Attainment of Water Quality Objectives
for
Lakelse Lake in

2001-2003

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Summary

Designated water uses for Lakelse Lake include raw drinking water supplies, primary-contact recreation, and aquatic and wildlife use. Water quality objectives set to protect the lake for these designated uses include: fecal coliform concentrations at beaches and water intakes, turbidity, dissolved oxygen, total phosphorus, and chlorophyll *a*. This report summarizes levels of attainment in 2001, 2002 and 2003, and provides recommendations for updating the objectives.

The 2001 sampling program was limited to October sampling of drinking water intakes around the lakes. The 2002 and 2003 sampling program included:

- Deep station water quality sampling in July, August and September 2002, and May, July and September 2003
- Beach monitoring of microbiological indicators in August 2002.
- Drinking water monitoring of turbidity and microbiological indicators at three intakes around the lake over a five-week period in August 2002, October 2002, April 2003 and August 2003.

Most turbidity concentrations were lower than the objective level, so the maximum turbidity objective was met most of the time; however, the objective for average turbidity was frequently exceeded. Fecal coliform, phosphorus, chlorophyll *a* and dissolved oxygen objectives were frequently met when tested in 2002 and 2003. In 2001, the fecal coliform objective was met at only one of three sites. The attainment results are illustrated in Figure 1 below.

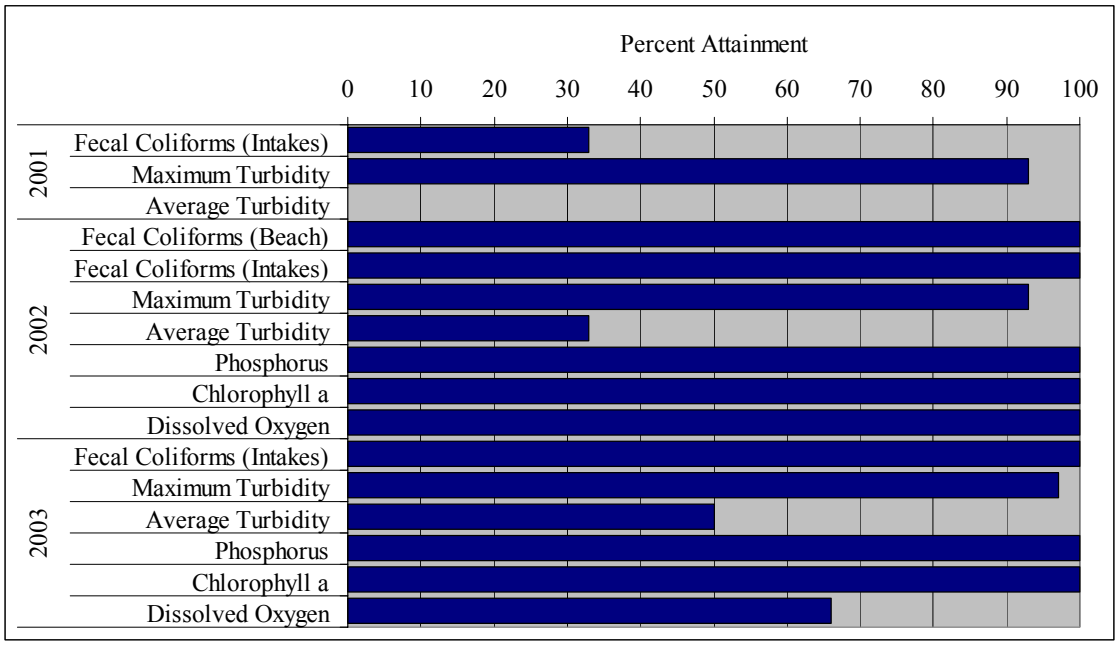

Figure 1: Summary of water quality objectives attainment for Lakelse Lake 2001-03

In 2001 only three of seven objectives were monitored, and although the 2001 results are included, we focus on objectives attainment in 2002 and 2003 when all the objectives were assessed. Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) values calculated for 2002 and 2003 describe the current state of water quality at Lakelse Lake. Attainment percentages and index values are summarized in Table 1.

Table 1: 2001, 2002 and 2003 Objectives Attainment and 2002 and 2003 WQI

Year	% Attainment	WQI Index Value	WQI Rating
2001	71%	n/a	n/a
2002	88%	**49**	Marginal
2003	89%	**48**	Marginal

Overall, sampling results indicate that some water quality objectives at Lakelse Lake are exceeded and that the designated uses may not always be protected. Domestic water users should be warned that fecal coliform and maximum turbidity objectives are occasionally exceeded, indicating that disinfection alone may not be sufficient to ensure that the water is safe for drinking.

It is recommended that two additional bacteriological variables (*E. coli* and enterococci) should be used as water quality objectives to evaluate microbiological water quality in Lakelse Lake:

1. The 90th percentile concentration of *E. coli* in Lakelse Lake should not exceed 10 CFU/100 mL at drinking water intakes, and the geometric mean should not exceed 77 CFU/100 mL in samples from recreational beaches.

2. The 90th percentile concentration of enterococci in Lakelse Lake should not exceed 3 CFU/100 mL at drinking water intakes, and the geometric mean should not exceed 20 CFU/100 mL in samples from recreational beaches.

Consistently meeting these objectives will indicate that no water treatment in addition to disinfection is required to protect drinking water supplies from bacteria, and that the risk of bacteria-caused gastrointestinal disease through primary-contact recreation at beaches is minimized. Meeting these objectives does not ensure protection from other contaminants; treatment beyond disinfection may still be required for these contaminants.

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1.0 Introduction

Water quality objectives are established for water bodies in British Columbia to protect designated water uses at specific locations. Attainment monitoring and reporting allows us to check whether the objectives are being met and is useful for preparing waste management plans, issuing waste management permits, pollution prevention orders and water licenses. Site-specific water quality objectives for Lakelse Lake were prepared by McKean in 1986, and attainment was last checked in 1992.

1.1 Purpose

The purpose of this report is to assess the state of water quality in Lakelse Lake in the period from 2001 until the end of 2003. In this report we present the results of monitoring completed in 2001, 2002 and 2003 to assess attainment of water quality objectives for the lake. The 2002-2003 sampling program was more comprehensive than the 2001 program and this report focuses on 2002 and 2003 data. We include calculations of a Water Quality Index value based on the Canadian Council of Ministers of the Environment (CCME) techniques and ranking for Lakelse Lake and determine if the water quality objectives are still valid or need to be updated.

1.2 Water Quality Index (WQI)

The CCME Water Quality Index (WQI) is a tool for simplifying the reporting of water quality data. The index is used to assess the state of water quality in a water body, relative to its desirable state (as defined by water quality objectives) and to provide insight into the degree to which water quality is affected by human activity.

The WQI for a water body is based on attainment of water quality objectives, and it incorporates three elements:

- *F1* ***scope*** – the number of variables not meeting water quality objectives

$$\text{where} \quad F1 = \left(\frac{Number\ of\ Failed\ Variables}{Total\ Number\ of\ Variables} \right) \times 100$$

F2 ***frequency*** – the number of times these objectives are not met

$$\text{where} \quad F2 = \left(\frac{Number\ of\ Failed\ Tests}{Total\ Number\ of\ Tests} \right) \times 100$$

- *F3* ***amplitude*** – the amount by which objectives are not met

$$\text{where} \quad excursion_i = \left(\frac{FailedTestValue_i}{Objective} \right) - 1$$

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests}$$

$$F3 = \left(\frac{nse}{0.01nse + 0.01} \right)$$

The elements are then combined according to the following equation:

$$CCMEWQI = 100 - \left(\frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732} \right)$$

The index calculation produces a number between 0 (worst water quality) and 100 (best water quality), which can then be related to one of the following categories:

- Excellent: (95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
- Good: (80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
- Fair: (65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
- Marginal: (45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
- Poor: (0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

For additional information about the CCME WQI and details of calculation of the index value, refer to the CCME website (CCME, 2001).

2.0 Overview of the Study Area

2.1 Location

Lakelse Lake is located along Highway 37 in northwestern British Columbia, approximately 9.7 km south from Terrace. It is 8.7 km long and 2.4 km wide, covering an area of 1,416.7 ha (see Figure 2). The mean and maximum depths of the lake are 8.6 m and 31.7 m, respectively.

The average flushing rate for Lakelse Lake is estimated to be five times per year. The high flushing rate is primarily due to the lake's large watershed and the high annual precipitation for the area. The Lakelse Lake Draft Management Plan (Kokelj, 2003) contains additional information about this lake.

2.2 Water Uses

Designated uses for Lakelse Lake have not changed significantly since 1986, and include drinking, recreation and aquatic life. Wildlife was added as a use for all Skeena Region lakes in 1996.

Since 1985, licensed withdrawals from Lakelse Lake have expanded to include domestic use and camps (Table 2).

Table 2: Water Licensing (2002 data from Province of B.C., 2003)

Water Body	Use Description	1985	2002
Lakelse Lake	Domestic		11.4 m^3/d
	Camps		13.6 m^3/d
	Waterworks	182 m^3/d	182 m^3/d

2.3 Potential Sources of Contamination

There is one permit for waste discharge to Lakelse Lake, which could affect water quality. This permit specifies that a resort can discharge sewage effluent to a facultative lagoon, wetland treatment lagoon, and canal leading to the lake. Although in compliance, this source contributes nutrients to the lake. Contamination may also originate from other non-point sources including residential (septic systems and stormwater runoff) and limited agricultural development around the lake. Forestry activities in watersheds that drain into the lake may also pose a threat to water quality. For more details about these and other potential sources of contamination, refer to the Lakelse Lake Draft Management Plan and Addendum (Kokelj, 2003 and 2004).

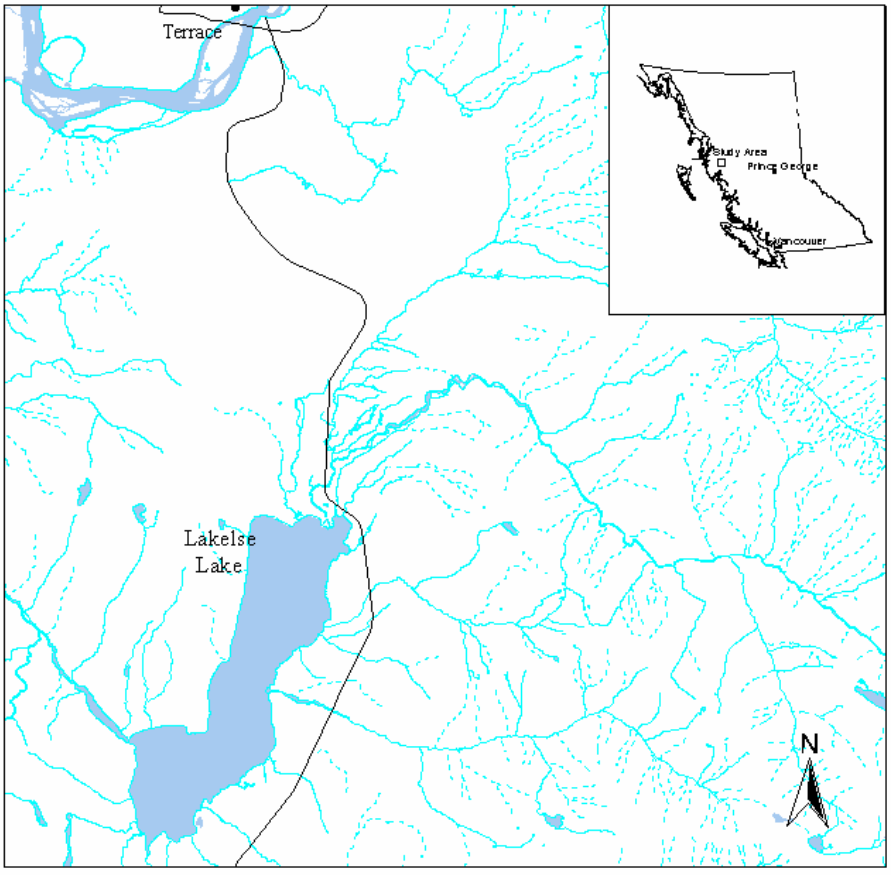

Figure 2: Map of Lakelse Lake

3.0 Water Quality Objectives

Water quality objectives for Lakelse Lake were originally set in 1986 for fecal coliforms, turbidity, total phosphorus, chlorophyll *a* and dissolved oxygen (McKean, 1986) (Table 3).

Table 3: Current Water Quality Objectives for Lakelse Lake

VARIABLE	WATER QUALITY OBJECTIVE
Fecal Coliforms	Near Intakes: ≤ 10/100mL (90^{th} percentile) At Beaches: ≤ 200/100mL (geometric mean); ≤ 400/100mL (90^{th} percentile)
Turbidity	≤ 1 NTU (average); ≤ 5 NTU (maximum)
Total Phosphorus (mean summer concentration)	≤ 10 µg/L (average)
Chlorophyll *a* (mean summer concentration)	≤ 3 µg/L (average)
Dissolved Oxygen	> 6.0 mg/L @5m above sediment

Objectives for microbiological indicators such as fecal coliforms are important because they are good indicators of the risk of gastrointestinal disease. There are three water quality objectives for fecal coliform bacteria. Consistently meeting the first objective (i.e. near intakes) indicates that no water treatment in addition to disinfection is required to protect drinking water supplies from bacteria, and the second two objectives ensure that the risk of bacteria-caused gastrointestinal disease through primary-contact recreation at beaches is minimized. These objectives are based on *British Columbia Water Quality Guidelines: 1998 Edition* (Province of B.C., 1998).

Turbidity is a measure of suspended solids and is most commonly an aesthetic consideration, but is also correlated with levels of algae and bacterial contamination. The water quality objectives for turbidity have been set to ensure that the water is suitable for domestic water supply (the most sensitive use) with no water treatment in addition to disinfection (i.e., no removal of suspended residues is required). The turbidity objective for Lakelse Lake includes a maximum acceptable level (which applies to any water sample taken from or near a domestic water intake) and a desirable level (which is the mean of at least 5 weekly samples from a 30-day period).

Objectives for chlorophyll *a* and phosphorus have been set to monitor nuisance algal growth in the lake. Some species or excessive amounts of algae can cause undesirable taste and odour in drinking water, poor water clarity, and hypolimnetic oxygen depletion which results in loss of fisheries habitat and possible winter and summer fish kills (Nordin, 1985). Algae, as measured by chlorophyll *a*, is usually the result of excessive phosphorus in a lake.

An objective for the dissolved oxygen content of the hypolimnion has been set to maintain the cold water fishery and zooplankton habitat of the lake (McKean, 1986).

4.0 Methods

4.1 Sampling

Water quality sampling at Lakelse Lake was conducted at the Deep Station Site, the public beach, and three drinking water intakes along the lake.

The Deep Station Site (EMS # E206616; Latitude 54.3972 ºN, Longitude 128.5447 ºW) was sampled on July 9, August 13 and September 10, 2002 and May 20, July 20 and September 3, 2003. On each date, temperature and dissolved oxygen profiles (using a Oxyguard Handy Mk II Temperature/DO meter) were obtained and secchi depth was measured. Grab samples were collected from the surface water at 0.5 m (epilimnion), and a Van Dorn sampler was used to obtain water samples from 6 m, and from the bottom (hypolimnion) depths in the water column. At each depth the following analyses were performed: pH, specific conductance, turbidity, total and dissolved metals, and various forms of nitrogen and phosphorus. In addition, chlorophyll a samples were collected from 0 m, 2 m, 4 m and 6 m depths. With the exception of the temperature and dissolved oxygen measurements, all analyses were conducted by PSC Analytical Services in Burnaby.

Grab samples for microbiological indicators were collected from the swimming area of the public beach on Lakelse Lake (EMS # E207583; Latitude 54.3908 ºN, Longitude 128.5342 ºW). The samples were collected once per week for five weeks beginning on August 8, 2002. They were analysed by Cantest Ltd. for fecal coliforms, *E. coli*, and *Enterococci*.

Three drinking water intakes on Lakelse Lake were monitored as part of the MoWLAP's 2002-03 Expanded Water Quality Monitoring Program. Five weekly samples were collected from each site in the summer (beginning August 8, 2002 and August 6, 2003), fall (beginning October 8, 2002) and spring (beginning April 8, 2003). They were analyzed for colour and turbidity by PSC Analytical Services and for the three microbiological indicators by Cantest Ltd. (JR Laboratories Inc. in 2003). For additional details about drinking water quality and the intake sampling sites refer to *Drinking Water Source Quality Monitoring Program Skeena Region: Lakelse Lake* (Downie, in prep.) or the Lakelse Lake Draft Management Plan and Addendum (Kokelj, 2003 and 2004).

4.2 Data Analysis

Attainment of the fecal coliform objectives at water intakes was judged once in 2001, and twice in 2002 and 2003. Ninetieth percentile values were calculated for each set of samples from drinking water intakes and compared to the objective. Ninetieth percentiles and geometric means were calculated for the set of five samples collected in the summer of 2002 from the beach.

The turbidity objective includes a maximum acceptable level [5 Nephelometric Turbidity Units (NTU)] for individual samples and a desirable level (1 NTU) based on the average of at least 5 samples. Attainment of the turbidity objective was judged by comparing individual samples to the 5 NTU maximum and averaging all samples from each site during each sampling season and comparing them to the average guideline of 1 NTU.

The phosphorus and chlorophyll *a* objectives are based on mean summer concentrations. Attainment of the phosphorus objective was judged by averaging samples taken from the surface, middle, and bottom of the water column on the three summer sampling dates.

Attainment of the chlorophyll *a* objective was judged by averaging results obtained from the four (epilimnion) depths in the water column on the three summer sampling dates. Each result at each depth is an average of duplicate filters collected from the same 1 L sample bottle.

Attainment of the dissolved oxygen (D.O) objective was judged by comparing individual D.O. concentrations from 5 m above the sediment, to the 6.0 mg/L objective.

All water quality data that was collected on the sampling days is available in WLAP's EMS database.

5.0 Results and Discussion

Attainment of water quality objectives for Lakelse Lake is summarized in Figure 3. Fecal coliform, turbidity, phosphorus, chlorophyll *a*, and dissolved oxygen results are provided in Table 4 (2003), Table 5 (2002) and Table 6 (2001) and are discussed in the following sections. Individual sample results for phosphorus and chlorophyll *a* are presented in Appendix 1.

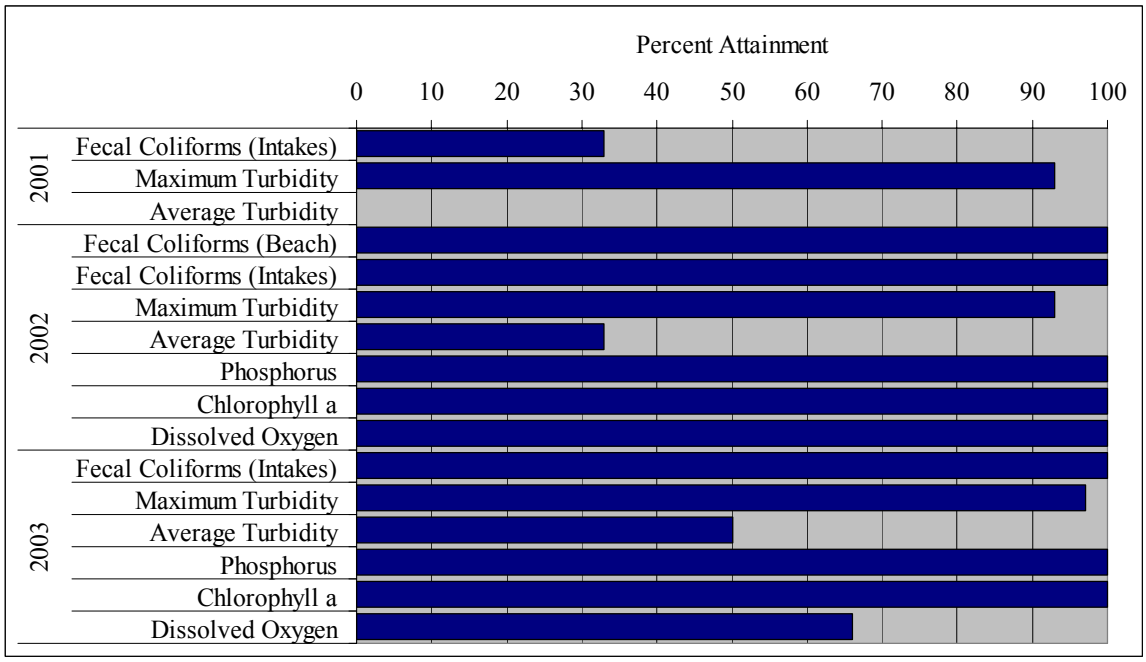

Figure 3: Attainment of Each Objective in 2001, 2002 and 2003 at Lakelse Lake

5.1 Fecal Coliforms

The fecal coliform objective was set to protect drinking water and recreational uses. The drinking water objective is ≤ 10/100mL (90th percentile) at intakes. In both 2002 and 2003, the drinking water objective was met 6 of 6 times at Lakelse Lake sites. It should be noted, however, that intake site #2 came very close to not meeting the objective in 2002; fecal coliforms were detected in moderate concentrations on many sampling dates (90th percentile was 8.8 CFU/100 mL in August and 9.8 CFU/100 mL in October). In 2001, departures from acceptable levels were noted at 2 of 3 sites. Because sampling was conducted in different seasons each year, it is not possible to determine if there was an improvement in water quality during the 2001-03 period.

Table 4: Lakelse Lake Water Quality Objectives - 2003

Variable & Objective	Site	Date	N	Value	Conclusion
Fecal Coliforms Intakes: ≤ 10/100mL ninetieth percentile (np) Beaches: ≤ 200/100mL geometric mean (gm) ≤ 400/100mL ninetieth percentile (np)	Lakelse Lake Furlong (beach) E207583	2003	0	No data collected	Omitted 2003
	Lakelse Lake #1 E207580	Apr 8 – Sept 3	10	<1 - 2/100mL	
		Apr 8, 15, 23, 29, May 5	1	np = <1/100mL	Objective met
		Aug 6, 12, 18, 26, Sept 3	1	np = 1.6/100mL	Objective met
	Lakelse Lake #2 E246120	Apr 8 – Sept 3	10	<1 - 3/100mL	
		Apr 8, 15, 23, 29, May 5	1	np = 1.2/100mL	Objective met
		Aug 6, 12, 18, 26, Sept 3	1	np = 2.2/100mL	Objective met
	Lakelse Lake #5 E251910	Apr 8 – Sept 3	10	<1 - 3/100mL	
		Apr 8, 15, 23, 29, May 5	1	np = <1/100mL	Objective met
		Aug 6, 12, 18, 26, Sept 3	1	np = 1.8/100mL	Objective met
Turbidity ≤ 5 NTU maximum (max) ≤ 1 NTU average (av)	Lakelse Lake #1 E207580	Apr 8 – Sept 3	10	0.74 – 1.76 NTU	Max Objective met
		Apr 8, 15, 23, 29, May 5	1	av = 1.15 NTU	**Objective not met**
		Aug 6, 12, 18, 26, Sept 3	1	av = 1.11 NTU	**Objective not met**
	Lakelse Lake #2 E246120	Apr 8 – Sept 3	10	0.55 – 7.84 NTU	**Max Objective not met (1 x)**
		Apr 8, 15, 23, 29, May 5	1	av = 2.71 NTU	**Objective not met**
		Aug 6, 12, 18, 26, Sept 3	1	av = 0.75 NTU	Objective met
	Lakelse Lake #5 E251910	Apr 8 – Sept 3	10	0.39 – 1.59 NTU	Max Objective met
		Apr 8, 15, 23, 29, May 5	1	av = 0.97 NTU	Objective met
		Aug 6, 12, 18, 26, Sept 3	1	av = 0.55 NTU	Objective met
Total Phosphorus ≤ 10 µg/L average (av)	Lakelse Lake Deep Station E206616	May 20 July 20 Sept 3	9	<2 – 10 µg/L	
			1	av = 5 µg/L	Objective met
Chlorophyll a ≤ 3 µg/L average (av)	Lakelse Lake Deep Station E206616	May 20 July 20 Sept 3	12	0.5 – 2.85 µg/L	
			1	av = 2.05 µg/L	Objective met
Dissolved Oxygen > 6.0 mg/L @5m above sediment	Lakelse Lake Deep Station E206616	May 20	1	13.0 mg/L	Objective met
		July 20	1	8.7 mg/L	Objective met
		Sept 3	1	4.4 mg/L	**Objective not met**

Table 5: Lakelse Lake Water Quality Objectives - 2002

Variable & Objective	Site	Date	N	Value	Conclusion
Fecal Coliforms Intakes: ≤ 10/100mL ninetieth percentile (np) Beaches: ≤ 200/100mL geometric mean (gm) ≤ 400/100mL ninetieth percentile (np)	Lakelse Lake Furlong (beach) E207583	Aug 8- Sept 3	5	<1 - 6/100mL	
		Aug 8, 14, 20, 28 Sept 3	1	gm = 2.0/100mL	Objective met
		Aug 8, 14, 20, 28 Sept 3	1	np = 4.8/100mL	Objective met
	Lakelse Lake #1 E207580	Aug - Nov 6	10	<1 - 5/100mL	
		Aug 8, 14, 20, 28 Sept 3	1	np = <1/100mL	Objective met
		Oct 8, 16, 23, 29, Nov 6	1	np = 5.0/100mL	Objective met
	Lakelse Lake #2 E246120	Aug - Nov 6	10	<1 - 14/100mL	
		Aug 8, 14, 20, 28 Sept 3	1	np = 8.8/100mL	Objective met
		Oct 8, 16, 23, 29, Nov 6	1	np = 9.8/100mL	Objective met
	Lakelse Lake #3 E246121	Aug - Nov 6	10	<1 - 1/100mL	
		Aug 8, 14, 20, 28 Sept 3	1	np = <1/100mL	Objective met
		Oct 8, 16, 23, 29, Nov 6	1	np = 0.6/100mL	Objective met
Turbidity ≤ 5 NTU maximum (max) ≤ 1 NTU average (av)	Lakelse Lake #1 E207580	Aug - Nov 6	10	0.98 - 5.04 NTU	**Max Objective not met (1 x)**
		Aug 8, 14, 20, 28 Sept 3	1	av = 1.48 NTU	**Objective not met**
		Oct 8, 16, 23, 29, Nov 6	1	av = 2.53 NTU	**Objective not met**
	Lakelse Lake #2 E246120	Aug - Nov 6	10	0.54 – 5.44 NTU	**Max Objective not met (1 x)**
		Aug 8, 14, 20, 28 Sept 3	1	av = 0.69 NTU	Objective met
		Oct 8, 16, 23, 29, Nov 6	1	av = 2.87 NTU	**Objective not met**
	Lakelse Lake #3 E246121	Aug - Nov 6	10	0.5 - 3.14 NTU	Max Objective met
		Aug 8, 14, 20, 28 Sept 3	1	av = 0.92 NTU	Objective met
		Oct 8, 16, 23, 29, Nov 6	1	av = 2.39 NTU	**Objective not met**
Total Phosphorus ≤ 10 µg/L average (av)	Lakelse Lake Deep Station E206616	July 9 Aug 13 Sept 10	8	2 – 5 µg/L	
			1	av = 4 µg/L	Objective met
Chlorophyll a ≤ 3 µg/L average (av)	Lakelse Lake Deep Station E206616	July 9 Aug 13 Sept 10	12	0.5 – 1.85 µg/L	
			1	av = 1.14 µg/L	Objective met
Dissolved Oxygen > 6.0 mg/L @5m above sediment	Lakelse Lake Deep Station E206616	July 9	1	9.1 mg/L	Objective met
		Aug 13	1	9.6 mg/L	Objective met
		Sept 10	1	8.5 mg/L	Objective met

Table 6: Lakelse Lake Water Quality Objectives - 2001

Variable & Objective	Site	Date	N	Value	Conclusion
Fecal Coliforms Intakes: ≤ 10/100mL ninetieth percentile (np) Beaches: ≤ 200/100mL geometric mean (gm) ≤ 400/100mL ninetieth percentile (np)	Lakelse Lake Furlong (beach) E207583	2001	0	No data collected	Omitted 2001
	Lakelse Lake #1 E207580	Oct 1, 9, 15, 22, 29	5	<1 - 3/100 mL	
			1	np = 3/100 mL	Objective met
	Lakelse Lake #2 E246120	Oct 1, 9, 15, 22, 29	5	<1 - 22/100 mL	
			1	np = 16/100 mL	**Objective not met**
	Lakelse Lake #3 E246121	Oct 1, 9, 15, 22, 29	5	<1 - 100/100 mL	
			1	np = 72.8/100 mL	**Objective not met**
Turbidity ≤ 5 NTU maximum (max) ≤ 1 NTU average (av)	Lakelse Lake #1 E207580	Oct 1, 9, 15, 22, 29	5	1.75 – 2.78 NTU	Max Objective met
			1	av = 2.3 NTU	**Objective not met**
	Lakelse Lake #2 E246120	Oct 1, 9, 15, 22, 29	5	3.42 – 3.75 NTU	Max Objective met
			1	av = 3.57 NTU	**Objective not met**
	Lakelse Lake #3 E246121	Oct 1, 9, 15, 22, 29	5	0.52 – 16.4 NTU	**Max Objective not met (1 x)**
			1	av = 5.43 NTU	**Objective not met**
Total Phosphorus ≤ 10 µg/L average (av)	Lakelse Lake Deep Station E206616	2001	0	No data collected	Omitted 2001
Chlorophyll a ≤ 3 µg/L average (av)	Lakelse Lake Deep Station E206616	2001	0	No data collected	Omitted 2001
Dissolved Oxygen > 6.0 mg/L @5m above sediment	Lakelse Lake Deep Station E206616	2001	0	No data collected	Omitted 2001

The fecal coliform objectives were met when checked in 1992 (see Province of B.C., 1993). It is worth noting that the methodology for collecting drinking water samples has changed since 1992, and actual drinking water intakes are now being sampled instead of nearshore surface waters. The expectation is that lower concentrations of fecal coliforms should be detected at actual intakes because nearshore waters are more prone to contamination from surface water runoff. This, however, was not the case, suggesting that fecal contamination may be worse in 2001-03 than in the past.

The objective concentration for the public beach (recreation) is: ≤ 200 CFU/100 mL (geometric mean) and ≤ 400 CFU/100 mL (90^{th} percentile). The fecal coliform geometric mean concentration calculated from the five weekly samples at the beach was 2.0 CFU/100mL, and the 90^{th} percentile calculated from the same five samples was 4.8. Both concentrations meet the objective.

Because the fecal coliform drinking water objective was not met at two sites in 2001, and was almost not met at one site in 2002, the risk of fecal contamination from non-point sources definitely exists. The fecal coliform objectives should remain unchanged to protect human health, and periodic monitoring should be conducted to determine if a deteriorating trend in water quality exists.

5.2 Turbidity

The turbidity objective is a maximum acceptable level of 5 NTU in individual samples, and a desirable average level of ≤ 1 NTU (average of five samples collected in a 30-day period). Most drinking water samples were below the maximum acceptable level (5 NTU). In 2003 this level was exceeded in 1 of 30 samples from Lakelse Lake; in 2002 it was exceeded in 2 of 30 samples; and in 2001 it was exceeded in 1of 15 samples.

In 2003 average turbidity exceeded the objective level in 3 of 6 sample sets, and in 4 of 6 sample sets in 2002. Each site exceeded the objective level at least once over the 2002-03 period. In 2001, average turbidity exceeded the desirable level in the single sample set at all 3 sites. Most exceedences occurred during freshet periods when the objectives do not apply; however, elevated turbidity at any time of the year poses a risk to (drinking) water users.

All of the turbidity objectives were met when last checked in 1992 (see Province of B.C., 1993), suggesting possible water quality deterioration. Turbidity can be influenced by various land uses, including those presently occurring in the Lakelse Lake watershed. To help manage this lake as a drinking water source, the turbidity objective for the Lakelse Lake should remain unchanged, and periodic monitoring should continue to determine if a deteriorating trend in water quality exists.

5.3 Total Phosphorus

The objective for mean summer concentration of total phosphorus in Lakelse Lake is ≤ 10 µg/L. In 2003, the mean summer concentration in Lakelse Lake was 5 µg/L, and the 2002 concentration was 4 µg/L[1] (see Appendix 1, Tables 9 and 10). Both values are well below the objective. Future sampling programs should follow McKean's (1986) recommendation and include samples collected over the entire summer season (May – August).

The Lakelse Lake water quality objective for mean summer concentration of total phosphorus was last reported in 1992. At that time the average was 16 µg/L, however, the high concentration is a result of elevated phosphorus concentrations in bottom water samples. When the 1992 mean summer concentration is calculated from upper and middle water column samples only[2], the average is estimated to be 5 µg/L. This concentration is the same as those measured in 2002 and 2003, and suggests that Lakelse Lake phosphorus concentrations have not changed over the past decade.

The original justification used in setting the phosphorus objective remains unchanged, and it is recommended this objective continue to be used at Lakelse Lake.

5.4 Chlorophyll a

The objective for mean summer concentration of chlorophyll a in Lakelse Lake is 3 µg/L. In 2003, the mean summer concentration in Lakelse Lake was 1.14 µg/L, and in 2002 the mean concentration was 2.05 µg/L (Appendix 1, Tables 11 and 12). Both concentrations are below the objective.

Chlorophyll a measurements are recognized as a useful estimate of algal growth in lakes, and this objective should remain unchanged.

[1] The August 13, 2002 the bottom water sample had a phosphorus concentration of 30 µg/L. This was likely due to a sampling error that resulted in contamination by phosphorus-rich sediments (McKean, 2003 pers. comm.). This assumption is supported by high D.O. concentrations in the hypolimnion, and the phosphorus value was not included in the calculation.

[2] Lakesle Lake is known to have a very high flushing rate, which maintains adequate D.O. concentrations throughout the water column and minimizes phosphorus loading of the hypolimnion from the sediments. It is suspected that the high phosphorus concentration in the 1992 bottom water sample was a result of sediment contamination.

5.5 Dissolved Oxygen

The dissolved oxygen (DO) objective for Lakelse Lake is a minimum of 6.0 mg/L at any point greater than 5m above the sediment-water interface. On September 3, 2003, the DO concentration at 5 m above the sediment was 4.4 mg/L, which does not meet the objective concentration. All other 2003 DO concentrations met the objective. In 2002, all the DO readings at 5 m above sediment easily met the objective level. Lakelse Lake is a relatively well mixed lake due to heavy winds and the rapid flushing rate of the lake, which helps to keep the bottom layers oxygenated, even throughout the summer months.

Because of its high fisheries values, it is recommended that this objective remain unchanged. Dissolved oxygen should continue to be measured in order to monitor conditions which may influence cold water fish and zooplankton populations in the lake.

6.0 Conclusions and Recommendations

6.1 Objectives Attainment Summary

Overall attainment of water quality objectives in 2001, 2002 and 2003 suggests that water quality in Lakelse Lake was slightly better in 2002 and 2003 than it was in 2001, however, the 2001 monitoring program did not include sampling for all objectives. Variations in attainment are likely a result of completeness of the monitoring program and differences in sampling frequency and season. Although the 2001 percentage is reported below, the results are not necessarily comparable to 2002 and 2003 results (Table 7).

Table 7: Objectives Attainment at Lakelse Lake (2001, 2002 and 2003)

Water Body	2001 Attainment	2002 Attainment	2003 Attainment
Lakelse Lake	71%	88%	89%

The CCME Water Quality Index (WQI) has been used to summarize overall water quality in Lakelse Lake in 2002 and 2003 (Table 8).

Table 8: WQI Elements and Index Values at Lakelse Lake (2002 and 2003)

YEAR	*f1*	*f2*	*f3*	Index Value	Rating
2002	25	12	84	**49**	Marginal
2003	50	11	74	**48**	Marginal

The relatively low index value and rating in 2002 is a result of the frequent number of times the turbidity objective was exceeded, and high values for the amplitude (*f3)* variable – indicating that when the objective was exceeded, it was exceeded by a large amount. Turbidity values in 2003 were better and overall attainment was higher (Table 7); however, the index value remains low because not meeting the dissolved oxygen objective in 2003 resulted in a much higher value for the scope (*f1*) variable. Overall, the CCME WQI index rating for Lakelse Lake in 2002 and 2003 was "Marginal", indicating that water quality concerns exist and the designated uses are not adequately protected.

6.2 Final Recommendations

Current water quality sampling results and lake conditions indicate that the Lakelse Lake water quality objectives are still valid and do not need updating. It is recommended that monitoring continue, and Lakelse Lake be re-assessed at least every five years to determine if any of the objectives should be updated. Sampling should match the monitoring program recommended by McKean (1986) when he established the water quality objectives, and consistent procedures will help determine whether or not a deteriorating trend in water quality exists. For future monitoring programs, two additional water quality objectives are proposed to evaluate microbiological water quality in Lakelse Lake[3].

Proposed Water Quality Objectives for Lakelse Lake:

The 90th percentile concentration of E. coli in Lakelse Lake should not exceed 10 CFU/100 mL at drinking water intakes, and the geometric mean should not exceed 77 CFU/100 mL in samples from recreational beaches. These values should be based on a minimum of 5 samples taken within 30 days.

The 90th percentile concentration of enterococci in Lakelse Lake should not exceed 3 CFU/100 mL at drinking water intakes, and the geometric mean should not exceed 20 CFU/100 mL in samples from recreational beaches. These values should be based on a minimum of 5 samples taken within 30 days.

Consistently meeting these objectives indicates that no water treatment in addition to disinfection is required to protect drinking water supplies from fecal contamination, and that the risk of bacteria-caused gastrointestinal disease through primary-contact recreation at beaches is minimized. Meeting these objectives does not ensure protection from other contaminants; treatment beyond disinfection may still be required for these contaminants.

[3] Fecal coliforms have historically been the microbiological indicator of choice, but many agencies are now using other indicators such as enterococci and *E. coli* in their water quality monitoring programs. Although complete results have not been reported in this document, Skeena Region sampling in 2001-2003 has included enterococci and *E. coli* in addition to fecal coliforms (see Downie, in prep.). Results are suggesting that the indicators behave differently and may not be correlated. Until new source tracking technologies are developed to enhance the ability of specific indicators to predict the health risks associated with bacterial pollution, sampling for multiple indicators is recommended.

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Appendix 1

Table 9: Lakelse Lake Phosphorus Data - 2003

Sampling Date	P Concentration in µg/L		
	Surface	Middle (Depth)	Bottom (Depth)
May 20	7	6 (6m)	10 (28m)
July 7	5	7 (6m)	5 (28m)
Sept 3	<2	3 (6m)	4 (28m)

Table 10: Lakelse Lake Phosphorus Data - 2002

Sampling Date	P Concentration in µg/L		
	Surface	Middle (Depth)	Bottom (Depth)
July 9	2	4 (6m)	3 (18m)
Aug 13	5	5 (6m)	30* (29m)
Sept 10	4	4 (6m)	5 (26m)

*Note: the high phosphorus concentration of 30µg/L at 29 m in August is likely due to sample contamination from the bottom sediments and was therefore disregarded in calculations for mean summer phosphorus concentration in Lakelse Lake.

Table 11: Lakelse Lake Chlorophyll a Data - 2003

Sampling Date	Chlorophyll a Concentration in µg/L			
	Surface (0 m)	2 m	4 m	6 m
May 20	1.85	2.85	3.40	2.35
July 7	2.60	2.65	2.70	2.30
Sept 3	<0.50	1.15	1.45	0.85

Table 12: Lakelse Lake Chlorophyll a Data - 2002

Sampling Date	Chlorophyll a Concentration in µg/L			
	Surface (0 m)	2 m	4 m	6 m
July 9	0.55	0.50	0.65	1.00
Aug 13	1.35	1.15	1.05	1.35
Sept 10	1.75	1.85	1.35	1.15