mL)	59	46	4	
Fecal Coliform (cfu/100 mL)	3	6	<1	
E. Coli (cfu/100 mL)	1	<1	<1	
Bromide Ion (mg/L)	<0.05	<0.05	<0.05	<0.05
Chloride Ion (mg/L)	4.2	4.11	4.08	<0.1
Fluoride Ion (mg/L)	0.15	0.15	0.16	<0.01
Conductivity (*u*S/cm)	286	275	279	2
NH_3 (mg/L)	0.041	0.034	0.071	0.018
NO_2 (nitrite) (mg/L)	<0.005	<0.005	<0.005	<0.005
NO_3 (nitrate) (mg/L)	0.007	0.024	0.03	0.002
TN (mg/L)	0.43	0.46	0.39	<.02
Ortho-P (mg/L)	0.003	0.004	0.002	0.001
TDP (mg/L)	0.017	0.017	0.018	<0.002
TP(mg/L)	0.024	0.024	0.023	<0.002
SO_4 (mg/L)	2.4	2.3	2.5	<0.50
Turbidity (FTU)	0.8	0.85	0.85	0.2
Total Inorganic Carbon (mg/L)	34.5	34.5	32.7	
Total Organic Carbon (mg/L)	6.7	7	6.4	

1996 Fluorometer Sampling - Secondary Sampling Results
File: 77500-20/Horse Lk

4. 96/06/27 Horse Lake @ S. Central at Boat Launch [NOSITE]

Variable	High Reading Sites		Background	DI Blank
	Rep 1	Rep 2		
Total Coliform (cfu/100 mL)	49	89	<1	
Fecal Coliform (cfu/100 mL)	18	43	<1	
E. Coli (cfu/100 mL)	15	12	<1	
Bromide Ion (mg/L)	<0.05	<0.05	<0.05	<0.05
Chloride Ion (mg/L)	16	16.6	4.69	<0.1
Fluoride Ion (mg/L)	0.22	0.17	0.2	<0.01
Conductivity (*uS*/cm)	433	442	287	2
Field Depth (m)	0.5	0.5	0.5	n/a
NH_3 (mg/L)	0.016	0.012	0.034	0.018
NO_2 (nitrite) (mg/L)	<0.005	<0.005	<0.005	<0.005
NO_3 (nitrate) (mg/L)	<0.007	<0.002	0.002	0.002
TN (mg/L)	0.58	0.61	0.36	<.02
Ortho-P (mg/L)	0.007	0.007	0.002	0.001
TDP (mg/L)	0.052	0.053	0.029	<0.002
TP (mg/L)	0.062	0.062	0.029	<0.002
SO_4 (mg/L)	<0.5	0.85	2.6	<0.05
Turbidity (FTU)	1.1	1.1	0.33	

Appendix III.   1996 Hydrolab Data

Hydrolab Data

Station: BRIDGE LK @ NORTH END
SEAM Number: E222871
Date: 96 05 22
Crew: TB and RP

Water Conditions: rippled
Weather Cloudy
Secchi: 6.4 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
1340	0.5	8.03	7.57	11.66	227	6.3
1344	10.0	9.12	5.35	11.63	236	3.9
1346	20.0	8.02	4.00	10.57	248	4.0
1349	40.0	7.98	3.87	9.76	249	4.1

Station: BRIDGE LAKE @ DEEPEST POINT
SEAM Number: E222870
Date: 96. 05 22
Crew: TB + RP

Water Conditions: wavy
Weather cloudy, rainy, windy
Secchi:

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
14:48	0.5 m	8.02	7.55	11.05	227	3.3
14:48	10.0 m	8.01	5.14	10.84	242	4.2
14:49	16.0 m	7.92	4.42	9.75	247	4.2
14:54	32.0 m	7.74	3.68	7.02	254	5.1

Station: ~~[illegible]~~ BRIDGE LAKE @ EAST END
SEAM Number: E222869
Date: 96/05/22
Crew: TB RAP

Water Conditions: RIPPLED
Weather RAIN
Secchi: 4.44 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
11:16	0.5	8.24	6.74	11.39	238	4.2
11:26	14.0	8.16	4.18	9.30	250	4.5
11:33	28.0	8.10	3.95	8.04	252	4.6

Hydrolab Data

Station: Bridge Lake @ West End
SEAM Number: E222872
Date: 96 05 22
Crew: TB & RP

Water Conditions: slight ripple
Weather cloudy
Secchi: 5.45

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
12:34	0.5 m	8.13	8.47	11.62	227	3.1
12:37	10.0 m	7.99	4.50	9.50	254	4.5
12:40	18.0 m	7.59	3.37	0.35	272	4.6

Station: OTTER LAKE @ WEST END
SEAM Number: 0803013
Date: 96 05 28
Crew: TB & RP

Water Conditions: rippled
Weather cloudy, slight wind
Secchi: 2.25

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
[illegible]	0.5	8.21	12.4	10.15	150	8.3
1140	1.0 m	8.22	12.32	10.16	149	8.4
1145	2.0 m	8.24	12.02	10.14	149	8.6
1151	2.5	8.23	11.32	10.19	145	30.0 BOTTOM

Station: OTTER LAKE @ DEEP END
SEAM Number: 0803012
Date: 96 05 28
Crew: TB & RP

Water Conditions: rippled
Weather cloudy slight wind
Secchi: 2.0

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
12:15	0.5 m	8.23	12.83	10.05	150	9.4
12:20	1.0 m	8.24	12.73	9.94	151	9.5
12:23	3.0 m	8.20	12.15	9.92	154	9.5
12:29	6.0 m	7.63	5.34	1.17	185	9.3
12:38	12.0 m	7.40	4.16	0.14	260	10.6
12:43	15.0 m	7.36	4.19	0.11	268	10.8

Hydrolab Data

Station: DEKA LAKE @ DEEP
SEAM Number: E222966
Date: 96 05 23
Crew: TB : RP

Water Conditions: calm
Weather: cloudy
Secchi: 7.75

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
1228	0.5m	8.11	8.10	10.56	55	5.1
1233	10.0m	8.14	6.24	11.15	191	5.5
1235	20.0	8.05	4.71	10.98	196	5.4
		~~8.02~~	~~4.15~~	~~10.65~~		
1239	39.0	8.01	4.1	10.62	197	5.3
1246	50.0	7.95	3.96	10.54	196	5.3
1248	60.0	7.93	3.92	10.33	197	5.4
1250	**65.0**	7.82	3.72	9.91	197	5.4

Station: DEKA LAKE @ CENTRE
SEAM Number: E222867
Date: 96 05 23
Crew: TB and RP

Water Conditions: calm
Weather: cloudy / sunny
Secchi: 8.50

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
11.36	0.5m	8.17	6.99	11.21	189	5.0
11.39	17.0m	8.02	4.81	11.06	195	5.2
11.42	34.0m	7.92	4.20	10.45	192	5.3

Hydrolab Data

Station: DEKA LAKE [illegible] SOUTH END
SEAM Number: [illegible]
Date: [illegible] 5/23
Crew: [illegible] + RAF

Water Conditions: [illegible]
Weather [illegible]
Secchi: 3.[illegible]5 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
9:25	0.5	8.18	9.38	10.82	202	[illegible]
	1.0			10.79		
	2.0			10.77		
	3.0			10.73		
	4.0			10.63		
9:32	5.0	8.06	8.51	10.20	208	5.5
	6.0			9.86		
	7.0			9.11		
	8.0			8.93		
	9.0			8.73		
	10.0			6.40		
9:44	11.0	7.64	5.49	5.67	221	5.9
	12.0			5.51		
	13.0			4.45		
	14.0			2.54		
	15.0			1.91		
	16.0			1.76		
	17.0			1.69		
	18.0			1.58		
	19.0			1.47		
	20.0			1.43		
	21.0			1.41		
9:55	22.0	7.48	4.46	1.22	23[illegible]	6.5
	23.0			~~[illegible]~~ 1.10		
	24.0			0.95		
	25.0			[illegible]		

Hydrolab Data

Station: HORSE LAKE @ DESPSST POINT
SEAM Number: 0603100
Date: 96 05 01
Crew: TB : RP

Water Conditions: windy - ripples
Weather: Sunny
Secchi: 4.50 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
1247	0.5	8.22	4.05	10.46	306	1.9
1254	5.0	8.22	3.91	10.39	304	2.3
1256	10.0	8.23	3.78	10.21	308	2.0
1257	17.0	8.22	3.55	9.93	310	1.9
1259	25.0	8.21	3.57	9.72	312	1.7
1303	32.0	8.17	3.55	8.90	317	1.9

Station: HORSE LAKE @ EAST END
SEAM Number: 0603101
Date: 96 05 01
Crew: TB : RP

Water Conditions: windy ripples
Weather: Sunny with some clouds
Secchi: 3.3

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
1401	0.5	8.20	4.5	10.95	289	1.7
1402	5.0	8.20	4.08	10.55	301	1.8
1405	10.0	8.19	3.14	10.18	308	1.7
1406	14.0	8.20	3.71	10.22	312	1.7
1412	26.0	8.00	3.40	6.40	325	2.3

Station: HORSE LAKE @ WEST END
SEAM Number: 0603099
Date: 96 05 01
Crew: TB : RP

Water Conditions: windy
Weather: Sunny
Secchi: 3.66

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
11:34	0.5	8.34	3.97	10.55	310	1.4
11:37	5.0	8.30	3.86	10.37	309	1.4
1139	10.0	8.30	3.86	10.27	311	1.7
1141	15.0	8.30	3.87	10.23	307	1.6
1142	22.0	8.26	3.67	9.63	314	1.9

Hydrolab Data

Station: SHERIDAN LK @ EAST BAY
SEAM Number: E216932
Date: 96 05 15
Crew: RP & TB

Water Conditions: wavy / rippled
Weather: cloudy
Secchi: 4.75

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
14:12	0.5	8.53	7.26	10.92	440	1.8
14:14	5.0	8.54	6.25	10.65	454	1.2
14:15	10.0	8.54	5.42	10.18	467	1.2
14:18	15.0	8.51	5.00	9.38	475	1.2

Station: SHERIDAN LK @ CENTER
SEAM Number: E216929
Date: 96 05 15
Crew: [illegible]

Water Conditions: rippled
Weather: Sunny w/ clouds
Secchi: 10.25 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
12:09	0.5	8.03	7.17	11.24	435	3.6
12:14	10.0	8.34	6.26	11.04	450	1.5
12:16	15.0	8.31	4.99	9.54	476	1.5
12:18	25.0	8.30	4.30	7.27	[illegible]	1.6
12:19	30.0	8.21	4.19	6.65	[illegible]	7.3

Station: SHERIDAN LK @ SOUTH BAY
SEAM Number: E216931
Date: 96 05 15
Crew: [illegible]

Water Conditions: rippled
Weather: Sunny with clouds.
Secchi: 5.0 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
13:37	0.5	8.85	7.90	11.85	449	1.9
13:39	5.0	8.49	7.14	11.76	440	1.3
13:40	7.0	8.50	6.30	12.05	463	1.4

Hydrolab Data

Station: SHERIDAN LK @ WEST BAY
SEAM Number: E216930
Date: 96 05 15
Crew: TB & RP

Water Conditions: rippled and wavy
Weather: cloudy
Secchi: 4.70m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
12:45	0.5	8.30	8.47	11.04	440	1.5
12:52	5.0	8.39	7.58	11.10	445	1.2
12:53	8.0	8.41	6.37	11.40	459	1.1

Station: SULPHUROUS LAKE @ WEST END
SEAM Number: E222873
Date: 96 05 23
Crew: TB & RP

Water Conditions: calm
Weather: cloudy
Secchi: 7.06 m

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
14:41	0.5	8.27	9.30	10.25	253	0.8
14:44	5.0	8.32	8.52	10.41	264	0.7
14:52	15.0	7.75	4.12	4.63	288	1.3
14:49	30.0	7.72	3.81	2.38	294	1.2

Station: SULPHUROUS LAKE @ DEEPEST PT
SEAM Number: E222874
Date: 96 05 23
Crew: TB & RP

Water Conditions: slight ripple
Weather: [illegible]
Secchi: 6.35

Time (24 hour clock)	Depth(m)	pH	Temp(°C)	Dissolved Oxygen (mg/L)	Conductivity	Turbidity (NTU)
15:30	0.5	8.26	9.16	10.16	261	0.0
15:32	5.0	8.30	8.44	10.26	262	1.1
15:36	15.0	7.92	4.35	6.22	288	1.2
15:39	30.0	7.73	3.80	2.55	293	1.4

APPENDIX IV - Miscellaneous Water Quality Data/Quality Assurance Data and Calculations

Quality Assurance/Quality Control

During the 1996 overturn field sampling program, a number of quality assurance/ quality control samples were collected to assess the overall quality of the data. One equipment blank, one de-ionized water blank, and one set of surface replicate samples were collected at each of the lakes.

Data Quality Objectives

Field blanks

As the values reported for the equipment blanks were similar to those reported for de-ionized water blanks, all blanks were included when calculating the system detection limit and system limit of quantification for each of the parameters. The system detection limit (SDL) refers to the concentration at which the method of analysis will likely report a true positive and the system limit of quantification (SLQ) refers to the concentration above which the method of analysis will report values falling within ± 30% of the true value (Pommen, pers. comm.). The equation used to determine the SDL is as follows:

*SDL = mean field blank + 3 * SD of field blanks*

Two different equations were used to determine the system limit of quantification. For parameters with blanks reporting values in excess of their method detection limit (MDL) the following equation was used to calculate the SLQ:

*SLQ = mean of field blanks ± 10 *SD of field*

For parameters with no exceedances of their MDL the following equation was used to calculate their SLQ:

*SLQ = 3.3 * SDL*

Parameters with environmental concentrations equal to or exceeding their SLQs are more reliable than parameters with environmental concentrations falling below their Therefore to have confidence in the data the minimum environmental levels for each parameter should be above the SLQ for that parameter.

Replicates

The percent difference was calculated to determine the precision of the data. Duplicate samples with a percent difference of greater than 25% were marked with a black box and white text (Replicate Samples). The percent of duplicate samples for each of the parameters was then calculated.

Phosphorus Data Quality

As phosphorus is the main parameter of interest in the water quality assessment of the six lakes presented in this report, the results of the quality assurance/ quality control assessment for phosphorus are presented. A Quality Assurance/ Quality Control assessment of the other parameters collected during this sampling program will be discussed in. the 1997 up-date of this report.

All 1996 total phosphorus values were reported above the SLQ for total phosphorus, suggesting the data is reliable. Total dissolved phosphorus concentrations for all of the lakes, with the exception of Sulphurous Lake, were greater than the SLQ for total dissolved phosphorus. Sulphurous Lake is believed to be a marl lake causing the precipitation of dissolved phosphorus from the water column, resulting in low total dissolved phosphorus levels. These low levels cause Sulphurous Lake's total dissolved phosphorus concentrations to be lower than the total dissolved phosphorus SLQ, making the data unreliable. None of the six lakes reported all of its values above the SLQ for orthophosphate. The three lakes Horse, Otter, and Bridge had at least some of their orthophosphate values falling above the orthophosphate SLQ. Therefore, orthophosphate data should not be considered reliable.

The only phosphorus duplicate which reported a percent difference of greater than the allowable 25% difference was the total dissolved phosphorus collected at Sulphurous Lake. Therefore, the overall precision of the total phosphorus and orthophosphate data can be considered high, with the precision of the total dissolved phosphorus data being somewhat questionable.

Replicate Samples

Site	Date			Colour / True (Rel.U.)	Nitrogen: Ammonia (mg/L)	Nitrogen: Nitrite (mg/L)	Nitrogen: Nitrite + Nitrate (mg/L)	Nitrogen: Total (mg/L)	pH (Rel. U.)	Phosphorus: Orthophosphate (mg/L)	Phosphorus: Total (mg/L)	Phosphorus: Total Dissolved (mg/L)
Bridge Lake	96/05/22	Replicates	I	7	0.014	< 0.002	< 0.002	0.48	8.16	0.002	0.022	0.016
@ North End			II	5	0.006	< 0.002	< 0.002	0.5	8.26	0.002	0.022	0.016
(E222871)		% difference		33	80	0	0	4	1	0	0	0
Horse Lake	96/05/01	Replicates	I	7.5	0.011	< 0.002	0.013	0.43	8.1	0.006	0.034	0.015
@ Deepest Pt			II	7.5	0.014	< 0.002	0.006	0.36	8.11	0.006	0.036	0.016
(0603100)		% difference		0	24	0	74	18	0	0	6	6
Sheridan Lake	96/05/15	Replicates	I	< 5	0.036	0.003	0.037	0.68	8.55	< 0.002	0.024	0.024
@ Center			II	< 5	0.055	0.003	0.039	0.72	8.56	< 0.002	0.023	0.023
(E216929)		% difference		0	42	0	5	6	0	0	4	4
Deka Lake	96/05/23	Replicates	I	5	0.008	< 0.002	0.007	0.29	8.23	0.004	0.015	0.008
@ Deepest Pt			II	5	0.006	< 0.002	< 0.002	0.24	8.23	0.004	0.015	0.008
(E222866)		% difference		0	29	0	111	19	0	0	0	0
Otter Lake	96/05/28	Replicates	I	45	0.011	< 0.002	< 0.002	0.42	7.96	0.002	0.023	0.022
@ Deep End			II	45	0.02	< 0.002	0.002	0.43	7.96	0.002	0.024	0.02
(0803012)		% difference		0	58		0	2	0	0	4	10
Sulphurous Lake	96/05/23	Replicates	I	< 5	0.011	< 0.002	< 0.002	0.26	8.23	< 0.002	0.007	0.004
@ Deepest Pt			II	< 5	0.01	< 0.002	< 0.002	0.29	8.25	< 0.002	0.007	0.006
(E222874)		% difference		0	10	0	0	11	0	0	0	40
		# duplicates		6	6	6	6	6	6	6	6	6
		# of duplicates exceeding 25% difference		1	4	0	2	0	0	0	0	1
		% of duplicates exceeding 25% difference		17	67	0	33	0	0	0	0	17

Site	Date			Conductivity (uS/cm)	Residue: Filterable (mg/L)	Residue: Non-Filterable (mg/L)	Silica (Reactive) (mg/L)	Turbidity (FTU)
Bridge Lake	96/05/22	Replicates	I	219	140	< 5	5.7	0.3
@ North End			II	219	120	< 5	5.7	0.3
(E222871)		% difference		0	15	0	0	0
Horse Lake	96/05/01	Replicates	I	288	190	< 5	9.8	0.88
@ Deepest Pt			II	287	180	< 5	9.6	0.75
(0603100)		% difference		0	5	0	2	16
Sheridan Lake	96/05/15	Replicates	I	450	270	< 5	14.3	0.22
@ Center			II	450	260	< 5	14.4	0.19
(E216929)		% difference		0	4	0	1	15
Deka Lake	96/05/23	Replicates	I	180	110	< 5	1.5	0.33
@ Deepest Pt			II	181	100	< 5	1.5	0.32
(E222866)		% difference		1	10	0	0	3
Otter Lake	96/05/28	Replicates	I	144	110	< 5	13	0.75
@ Deep End			II	145	100	< 5	14	0.75
(0803012)		% difference		1	10	0	7	0
Sulphurous Lake	96/05/23	Replicates	I	252	140	< 5	1.3	0.26
@ Deepest Pt			II	254	130	< 5	1.3	0.26
(E222874)		% difference		1	7	0	0	0
		# duplicates		6	6	6	6	6
		# of duplicates exceeding 25% difference		0	0	0	0	0
		% of duplicates exceeding 25% difference		0	0	0	0	0

Values reported as less than are considered equal to, for calculation purposes.

Analysis of Blanks

Site	Date	Comments *	Colour / True (Rel.U.)	Conductivity (uS/cm)	Nitrogen Ammonia (mg/L)	Nitrogen Nitrite (mg/L)	Nitrogen Nitrite + Nitrate (mg/L)	Nitrogen Total (mg/L)	pH (Rel. U.)	Phosphorus Orthophosphate (mg/L)
Bridge Lake (E222871)	96/05/22	DI	< 5	2	0.005	< 0.002	0.004	0.07	5.41	< 0.002
		Kem	< 5	2	0.009	< 0.002	< 0.002	0.06	5.31	< 0.002
Horse Lake (0603100)	96/05/01	DI	< 5	< 2	< 0.002	< 0.002	< 0.002	< 0.02	5.48	< 0.002
		Kem	< 5	3	< 0.002	< 0.002	< 0.002	< 0.02	5.89	< 0.002
Sheridan Lake (E216929)	96/05/15	DI	< 5	3	< 0.002	< 0.002	0.003	0.22	5.27	< 0.002
		Kem	< 5	3	< 0.002	< 0.002	0.004	0.05	5.12	< 0.002
Deka Lake (E222866)	96/05/23	DI	< 5	2	0.004	< 0.002	< 0.002	0.02	5.34	< 0.002
		Kem	< 5	2	0.002	< 0.002	< 0.002	< 0.02	5.34	< 0.002
Otter Lake (0803012)	96/05/28	DI	< 5	2	< 0.002	< 0.002	0.221	0.37	5.7	< 0.001
		Kem	< 5	2	< 0.002	< 0.002	0.014	< 0.02	5.92	< 0.001
Sulphurous Lake (E222874)	96/05/23	DI	< 5	< 2	0.003	< 0.002	< 0.002	< 0.02	5.2	< 0.002
		Kem	< 5	2	0.003	< 0.002	< 0.002	< 0.02	5.88	< 0.002
		average	5	2.25	0.003	0.002	0.022	0.08	5.49	* 0.002
		standard deviation	0	0.45	0.002	0	0.063	0.11	0.29	* 0
		system detection limit	5	3.61	0.009	0.002	0.210	0.40		* 0.002
System limit of quantification		SLQ = 3.3 *SDL	17			0.007				* 0.007
System limit of quantification		SLQ = mean field blank + 10*SD		7	0.024		0.650	1.16		
		# of samples	12	12	12	12	12	12	12	* 12
		# over MDL	0	10	6	0	5	6		0
		% flagged blanks	0	83	50	0	42	50		0

Site	Date	Comments	Total (mg/L)	Total Dissolved (mg/L)	Residue Filterable (mg/L)	Residue Non-Filterable (mg/L)	Silica (Reactive) (mg/L)	Turbidity (FTU)
Bridge Lake (E222871)	96/05/22	DI	0.002	< 0.002	< 10	< 5	< 0.2	< 0.05
		Kem	0.003	< 0.002	< 10	< 5	< 0.2	0.1
Horse Lake (0603100)	96/05/01	DI	< 0.002	< 0.002	< 10	< 5	< 0.2	< 0.05
		Kem	< 0.002	< 0.002	< 10	< 5	< 0.2	0.08
Sheridan Lake (E216929)	96/05/15	DI	< 0.002	< 0.002	< 10	< 5	< 0.2	0.2
		Kem	< 0.002	< 0.002	< 10	< 5	< 0.2	0.08
Deka Lake (E222866)	96/05/23	DI	< 0.002	< 0.002	< 10	< 5	< 0.2	0.06
		Kem	< 0.002	< 0.002	10	< 5	< 0.2	0.08
Otter Lake (0803012)	96/05/28	DI	< 0.002	< 0.002	< 10	< 5	< 0.2	< 0.05
		Kem	< 0.002	< 0.002	< 10	< 5	< 0.2	< 0.05
Sulphurous Lake (E222874)	96/05/23	DI	< 0.002	< 0.002	< 10	< 5	< 0.2	< 0.05
		Kem	< 0.002	< 0.002	< 10	< 5	< 0.2	0.14
		average	0.002	0.002	10	5	0.2	0.08
		standard deviation	0.000	0	0	0	0.0	0.05
		system detection limit	0.003	0.002	10	5	0.2	0.22
System limit of quantification		SLQ = 3.3 *SDL		0.007		17	0.7	
System limit of quantification		SLQ = mean field blank + 10*SD	0.005		10			0.54
		# of samples	12	12	12	12	12	12
		# over MDL	2	0	1	0	0	7
		% flagged blanks	17	0	8	0	0	58

*Before analysis of samples from Otter Lake the detection limit for ortho-phosphorus was changed from 0.002 to 0.001 mg/L. For calculation purposes the value of 0.001 has been made equivalent to 0.002.

Data in a shaded box represents data exceeding the MDL for that parameter.

The black box with white text represents a parameter with more than 5% of its samples exceeding the detection limit.

Six Lakes Data and Quality Assurance/Quality Control Summary

Site		Date	Depth	Colour / True (Pt-Co U)	Conductivity (uS/cm)	Nitrogen: Ammonia (mg/L)	Nitrogen: Nitrite (mg/L)	Nitrogen: Nitrate + Nitrite (mg/L)	Nitrogen: Total (mg/L)	pH (pH U)	Phosphorus: Orthophosphate (mg/L)	Phosphorus: Total (mg/L)	Phosphorus: Total Dissolved (mg/L)	Residue: Filterable (mg/L)	Residue: Non-Filterable (mg/L)	Silica (Reactive) (mg/L)	Turbidity (NTU)
Horse Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Otter Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sulphurous Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sheridan Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Deka Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bridge Lake	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min.				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Overall Values																	
Minimum				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maximum				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Standard deviation				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = 3.3 * SDL				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SLQ = mean field blank + 10*SD				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
average env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
min. env. levels above SLQ				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Data inside a box with shading represents the average of replicate samples taken at 0.5 m at the site