Water Quality

Ambient Water Quality Objectives For Williams Lake

Overview Report (1996 Reprint)

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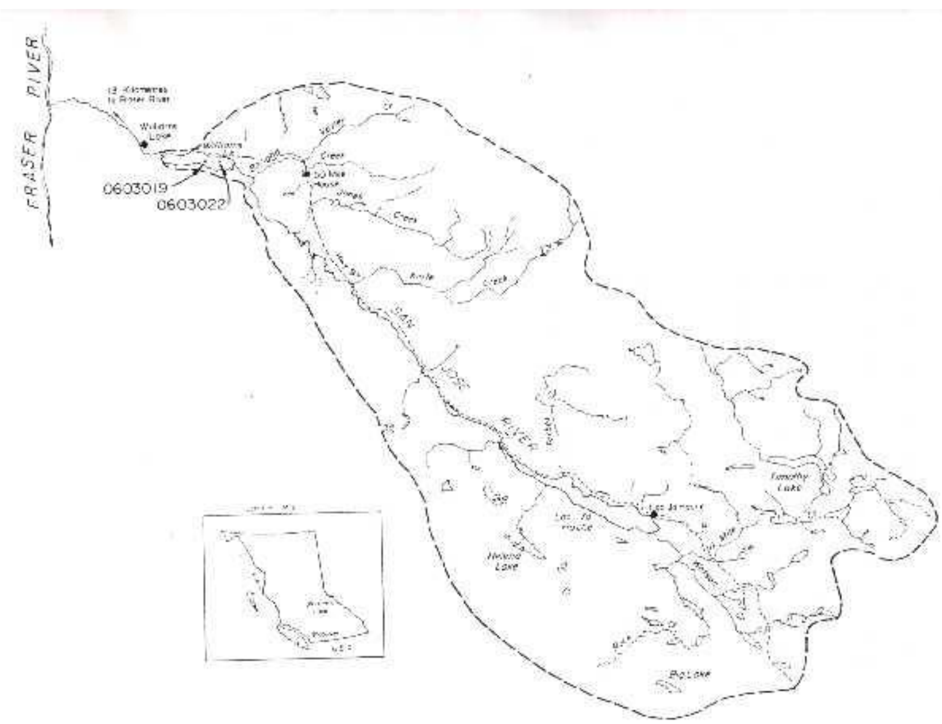
SUMMARY
This report assesses the water quality of Williams Lake and sets provisional water quality objectives to protect its use for drinking water, recreation and aquatic life.

The main inflow into Williams Lake is the San Jose River which drains the area to the south including Lac la Hache. Williams Lake then drains into the Fraser River about 120 km south of Quesnel. The lake water is used for domestic, irrigation and industrial purposes. The City of Williams Lake used the lake as a source of drinking water but now obtains most of its water from wells adjacent to the lake. Coarse fish dominate the fishery with kokanee and rainbow playing a minor role.

The lake is in a eutrophic state, due mainly to phosphorus originating from traditional farming practices in the San Jose River watershed. The existing poor water quality limits drinking water use, recreation and fisheries production.

Recently, overwintering of cattle away from the San Jose River has reduced phosphorus loading to the lake. A major source of phosphorus at this time is internal recycling from lake sediments. This problem could be corrected by measures such as lake aeration, iron addition to the lake or liming. Further progress in managing livestock is also necessary in the long-term to keep phosphorus levels down. The provisional water quality objectives for phosphorus, chlorophyll-a and dissolved oxygen provide an achievable goal for future lake water quality, provided some form of lake and river restoration is successfully completed. How such restoration might be implemented is beyond the scope of this report.

FIGURES
Figure 1. Williams Lake Watershed Map



PREFACE
Purpose of Water Quality Objectives

Water quality objectives are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment, Lands and Parks' mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the near future.

How Objectives Are Determined

Water quality objectives are based the BC approved and working criteria as well as national water quality guidelines. Water quality criteria and guidelines are safe limits of the physical, chemical, or biological characteristics of water, biota (plant and animal life) or sediment which protect water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the criteria by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. A designated water use is one that is protected in a given location and is one of the following:

- raw drinking water, public water supply, and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies.

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

How Objectives Are Used

Water quality objectives routinely provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licences and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated.

Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses. While water quality objectives have no legal standing and are not directly enforced, these objectives become legally enforceable when included as a requirement of a permit, licence, order, or regulation, such as the Forest Practices Code Act, Water Act regulations or Waste Management Act regulations.

Objectives and Monitoring

Water quality objectives are established to protect all uses which may take place in a waterbody. Monitoring (sometimes called sampling) is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less.

The monitoring usually takes place during a five week period, which allows the specialists to measure the worst, as well as the average condition in the water.

For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (*i.e.*, mean value, maximum value).

INTRODUCTION

This study assesses the water quality of Williams Lake which drains via the Williams Lake River into the Fraser River (Figure 1). Poor water quality caused by excessive eutrophication has plagued Williams Lake for many years. The poor water quality reduces the lake's suitability for drinking water, water-contact recreation, and fisheries production. Non-point nutrient loading from cattle ranches within the drainage basin of the San Jose River and the inability of the lake's sediments to absorb and retain phosphorus have been identified as the primary causes of the eutrophic conditions.

This report discusses water quality data for Williams Lake, interprets the impact of nonpoint sources on the lake, and develops provisional water quality objectives to protect major uses in the long term. It also offers some suggestions on reducing nonpoint nutrient loading from traditional farming practices, and proposes methods to reduce the impact of internal phosphorus loading within Williams Lake.

A detailed Technical Appendix was prepared and forms the basis for the conclusions presented in this report.

HYDROLOGY

The San Jose River is the main inflow to Williams Lake, draining Lac la Hache and the San Jose Valley. Approximately 70 percent of the hydraulic loading to Williams Lake originates above Lac la Hache. The San Jose River and its tributaries account for the remaining hydraulic flow.

Based on stream flow measurements since 1974, the flushing rate of Williams Lake averaged 0.62 plus or minus 0.88 lake volumes per year (n=12), or about one lake volume every two years. The maximum and minimum flushing rates were 1.37 and 0.24 lake volumes per year, respectively. A large percentage of the precipitation occurs in the winter as snow, causing stream flows to peak in May and June.

WATER USE

In 1986 the water licences registered on Williams Lake were 21 for domestic use, 5 for waterworks, 3 for industrial use, and 1 for storage. Three of the five waterworks licences are held by the City of Williams Lake which is permitted to withdraw up to 17 500 m^3/day. The average 1985 water consumption was reported at 8400 m^3/day. The storage licence is also held by the city to prevent excessive drawdown during the summer months. The City of Williams Lake has two points of withdrawal on the northwest side of the lake and 4 wells located on Scout Island. Because of the lake's poor water quality, the City relinquished two of its three water licences in 1987 and reduced its lake withdrawal to 106 m^3/day.

The recreational uses of Williams Lake are fishing, water skiing, swimming, sailing and canoeing. The volume of such uses on Williams Lake is rated low because of the poor water quality. Lac la Hache and the Chimney Lake systems serve as the main recreational lakes for the Williams Lake area.

Williams Lake is characterized as having a large coarse fish population with a minor recreational fisheries value, and no anadromous salmonid spawning or juvenile production. Coarse fish dominate the lake because of its high algal productivity, poor water clarity, and extensive weedy areas. Sports fish include rainbow trout and lake whitefish. Eyed kokanee eggs were introduced in 1985 to the San Jose River to establish an ice-fishery in Williams Lake. The rainbow fishery on Williams Lake extends for three to four weeks following ice-out, and was estimated at 1000 angler-days per year. In comparison, the rainbow trout fishery on Lac la Hache was estimated between 6000 and 9000 angler-days, with an additional kokanee ice fishery of 6000 angler-days.

WASTE DISCHARGES

There are no direct waste discharges within the Williams Lake or San Jose River drainages. Nonpoint waste discharges from cattle have been recognized as the main problem for the past 10-15 years. Traditionally, cattle were overwintered next to the San Jose River and its tributaries. The accumulation of animal waste and the trampling of the river banks were believed to be a major source of nutrients and suspended solids to Williams Lake. During the summer months cattle were moved away from the river and the overwintering pastures were used for growing hay.

A committee of the Ministry of Agriculture and Fisheries, the Ministry of Environment and Parks, and the Cariboo Cattlemen's Association was established in 1979 to document the loadings of nutrients and establish ways of reducing the impact. One important accomplishment of the committee was to have cattle moved back from the river during the winter months. Inspection of the agricultural areas in 1985 showed little stream bank trampling. This will reduce the stream bank erosion and the suspended solids loading to Williams Lake. The main areas of concern as indicated by current water quality data are Borland and Knife Creeks, the main tributaries of the San Jose River.

WATER QUALITY

Temperature and Dissolved Oxygen

Williams Lake is a typical interior lake with extensive periods of thermal stratification and brief periods of mixing in the spring and fall. During the period of summer stratification, adult and juvenile salmonid habitat is severely limited because of high surface-water temperatures and oxygen concentrations below 4 mg/L in the hypolimnion. By the end of July, approximately 58% of Williams Lake has a dissolved oxygen concentration unsuitable for salmonids.

General Water Chemistry

The general water chemistry for Williams Lake was characterized as very hard water (hardness=250 mg/L), with very high bicarbonate concentrations (average=350 mg/L). The City of Williams Lake obtains most of its drinking water from wells located on Scout Island near the outlet of Williams Lake. The well water's pH, iron (total), maganese and occasionally lead were above guidelines for Canadian drinking water quality. The sodium concentrations were three times above the alert level for very restricted sodium diets, based on the same guidelines. The iron and maganese guidelines are for aesthetics (*i.e.*, not health related), and the pH guidelines are intended to minimize scaling (the formation of carbon salts) and to maintain the efficiency of chlorine disinfection.

Williams Lake could provide better quality drinking water with respect to pH, sodium, iron, maganese and lead; however, the present eutrophic nature of the lake would cause other problems. Dissolved organics within Williams Lake would colour the water and could, on chlorination, combine with chlorine to form various chlorinated organics that can be hazardous in water supplies. Also, high concentrations of algae associated with the eutrophic conditions would cause clogging of filters and may impart a taste or odour to water. Reversal of eutrophication using lake restoration techniques would eliminate the drinking water problems caused by the eutrophic conditions.

Turbidity from the San Jose River can influence the water clarity at the east end of the lake, particularly in high flow years. Planktonic algae are the principal cause of poor water clarity during the summer months. Turbidity values averaged 2.4 plus or minus 1.9 NTU (n=6) with a maximum of 6.3 and a minimum of 1.1. The turbidity of Williams Lake exceeded the Canadian drinking water guidelines which are an objective of 1 NTU and a maximum of 5 NTU.

Secchi disc records are more frequent (n=25), average 1.9 plus or minus 1.0 m with a maximum and a minimum of 4 and 0.5 m respectively. The recommended Secchi value for bathing and a swimming areas is 1.2 m. It is set to ensure sufficient visibility to estimate depth, to see sub-surface hazards easily, and to detect the submerged bodies of swimmers or divers who may be in difficulty. The average of the Secchi results met the swimming guideline, although some individual results were significantly lower.

Phosphorous Levels

Nitrogen and phosphorus are the critical micronutrients in freshwater. Phosphorus was determined to be the nutrient limiting phytoplanctonic growth and hence the biological productivity of Williams Lake. The productivity and water clarity of Williams Lake will be determined to a large degree by the total phosphorus concentration at spring overturn. The spring overturn total phosphorus concentrations from 1974 to 1985 averaged 0.065 plus or minus 0.010 mg/L (n=10). There appears to be a one-or-two-year time lag between the phosphorus loading via the San Jose River and the resultant spring overturn phosphorus concentration.

Phosphorous Loading
The San Jose River is the only major tributary to Williams Lake. As a result it represents the largest external phosphorus source to the lake. Areas contributing high loadings of phosphorus from diffuse sources can be identified by calculating changes in phosphorus concentration between two stream sites and dividing by the watershed area between the two sites. The change in dissolved phosphorus concentration per unit area for the entire San Jose River (n=38) was 0.059 plus or minus 0.058 micrograms P/L/km^2. The upper part of the San Jose River between Lac la Hache and Knife Creek had similar increases in phosphorous while the lower section of the San Jose River was 120 percent higher. Knife and Borland Creeks had the highest increases averaging 500 and 950 percent higher than the average dissolved phosphorus increase for the San Jose River. Increases in total phosphorus concentrations showed a similar pattern as the dissolved phosphorus concentrations.

The relative increase in phosphorus concentrations appeared to be related to the soil and landforms within the watersheds. The soils and landforms adjacent to the San Jose River between Lac la Hache and Knife Creek are generally characterized as having normal runoff and moderate erosion-potential.

Some pollution problems caused by traditional farming practices are noted below together with suggested measures to alleviate them. The suggestions are for the consideration of the Ministry of Environment and Parks, the Ministry of Agriculture and Fisheries, the Cariboo Cattlemen's Association, and the landowner. A site specific evaluation is required for these groups to consider the cost and effectiveness of the measures proposed.

1. Livestock having free access to streams and congregating around feeding, watering and resting areas located close to the receiving waters cause water quality problems.
    - i. Fencing livestock away from streams and
    - ii. establishing feeding, watering and resting areas away from waterways are possible remedies.
2. Over-wintering cattle in high densities damage vegetative cover and soil structure by trampling and compacting soil and dormant sod. This results in increased surface runoff and pollutant load (including suspended sediment) damaging nearby streams and waterways.
3. Cattle activity should be limited to a minimum in areas
    - i. prone to spring flooding (*e.g.*, near 130 Mile Lake) and
    - ii. with imperfectly or poorly drained soils (below Borland Creek) because such soils have poor phosphorus renovation ability.

Internal phosphorus loading refers to the process by which orthophosphorus is released from lake sediments. There appears to be a two-year lag between years of high phosphorus loading from the San Jose River and high spring overturn concentrations. The observed lag appears to be the result of phosphorus from high runoff years being released from lake sediments one or two years later during the anoxic conditions present during the summer months.

Sufficient data were available to estimate an internal loading of 5700 kg of orthophosphorus in 1976 and 4500 kg in 1983, The internal loading was approximately equivalent in mass to the total phosphorus loading from the San Jose River, but was 65 percent higher than the dissolved phosphorus loading from the river. Because not all total phosphorus discharged by the San Jose River is biologically availbale, internal phosphorus loading appears to be the most significant phosphorus source influencing the spring overturn phosphorus concentration in Williams Lake.

Algae

The algal standing crop of a lake is usually estimated by chlorophyll a. Only one year of chlorophyll a data is available. The mean summer chlorophyll-a for Williams Lake was 0.030 mg/L in 1977. The concentration of chlorophyll-a is determined by the phorphorus concentration at spring overturn. Decreased phosphorus loading will result in decreased chlorophyll-a resulting in improved water quality.

Williams Lake is considered to be eutrophic because of its high phosphorus concentrations, high oxygen depleting rates of the bottom waters, and high chlorophyll-a results. These attributes, in association with the lake's poor water clarity, detract from the recreational, fisheries and domestic drinking water suitability of the lake.

The blue-green alga *Aphanizomenon flos-aquae* was the dominant species in all samples taken during the summer months. It can cause taste and odours in drinking water supplies, and can clog filters.

Sediments

Surface sediment samples and a two-metre core indicated that the phosphorus binding capacity of the sediments was reduced by the formation of iron monosulphides (FeS). The presence of FeS is the principle reason for the low orthophosphorus precipitation rates observed during the winter months. Analysis of the core showed that the FeS was present throughout the lake's recent history. The core also indicates that the historical water quality of Williams Lake, prior to cultural development, was more like the present water quality of Lac la Hache, which is considered a mesotrophic lake.

The chemical analysis of the Williams Lake sediments were compared with sediment analyses from 34 other Cariboo lakes. The core data indicated that the calcium in Williams Lake was associated with carbonate, not organic matter. Lakes that form calcium carbonate precipitates are called marl lakes. The amount of calcium carbonate precipitation in Williams Lake, however, was lower than other marl lakes (*e.g.*, Lac la Hache, Green, and Kalamalka Lakes), which indicates Williams Lake has some marl formation but is not a true marl lake.

Marl precipitation is important in limnology because of its ability to co-precipitate phosphorus. Enhancement of the calcium carbonate-phosphorus co-precipitation is a possible lake restoration technique.

Possible Lake and River Restoration Techniques

The San Jose River is the major external source of phorphorus to Williams Lake and significant reductions in nonpoint loading would be one step to improve the water quality of the lake. Overwintering of cattle away from the San Jose River has occurred since 1984 and has reduced stream bank trampling and direct phosphorus loading from manure. Because of the internal phosphorus cycling problem in Williams Lake, reduction in nonpoint loading will not by itself cause significant improvements in water quality. Some type of lake treatment will be required to reduce the impact of internal phosphorus loading. The possible options are:

1. aeration
2. iron addition
3. liming

These are described below with preliminary cost estimates given for comparative purposes.

Aeration

This technique is designed to introduce oxygen into the hypolimnion of lakes during summer and winter stratification. The benefits are increased fisheries and zooplankton habitat, and elimination of the reducing conditions that cause internal phosphorus loading. Installation and operating costs are estimated at $100 000 and $10 000 a year, respectively.

Iron Addition

The addition of iron chloride would increase the phosphorus binding capacity of the sediments. Preliminary work indicates a dosage rate of 4.5 kg iron per hectare every five years, at a cost of approximately $40/ha or $30 000 per application.

Liming

The addition of calcium hydroxide causes pH to increase temporarily to approximately 9.4. At these pH levels, carbonate will exceed its saturation point and precipitate as calcium carbonate. Dissolved and suspended phosphorus as well as magnesium and sodium co-precipitat with the calcium carbonate. The cost of liming is approximately $15000 per hectare per year or a total of $1 000 000.

It is difficult to determine without some experiments which technique will provide the best and most cost-effective results. Based on a preliminary assessment of the lake restoration techniques implemented in other lakes, a combination of aeration and iron addition may be the most successful in Williams Lake. Lake restoration will improve the recreational, cold-water fisheries production and drinking water suitability of Williams Lake. How such restoration might be implemented is beyond the scope of this report.

PROVISIONAL WATER QUALITY OBJECTIVES

Provisional water quality objectives were established to protect the most sensitive water uses of Williams lake and are summarized in Table 1.

The objectives are based on preliminary working criteria for water quality and on available data on ambient water quality, waste discharges, water uses and limnological characteristics. The objectives will remain provisional until the water quality monitoring programs provide adequate data, and the Ministry has established approved water quality criteria for the characteristics of concern.

Water quality objectives have no legal standing and would not be directly enforced. The objectives should be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They will guide the evaluation of water quality, the issuing of permits, licences and orders, and the management of the fisheries and of the Province's land base. They will also provide a reference against which the state of water quality in a particular water body can be checked, and serve to make decisions on whether to initiate basin wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, obectives are only being prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now and in the foreseeable future.

The designated water uses to be protected in Williams Lake are:

- aquatic life (recreational freshwater fishery)
- primary-contact recreation
- drinking water supply

Two water quality objectives are proposed for fecal coliform bacteria. The first objective is proposed to ensure that no water treatment in addition to disinfection is required for drinking water. The second is to ensure safe recreation at beaches, and throughout the lake.

The provisional water quality objective for fecal coliform bacteria samples taken at public beachers during the summer months is: a geometric mean of less than 200/100 mL, calculated from at least 5 weekly samples taken during the recreation season, and not more than 10 percent of samples during any 30-day period to exceed 400/100 mL.

Although bacterial data are limited, there seems no reason to believe that these objectives are being exceeded. Further monitoring will be required to check the objectives accurately.

Nuisance algal growth in lakes, as measured for example by chlorophyll-a, is usually the result of excessive phosphorus in a lake. Algae can cause taste and odours in drinking water, aesthetic problems, poor water clarity and hyplimnetic oxygen depletion. Lack of oxygen results in loss of fisheries habitat and possible winter or summer kills.

Water quality objectives are proposed for the spring overturn phosphorus concentration, mean summer chlorophyll-a concentration, turbidity, water clarity and dissolved oxygen. The majority of these objectives cannot be achieved until some form of lake or river restoration is successfully completed.

The objectives for spring overturn phosphorus and mean summer chlorophyll-a are averages of 0.020 mg/L total phosphorus and 0.005 mg/L chlorophyll-a. For the measurement of total phosphorus, three discrete samples should be taken during spring overturn at sites 060322 and 0603019 (surface, mid-depth, and 1 m above the sediment-water inferface at each site). These sites are near the centre of the lake as shown in Figure 1. Chlorophyll-a samples should be taken at least monthly from May to August at site 0603019 at 0.5 m depth. Additional ortho- and total phosphorus monitoring is recommended using the same sampling schedule as for the chlorophyll-a to determine what factors are responsible for the observed algal blooms.

An objective is also proposed for dissolved oxygen in the hypolimnion in order to maintain some habitat for the cold water fishery and zooplankton. The dissolved oxygen content should not drop below 4.0 mg/L at any point greater than 5 m above the sediment-water interface.

The provisional turbidity objectives for the lake are an average of 1 NTU and a maximum of 5 NTU. The objectives are set to ensure that the water quality is suitable for domestic water supply (the most sensitive use) with no water treatment in addition to disinfection (*i.e.*, no removal of turbidity or suspended residues would be required). The turbidity objectives should apply to any discrete sample (surface or bottom) collected anywhere at any time of the year, the average being calculated from at least 5 weekly samples collected in 30 days.

The last objective proposed for Williams Lake is for water clarity to ensure safe water contact recreation. The objective is a minimum Secchi disc reading of 1.2 m taken at any point in the lake from May to August.

WATER QUALITY MONITORING

A summary of recommended water quality monitoring is given in Table 2. Monitoring is required to determine whether provisional water quality objectives are being achieved, and to provide ambient data to fill important data gaps. Although some of the objectives outlined in Table 1 cannot be achieved until some form of lake and river restoration is implemented, monitoring for all objectives is recommended to develop a better data base.

TABLES

Table 1 Provisional Water Quality Objectives for Williams Lake

Characteristics	Objectives
designated water uses	drinking water, aquatic life, recreation
fecal coliforms near water intakes	less than or equal to 10 MPN/100 mL 90th percentile
fecal coliforms at bathing beaches	less than or equal to 200 MPN/100 mL geometric mean less than or equal to 400 MPN/100 mL 90th percentile
turbidity	less than or equal to 1 NTU average; 5 NTU maximum
total phosphorus	less than or equal to 0.020 mg/L average at spring overturn
chlorophyll-a	less than or equal to 0.005 mg/L mean
dissolved oxygen	greater than or equal to 4.5 mg/L at 5 m above the sediment
water clarity	greater than or equal to 1.2 m Secchi

1. The coliform geometric mean and 90th percentile are calculated from at least 5 weekly samples taken in a 30-day period. The drinking water objective (10/100 mL) applies year-round and the recreation objective (200-400/100 mL) applies during the recreation season.
2. The average turbidity is calculated from at least 5 weekly samples taken in a 30-day period and applies to any point in the waterbody.
3. The average total phosphorus is calculated from a set of at least 3 samples, including near the surface, at mid-depth and near the bottom, at sites 0603019 and 0603022 durong spring overturn. These sites are near the center of the lake as shown in Figure 1.
4. The average chlorophyll-a is calculated from a set of discrete surface samples, taken at least monthly from May to August at site 0603019.
5. Water clarity is defined as a minimum of a 1.2 Secchi depth measured weekly from May to August between 10 am and 2 pm at site 0603019,

Table 2 Recommended Water Quality Monitoring for Williams Lake

Sites	Frequency and Time	Characteristics
near water intakes	5 weekly samples in a 30-day period any time of year	fecal coliforms
bathing beaches	5 weekly samples in a 30-day period in the recreation season	fecal coliforms
at any point in the water body	5 weekly samples in a 30-day period excluding freshet period	turbidity, Secchi disc
sites 0603019 and 0603022 at surface, mid-lake and 1 m above the sediment	spring overturn	ammonia-N, nitrate-N, kjeldahl-N, total nitrogen, ortho and total phosphorus
site 0603019	weekly May to August	Secchi disc

site 0603019 at 1 m intervals	**Once at spring overturn and monthly May to August**	**temperature and dissolved oxygen profiles**
site 0603019 at 0.5	**monthly May to August**	**chlorophyll-a, ortho- and total phosphorus**

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