Lakelse Lake
Draft Management Plan

PREPARED FOR:
THE LAKELSE WATERSHED SOCIETY

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1.0 Acknowledgements

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Julia Kokelj
Regional Lake Planner

2.0 Executive Summary

Lakelse Lake is located on the eastern margin of the Coast Range Mountains in North-western British Columbia. In recent years, residents in the Lakelse watershed have noticed growth of the invasive species *Elodea canadensis* in their lake. Based on patterns of infestation in other lakes in the region, it is likely that the growth of *Elodea* in Lakelse will continue, until it occupies most of the shoreline. The beginning of significant human activity in the Lakelse watershed coincides with increases in sediment delivery rates to the lake. This suggests that land use activities in parts of the watershed may be contributing to the water quality concerns in Lakelse Lake, and may be a contributing factor to the *Elodea* infestation.

The overall mission of this lake management planning process is to devise methods **"**to preserve and protect the quality and health of the Lakelse watershed**".** This management plan marks the end of the first iteration of the process, and is intended to provide long-term direction to the Lakelse Watershed Society (LWS) as it undertakes projects to improve the quality of the watershed. To date, the planning process has opened communication links between numerous stakeholders, and has created a local awareness of lake management and watershed health.

2.1 Priority Issues in the Watershed

At the beginning of the management planning process, stakeholders identified seven priority issues in the watershed:

1. *Elodea canadensis* - The amount of *Elodea canadensis* in Lakelse Lake has been steadily increasing. Area residents are concerned about how the growth will affect lake quality and health, the recreational and fisheries value of the lake, and its potential to reduce individual property values.

2. Fish Species - The lake provides important spawning and rearing habitat for many species of fish. There are concerns that excessive plant growth may potentially affect the food chain in the lake, limit sockeye production, cause harmful winter oxygen deficits, reduce the amount of fish habitat and result in a change in the distribution of fish species in the lake. Working toward the maintenance and restoration of fish habitat and stocks is of high importance to stakeholders around the lake.

3. Forestry - The loss of riparian areas from past forestry practices has led to erosion and increased sediment and nutrient inputs to the lake. Sediment core results from Lakelse Lake indicate that increases in sediment delivery rates correspond with the onset of major forestry activities. The possible link between the *Elodea* infestation and sediment and nutrient loading suggests it is important to ensure future forestry practices are improved and monitored and that appropriate remedial actions are pursued regarding past forestry practices that affect the watershed.

4. Shoreline Development/Modification – LWS is concerned about how various commercial, agricultural and residential activities have lead to shoreline erosion and possible increases in nutrient and sediment inputs to the lake. The Regional District of Kitimat-Stikine has expressed concerns about impacts of current sewage disposal systems on drinking water quality and fish habitat in the lake.

5. Stream Modification - Channel modifications on various tributaries have created problems with slope failures, and likely amplified sediment delivery rates from these streams. This is compounded by the loss of riparian areas around Lakelse tributaries from residential land clearing and forestry practices. Increases in sediment delivery may impact Lakelse drinking water, degrade valuable fisheries habitat and spawning areas, and potentially contribute to *Elodea* growth.

6. Water Level Changes & Effects - Effects from water level changes may include erosion and loss of property, contamination from disposal fields (especially when they are under water), and greater inwash of sediments and nutrients to the lake. Some residents have suggested that high water levels in Lakelse Lake persist for much longer than they used to, and they are concerned about why this is occurring and how it is affecting water quality.

7. Drinking Water Quality - Lakelse Lake is a drinking water source for seasonal and permanent residences along the lakeshore. Recent drinking water quality studies have noted source quality concerns at Lakelse Lake. As the water table is only a few feet below the ground surface on the east side of the lake, non-point sources of contamination may include sewage disposal fields, in addition to forestry activities, and commercial and agricultural development in the watershed.

2.2 Management Approaches

To address the priority issues, a series of potential management approaches were identified:

1. *Elodea canadensis*

1.1. Monitor and identify trends in *Elodea canadensis* growth.
1.2. Continue water monitoring program on Lakelse Lake to gain a better understanding of the watershed system and *Elodea*
1.3 Remove excessive *Elodea* plants from Lakelse Lake
1.4. Reduce non-point source nutrient inputs to the lake
1.5. Reduce sediment inputs resulting from human activities within the watershed

2. Fish Species

2.1 Promote fisheries research and data collection
2.2 Improve fish habitat

3. Forestry

3.1 Encourage improved forestry practices in the watershed to minimize impacts and support remediation activities on conditions that impact the lake.

4. Shoreline Development/Modification

4.1. Examine trends via shore and water monitoring programs

4.2 Encourage development and activities that minimize nutrient and sediment inputs to the lake system

5. Stream Modification

5.1 Identify and monitor stream sources of sediments entering the lake

5.2 Work to minimize impacts of watershed activities on streams and encourage remediation work to mitigate problem conditions

6. Water Level Changes & Effects

6.1 Initiate a hydrology study of Lakelse Lake

6.2 Improve general public awareness about the watershed system

7. Drinking Water Quality

7.1 Work with local and provincial governments to improve drinking water quality

7.2 Improve public awareness about drinking water issues in the Lakelse watershed

2.3 Plan Highlights

For each management approach, a comprehensive list of remedial actions was compiled. The advantages and disadvantages of the actions were summarized, and key stakeholders reviewed and discussed the overall merit of each action. LWS determined which remedial actions were realistic and likely to be effective in the Lakelse Lake watershed. The core recommendations in this management plan are derived from discussions with LWS and other resource managers; some highlights are summarized below.

Recommendations

- Monitor and identify trends in *Elodea canadensis* growth in Lakelse Lake by conducting a volunteer inventory of aquatic plants
- Investigate if *Elodea canadensis* appears at other local lakes
- Continue volunteer water monitoring program on Lakelse Lake
- Improve general awareness and public education relating to human influences on lake quality and health
- Support initiatives for fisheries research and data collection and initiatives that will improve fish habitat
- Gather information on the Water Management Branch 1988 lake-outlet profile survey to investigate the viability of a repeat survey
- Establish a lake level gauge.

- Encourage a multi-agency approach for effective wastewater management
- Participate in regional planning initiatives
- Support initiatives to implement recommendations listed in WLAP's *Drinking Water Source Quality Monitoring Program: Lakelse Lake & Jackpine Flats & Attainment of Water Quality Objectives for Lakelse Lake, 2002*

3.0 Table of Contents

4.0 Lake Management Planning –Impetus, Mission and Purpose

4.1 Impetus for the Plan

The impetus for this Lake Management Plan is the recent aquatic plant infestation in Lakelse Lake, which may be due to a range of processes related to eutrophication. In recent years, residents in the Lakelse watershed have noticed growth of the invasive species *Elodea canadensis* in their lake. The growth of *Elodea canadensis* in the lake over the last 4 years has reached a level that seasonally occludes beaches and shorelines. It currently occupies most of the volume of several shallow bays of the lake, as well as patches of shoreline where fine sediments allow rooting. This same infestation also exists in over 25 lakes in the Highway 16 corridor between Prince George and Terrace B.C. Based on growth in the other Highway 16 corridor infested lakes, it is likely that the pattern of invasion of *Elodea* in Lakelse will continue, until it occupies most of the littoral zone (Sharpe, 2002 pers. comm.).

Elodea canadensis

Elodea canadensis is endemic to North America. Commonly found in south-western B.C., it is rare northward, with the exception of occurring in lakes along Highway 16. It can be found in lakes, ponds, streams and ditches in lowland, steppe and montane zones. *Elodea canadensis* is often referred to by various names including Canadian waterweed, American elodea, Canadian pondweed, Common elodea and Water thyme (Warrington, 2001).

Elodea species are widespread in a variety of habitats and may become weeds in eutrophic conditions. The leaves occur in whorls of 3, rarely being over 1.5 cm long and approximately 2 mm wide, and taper abruptly to a blunt point. It is commonly found at depths of 1 to 8 meters. Since these are favoured aquarium plants, they may be introduced to a number of lakes. Flowers are very small, white, and on the end of a very long thin stalk, that reaches the surface (Warrington, 2001).

The literature suggests that once introduced into a region, *E. canadensis* tends to disperse rapidly. *Elodea canadensis* reproduces mainly by fragmentation, which occurs when sections become detached from parent plants by water traffic such as animals, currents, waves or any other mechanical force. These take root as the fragments eventually settle in the sediments at the lake bottom (French and Chambers, 1992). This plant has two over-wintering strategies: it can over-winter as an entire plant, or as dormant species which germinate in the spring. *E. canadensis* has a history of population explosions and sudden declines, the causes of which are unclear. It has been suggested that iron may be the primary micronutrient limiting the growth of *Elodea* species (French and Chambers, 1992).

Aquatic plants can accumulate non-essential elements such as arsenic, copper, mercury lead and cadmium. *E. canadensis* has been shown to mobilize copper, lead and cadmium from the sediments, transport them to its stems and leaves and subsequently release them to the water column. The apparent ability of macrophytes to cycle metals from the sediments to the water column has significant ecological implications. The transport of metals from the sediments to the water column results in metals being incorporated into the aquatic and terrestrial food chains (French and Chambers, 1992).

Figure 1. *Elodea canadensis* in Lakelse Lake, October 2002

4.2 Mission

The mission of this lake management planning process is to devise methods:

> ***"****To preserve and protect the quality and health of the Lakelse watershed****"***

4.3 Purpose of the Planning Process

The lake management planning process for the Lakelse Lake watershed is ongoing. This document will provide the long-term direction necessary to achieve the overall mission. This version of the plan is intended to act as a handbook and reference guide for both resource managers and the Lakelse Watershed Society (LWS). It identifies priority issues in the watershed, and describes the concerns of natural resource managers and local stakeholders regarding water quality and ecosystem protection. It then outlines in detail, the logistics and resources required to implement desirable management approaches for the watershed. It is intended that the society will refer to the document on an ongoing basis, to identify projects that will prevent further degradation to the lake and its watershed, and improve lake quality.

It is important to remember that this document does not indicate completion of the lake management planning process. As recommendations in the plan are implemented, the planning process will continue in a cyclical nature with assessments and revisions occurring on an ongoing basis (Section 5 provides more details on the entire process).

To date, the lake management planning process has served many other important purposes that go far beyond this document. They include:

- Developing communication links between the LWS, multiple levels of government, industry, and other local residents and stakeholders.
- Improving public education about issues affecting water quality in the lake and the watershed.
- Creating awareness in the community about lake management, and motivating people to get involved.
- Identifying opportunities for volunteer-driven actions, and setting the stage for a volunteer program to monitor lake conditions.

If the management planning process is successful and the plan contributes to a healthy watershed with functioning ecosystems, everyone will benefit:

- Area residents will see an enhanced quality of life, with safe water to drink, an aesthetically pleasing lake, healthy fish populations and many recreational opportunities.
- Government officials will be able to comfortably make decisions which represent the best interests of all stakeholders.
- Business and industry will thrive by operating in a vibrant, healthy community centered around the lake.

5.0 Lake Management Planning - Methodology

5.1 Strategic Planning

Developing management strategies for environmental protection is not a simple task. Ecological systems are complex, and there are many relationships and interactions that we still do not completely understand. Signs that indicate a potential decrease in lake water quality (for example a weed infestation) should be regarded seriously and efforts to lessen impacts need to be investigated. Postponing remedial action may result in forgoing relatively low-cost means of problem solving. Now is the time to determine a long-term plan of action to protect environmental and social values associated with Lakelse Lake and its watershed.

Problem solving can be approached using short-term tactical thinking or long-term strategic thinking (Spitzer, 1991). In general, tactical approaches treat only the symptoms of a problem, and are *relatively* simple and appear to be the least expensive. Strategic approaches tend to require long-term commitment, treat the causes of the problem and may be expensive. For solving complex problems, however, they are often the most practical and efficient approach that can be used.

Lake management planning is complex because solutions cannot simply be generated by applying technical or scientific reasoning. There are many economic and social considerations and consequences associated with any proposed technical solution. For example, eutrophication (nutrient enrichment) concerns will not likely go away by employing tactical solutions that treat the symptoms of the problem. While in-lake treatment methods may form an important part of the overall solution, a long-term sustainable solution needs to look beyond the symptoms and treat the underlying causes: nutrient inputs from the surrounding watershed.

5.2 Consensus Building

Due to the complexity of the concerns and the variety of the stakeholders, consensus-building is an important part of the lake management planning process. A successful lake management program begins with a Lake Management Plan that has widespread support from stakeholders and involves all interested groups and regulatory agencies throughout the planning process (Gibbons et al., 1994). There is no substitute for local knowledge of the lake's problems and/or a lifetime of observations of a lake (Rast and Holland, 1988).

In 2002 a group of lake residents and users joined to form the Lakelse Watershed Society (LWS). The society has representation from various communities around the lake, and throughout this planning process the group has served as a primary voice for the community. The LWS used a procedure called the *Kepner-Tregoe (K-T) Rational Process* to build consensus and to clarify what issues require action. Kepner-Tregoe is a management consulting and training company that specializes in the areas of strategy formulation and implementation. The first step in the Rational Process developed by K-T is called "Situation Appraisal". It provides a logical, common sense approach to clarifying concerns and making them manageable. The results of this analysis formed the basis of the planning process (For further information regarding the Kepner-Tregoe Rational Process, see section 5.4).

5.3 Project Partners

Stakeholders identified in the Lakelse Lake management planning project include government agencies (Water, Land and Air Protection, Regional District of Kitimat-Stikine, Department of Fisheries and Oceans and B.C. Parks), lakeshore and watershed residents, lake user-groups, and environmental organizations (Northwest Stewardship Society). For many parts of the plan, public input was sought through the Lakelse Watershed Society (LWS). Habitat Stewards and government representatives (from all levels of government) were consulted as necessary. A list of contacts and stakeholders involved in the Lakelse Lake Management Plan is included in Appendix B.

Interested parties were involved from the formative stages and throughout the planning process to discuss the issues and work towards achieving widespread support. Regular meetings were held so that stakeholders had the opportunity to provide input: during identification of the problems, during creation of plan goals, and when potential management approaches were identified and evaluated. It is important to continue meeting after desirable actions are selected but before they are implemented, and during implementation of the chosen lake management program to evaluate and review the program's success. The schematic diagram in Figure 2 (pg. 13) illustrates the opportunities for input at critical stages in the management planning process.

5.4 Project Methodology

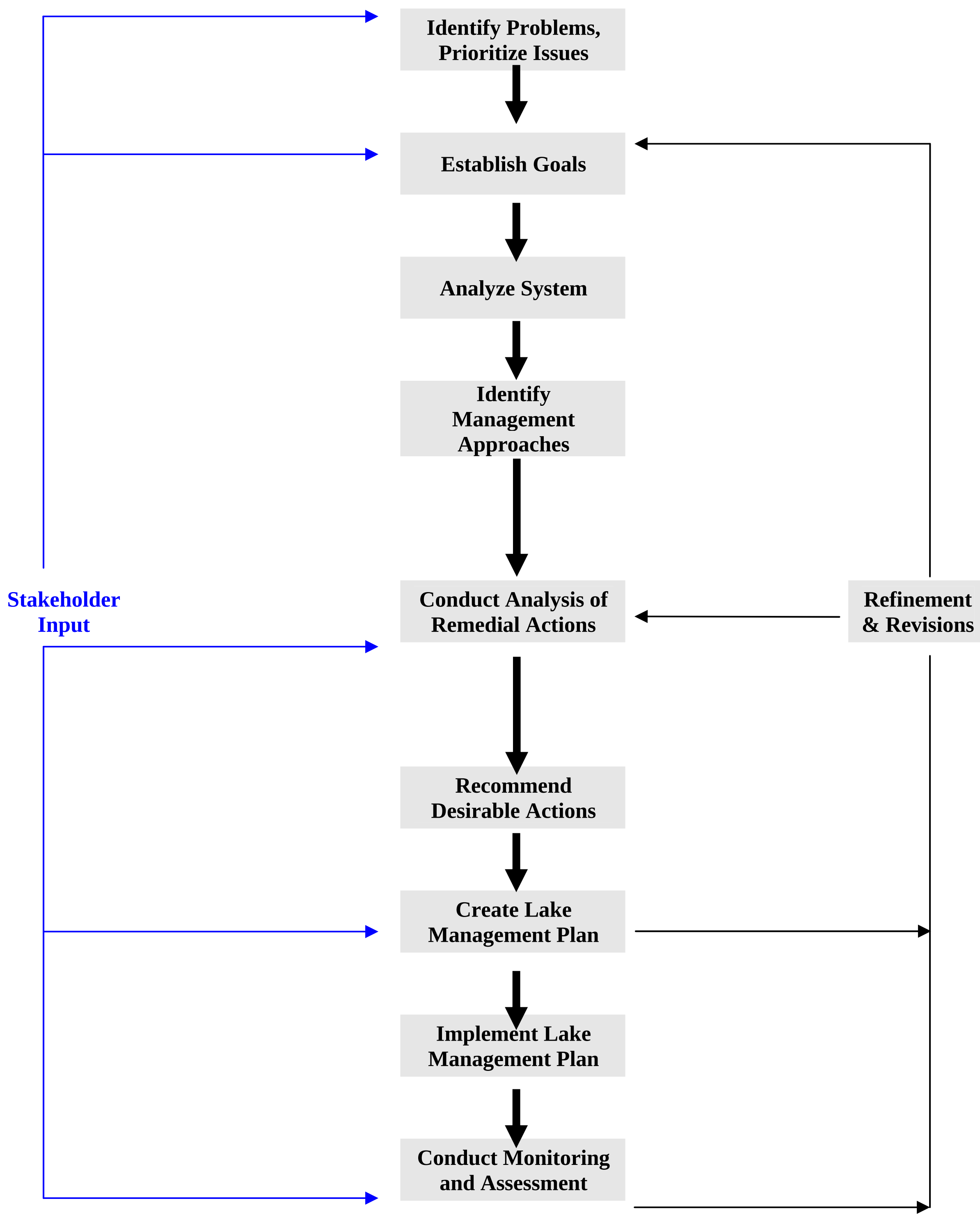
To implement a strategic approach for the Lakelse Lake Management Plan, a framework similar to the one outlined by Rast and Holland (1988) was used (Figure 2). It has been modified from its original form, to reflect the actual process of creating this management plan. Incorporated into the method was the K-T "Situation Appraisal" procedure that helped to identify and prioritize concerns, make decisions and identify possible actions.

The following is a summary of the "Situation Appraisal" procedure developed by K-T (www.kepner-tregoe.com) that was used by LWS in the lake management planning process. For further information about K-T, and the original LWS "Situation Appraisal" document see Appendix A.

Situation Appraisal:

- Identify concerns
- Break issues down into workable pieces
- Set priorities
- Plan next steps
- Select appropriate people to resolve issues

Figure 2. The Lake Management Planning Process (Modified from Rast and Holland, 1988).



The management planning framework consists of the following steps:

Step 1: Identify local problems and prioritize issues of concern – concerns were identified by talking with natural resource managers/scientists and members of the LWS. Using Kepner-Tregoe Situation Appraisal analysis, the issues were prioritized by LWS and the top seven will be discussed in this plan. The issues are described in Section 8.0.

Step 2: Define lake management goals– the issues outlined in step 1 were considered and 4 general goals were devised to encompass the issues. Section 9.0 provides details.

Step 3: Analyze the Lakelse Lake system - background information on the physical and chemical/biological systems was gathered for Lakelse Lake. It must be recognized that all components of the system are interrelated. The background information is presented in Section 7.0 and the data collected in the 2002 summer sampling program is in Appendix D.

Step 4: Identify possible management approaches to achieve the goals – management approaches were defined for each of the issues based on the general goals of LWS. To identify possible approaches, a comprehensive literature search was conducted and experts from around the province were consulted. Descriptions of each approach, along with considerations for remedial actions, are included in Section 10.

Step 5: Conduct an analysis of remedial actions – the costs and benefits of each action were researched. The analysis takes into account the values of various stakeholders, and is based on judgements made by experts and key stakeholders. LWS used "Situation Appraisal" analysis to create and action plan. They reviewed the tables describing the advantages and disadvantages of each action to conclude which best suited their purposes. The process is described in Section 10.0.

Step 6: Provide recommendations – the most desirable actions are the ones that LWS thought feasible and which best addressed the priority issues. These are summarized in the Section 11.0. In addition, information on possible resources, and other implementation considerations are included in this section of the plan.

This management plan represents completion of Step 6 in the management planning process. The framework shown in Figure 2 (pg. 13) includes 2 additional steps, which form an important part of the ongoing process. It is anticipated that management planning for the Lakelse Lake watershed will continue through Steps 7 and 8 and become an ongoing and cyclical process.

Step 7: Plan implementation – it is hoped that the LWS will continue to generate support in the community and gather resources to undertake activities recommended in the plan.

Step 8: Assessment (and revisions) – as the plan is implemented, arrangements should be made to monitor the success of the plan, and to make changes as necessary. It is advisable to schedule regular meetings (eg. once a year) to review and update the management plan.

6.0 Lake Characteristics

Over tens of thousands of years, lake basins change in size and depth as a result of climate, movements of the earth's crust, shoreline erosion, and the accumulation of sediment. Lakes receive inflows of water from the surrounding basin and from the atmosphere, so the observed water quality in a lake reflects, in part, the cumulative effects of the materials carried in all waters flowing into the waterbody (Rast and Holland, 1988).

6.1 Eutrophication

Eutrophication is the natural "aging" of small lakes. This is a slow process associated with the gradual build-up of organic matter, nutrients and sediments in lake basins. Over long periods of time, an open lake will first become a marsh, and then eventually fill in completely and become a terrestrial ecosystem (Rast and Holland, 1988). Throughout this process, rooted plant biomass will increase, water clarity will become reduced, the lake volume will decrease and algal blooms can become more frequent.

Cultural Eutrophication is a term used to describe the accelerated rate of the eutrophication process due to human settlement, clearing of forests, and development of farms within a lake's watershed (Rast and Holland, 1988). These activities increase the rate of nutrient enrichment and biomass production by increasing nutrient inputs to the lake. A lake that is undergoing cultural eutrophication can be restored so that it will again have water quality that is more characteristic of the natural situation. However, if cultural eutrophication is left unmanaged, the result will be significant ecological changes (water quality degradation) and a reduction in appeal of the lake for residents and recreational user-groups.

6.2 Trophic Status

Trophic status refers to the amount of biological productivity in a lake system and is directly related to nutrient inputs. The amount of algae and aquatic plant growth, water transparency, chlorophyll a levels, phosphorus concentration, dissolved oxygen in the hypolimnion (bottom layer of a thermally stratified lake), and populations of other organisms such as fish, are all indicators of trophic state. Table 1 on the following page provides an index for trophic classification based on total phosphorus measurements, chlorophyll a, and water clarity. Highly productive lakes with abundant aquatic life (mainly algae and macrophytes) are called *eutrophic* and are usually relatively shallow and warm in the summer. Lakes which produce little aquatic life are called *oligotrophic*. These lakes are characteristically deep and cold, usually with clear water and rocky shores. *Mesotrophic* lakes are waterbodies in transition between oligotrophic and eutrophic. There is a continuum of trophic states that ranges from ultra-oligotrophic through mesotrophic to hyper-eutrophic.

The productivity of a lake is dependent on many factors. One of the most important is the amount of nutrients, particularly phosphorus, in the water. Individual lakes or reservoirs will respond differently to phosphorus loading because of differences in basin depth, water residence time, degree of stratification, and watershed characteristics such as geology, soil type, vegetation, topography, and climate (Daniel et. al., 1994).

Lakelse Lake has relatively low phosphorus concentrations, low levels of chlorophyll a, good water transparency, and relatively high dissolved oxygen throughout the water column. These are all indicators of an oligotrophic lake. In addition, a recent sediment core diatom analysis (see Section 7.6 for further details) indicates that diatom populations in the lake have been historically dominated by species with affinities for oligotrophic conditions (Cumming, 2002). The lake has, however, been experiencing an increase in aquatic plant growth. The lake is also relatively shallow and subject to considerable enrichment, though the high flushing rate appears to be preventing excessive accumulation of nutrients in the water column (Abelson, 1976).

McKean (1986) indicated that since phosphorus concentrations have been close to surpassing allowable levels in the past, large-scale watershed development should be discouraged. To further protect the lake's long term water quality and prevent excessive plant growth, small-scale development should only occur on landforms determined to be good for the treatment of septic tank effluents. Sedimentation rates have increased since the 1950's in Lakelse Lake and residents of the watershed are concerned that this may alter the current trophic status of the lake. Further cause for concern is the increase in aquatic plant production possibly due to this sediment loading, and the impact this will have on the ecosystem.

Table 1. Trophic classification based on chlorophyll a, water clarity measurements, and total phosphorus values (Adapted from Lillie and Mason, 1983).

Trophic class	**Total phosphorus** (ug/l)	**Chlorophyll a** (ug/l)	**Secchi Disc** (m)
Oligotrophic	3	2	3.7
	10	5	2.4
Mesotrophic	18	8	1.8
	27	10	1.8
Eutrophic	30	11	1.5
	50	15	1.2

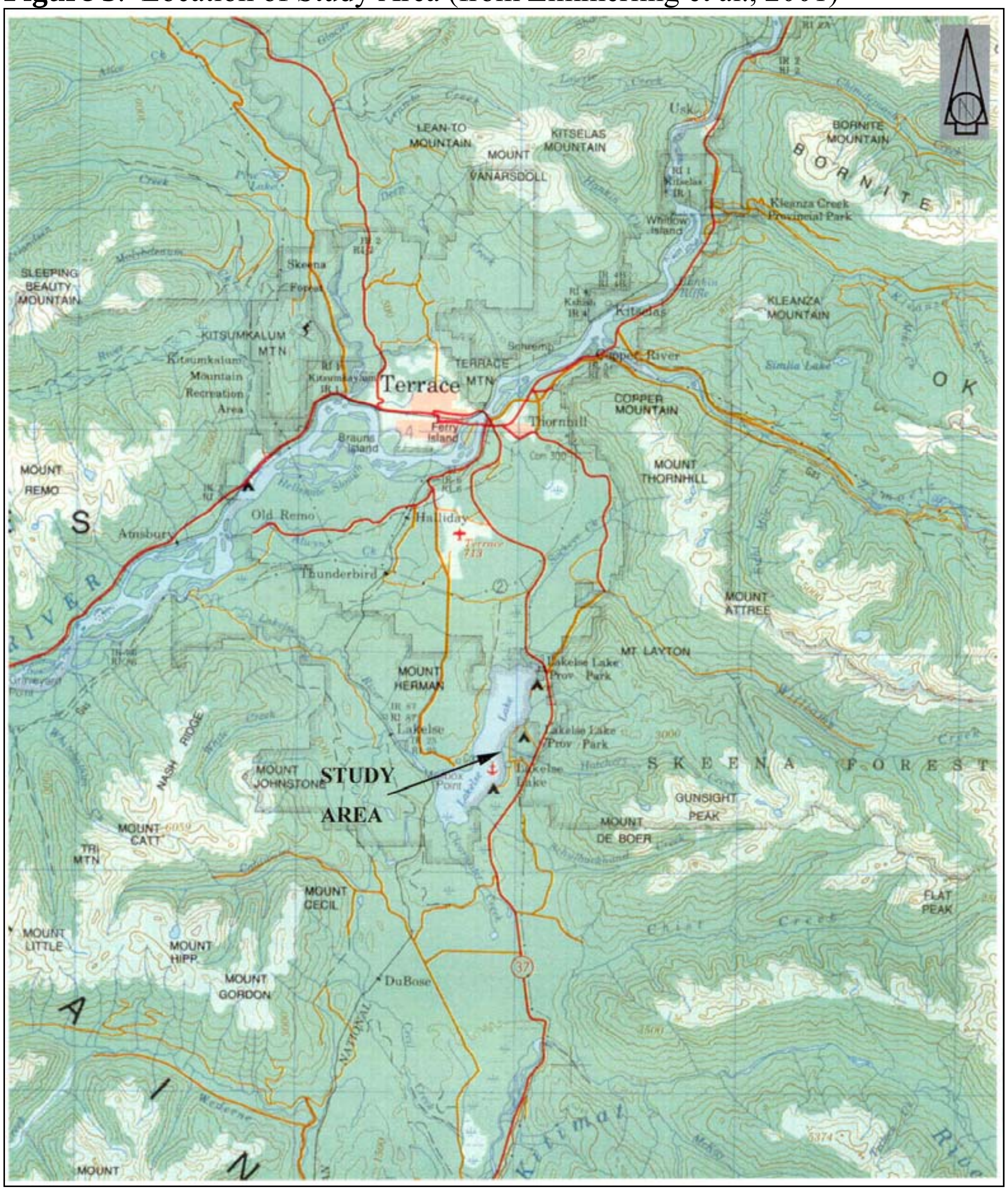
7.0 Lakelse Lake: Background Information

This section includes a description of the region around Lakelse Lake, including maps, morphometric, hydrometric, and water quality data and a summary of all measurement methods and sample locations.

7.1 Watershed Characteristics

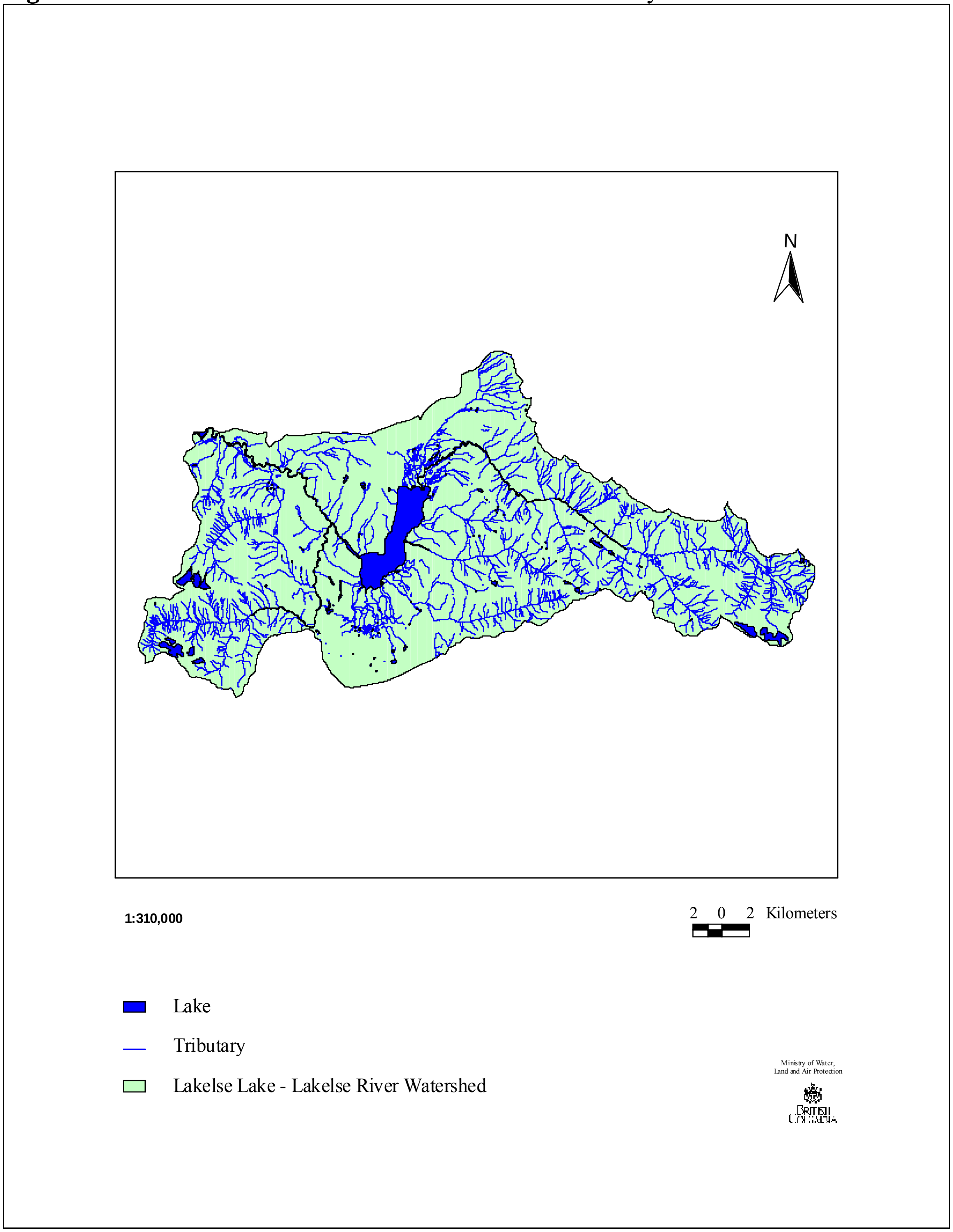
Lakelse Lake is located on the eastern margin of the Coast Range Mountains, approximately 9.7 km south of the city of Terrace (Figure 3). The lake lies at 54^{o} 30’ N latitude, 125^{o} 49’ W longitude and is located within the Regional District of Kitimat-Stikine in the Skeena Region (Cleugh, 1978).

Figure 3. Location of Study Area (from Zimmerling et al., 2001)



The Lakelse Lake-Lakelse River watershed drainage basin has an area of approximately 589 km² and a perimeter of 150.5 km. Note that Figure 4 shows the Lakelse River watershed (which includes Lakelse Lake). Most of the land west of Lakelse Lake does not drain into the lake itself; therefore the activities there do not affect *lake* water quality.

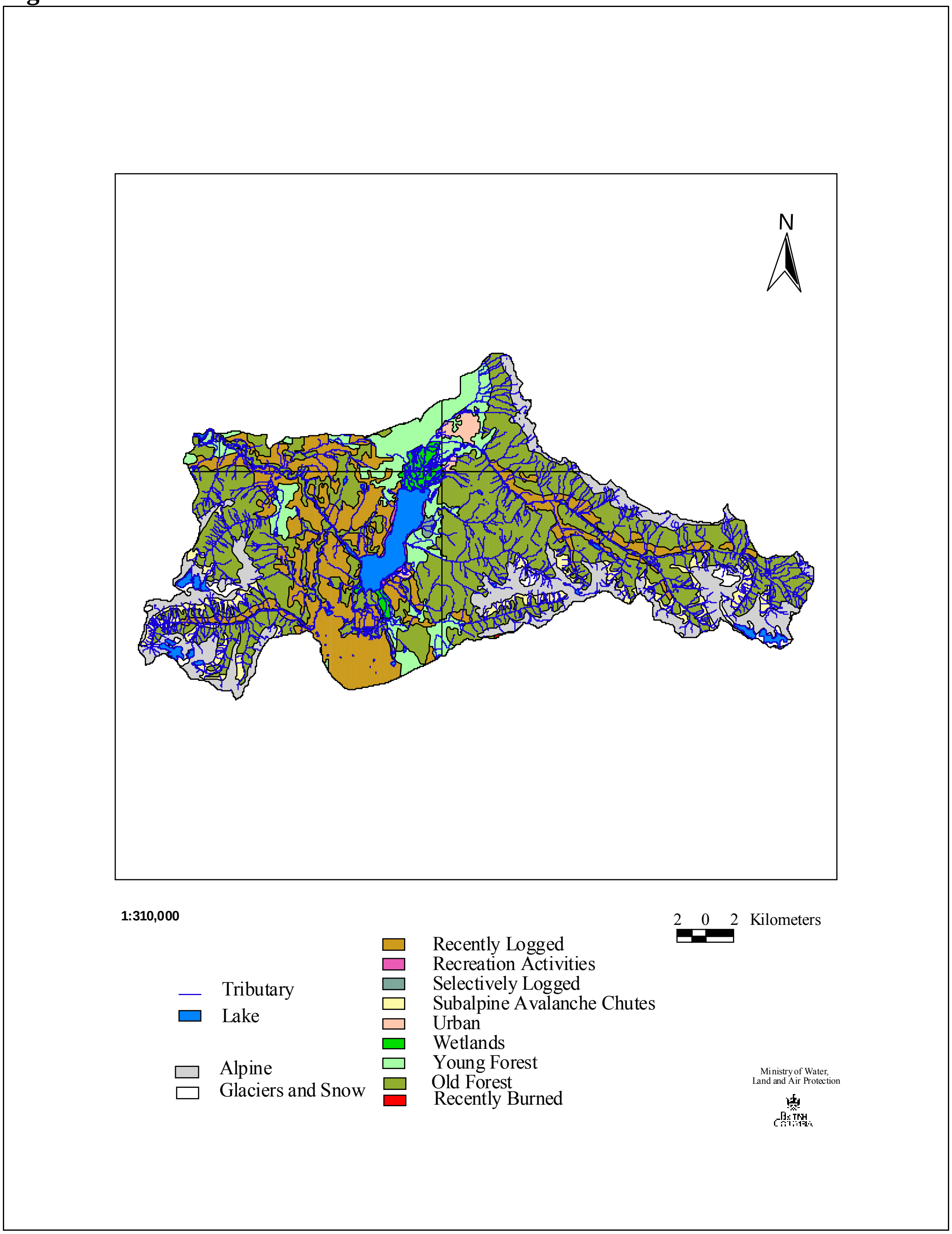
Figure 4. Lakelse Lake – Lakelse River Watershed Boundary



Current Land Use Activities

Lakelse River and Lake watershed land use activities include recreation, agriculture, forestry, residential and commercial uses. Figure 5 shows general land uses and forest types around the lake.

Figure 5. Land use activities in the Lakelse Lake watershed



First Nations Traditional Land Use in the Lakelse Watershed

People of the Tsimshian nation have historically inhabited areas around the Lakelse River and Lakelse Lake. The people lived in permanent villages, sustained by the rich natural resources in the area. Their main food sources included berry harvesting, salmon fishing, and hunting. Cedar was also utilized extensively in the watershed, and traditional uses for cedar included the making of canoes, long houses and cedar baskets (Kerby, 1984). Lakelse Lake Provincial Park contains numerous examples of culturally modified trees (Schultz, 2003 pers. comm.).

The current Tsimshian *Statement of Intent* boundary submitted for treaty negotiations includes the Lakelse watershed. The Tsimshian First Nations includes the seven First Nations of Kitasoo/Xaixais, Gitga'at (Hartley Bay), Kitkatla, Metlakatla, Lax Kw'Alaams, Kitsumkalum and Kitselas, with an estimated population of approximately 10,000 members. For further information about the Tsimshian and a map of the intent boundary visit the following websites:

http://srmwww.gov.bc.ca/dss/initiatives/treaty/soi.htm
http://www.gov.bc.ca/tno/nations/tsimshia/

7.2 Watershed Hydrology

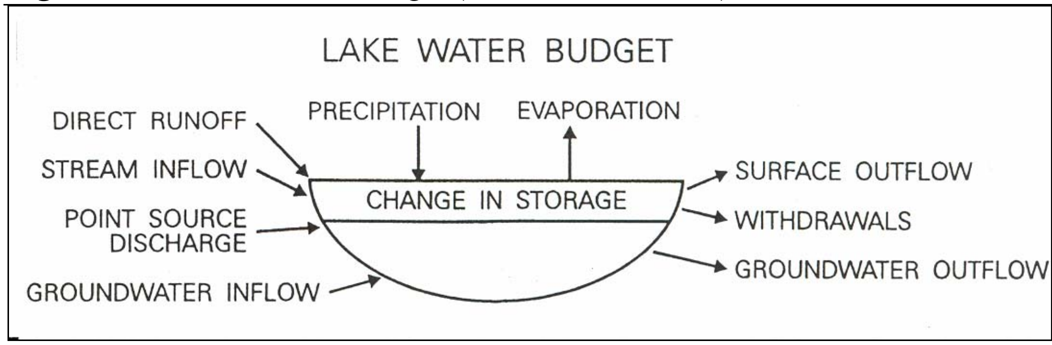
Sources of Water Inflows and Outflows

Water carries nutrients, pollutants and sediments into and out of lakes, therefore an understanding of lake hydrology is required to analyse water quality problems. A basic water balance equation can be expressed as:

Inflow + precipitation = outflow + evaporation + change in storage

Figure 6 illustrates possible water flows that contribute to the total water budget.

Figure 6. Schematic water budget (Holdren et al., 2001).



Inflows to Lakelse Lake include:

- *Precipitation*: water falling directly onto the surface of the lake
- *Direct runoff*: water that enters after flowing over the land surface
- *Groundwater flow*: water that enters after flowing through pores and spaces in the soil, either from subsurface or deep substrate
- *Stream flow*: there are at least 13 tributaries feeding Lakelse Lake. Some of the larger ones include:
    - ***Williams Creek***: Drains a 25 km long valley east of the lake, providing the main stream drainage into the lake at the north end
    - ***Hatchery Creek (a.k.a. Granite Creek)**** : 12 km long drainage (stream modifications due to human development cause greater concentrations of water flow within stream)
    - ***Scully Creek (a.k.a. Schulbuckhand Creek)***: 10 km long drainage
    - ***Furlong Creek***: 5 km long drainage (stream modifications due to human development cause greater concentrations of water flow within stream)
    - ***Clearwater Creek***: Drains north through extensive swamplands at south end of lake, originating from two small lakes
    - ***Hotsprings***: South of Granite Creek, a main channel flows into the east side of the lake from a set of nine hotsprings
      (Kerby, 1984)

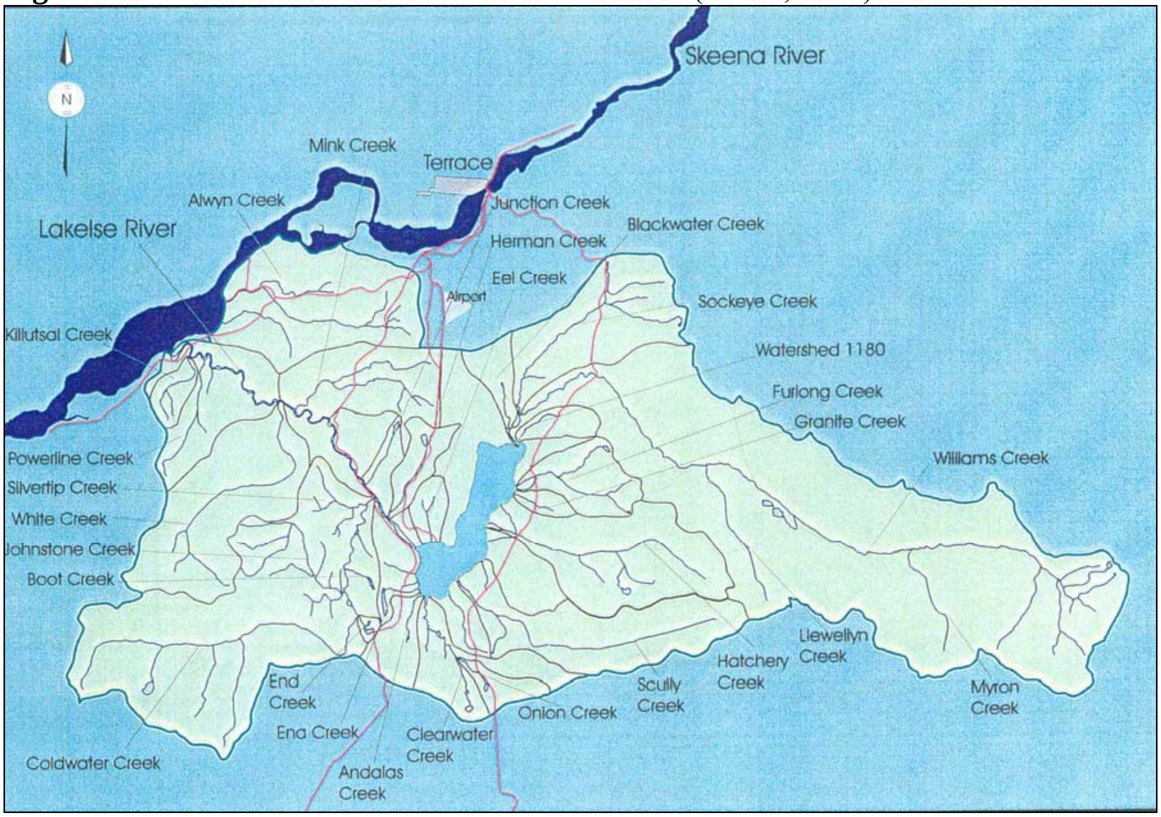
      (* there is some inconsistency noted between survey maps and road signs regarding Hatchery and Granite Creeks)

Figure 7 shows the locations of most tributaries to Lakelse Lake.

Outflows from Lakelse Lake include:

- *Lake Outlet*:
    - ***Lakelse River***: 20km long, it drains from the southwest corner of the lake into the Skeena River (Triton, 2000)
- *Groundwater outflow*: water that leaves via pores and spaces in the soil
- *Withdrawals*: water supply, irrigation, etc…
- *Evaporation*

Figure 7. Lakelse Lake and Lakelse River tributaries (Triton, 2000).



7.3 Lake Characteristics

Morphometric Data

Lakelse Lake is roughly 8.7 km long and is oriented in a north-south direction. It has a regular shoreline, no islands and one main basin. The maximum depth of the lake is 32m, but a large portion of the lake is considered littoral. The surface area is 14.2 km², with a shoreline perimeter of 26.87 km. Morphometric characteristics of Lakelse Lake are summarized in Table 2.

Table 2: Summary of Lake Characteristics for Lakelse Lake (McKean, 1986).

Lakelse Lake Characteristics	
Max. Depth	32 m
Mean Depth	8.6 m
Volume	120 000 dam^3
Surface Area	14.2 km^2
Elevation	72.2 m
Shoreline Length	26.87 km
Retention Time	69 days

Flushing Rate and Water Retention Time

Flushing rate describes how fast water passes through a lake basin, relative to lake volume. This value is determined by taking the inverse of the water retention time multiplied by 100 to get a percentage (Flushing rate = $^{1}/_{RT}$ x $100^{\%}$).

The average lake flushing rate was estimated by Cleugh et al. (1978) and Abelson (1976) to be five times per year, flushing 4 times during the six month period from spring to summer, and only once during the remaining fall-winter period. The lake's large watershed and the high annual precipitation for the area, results in a high flushing rate.

Water retention time (RT) is the average time that a given molecule of water remains within the lake basin. This is estimated to be an average of 69 days in Lakelse Lake. It is calculated by dividing the entire volume of water in the lake by the annual outflow volume (RT = lake volume ÷ annual outflow). Retention times are dependent on the bathymetric characteristic of the lake basin (lake size, shape and depth).

Bathymetry

A bathymetric map is a contour map of the depths in a lake basin. Lakelse Lake has a maximum depth of 32m, though a large portion of the lake (42%) is littoral. Temperature, dissolved oxygen, aquatic plants and overall productivity of the lake are affected by the extensive littoral zone (Gottesfeld et al., 2002). Figure 15 (pg 40) shows the bathymetric map for Lakelse Lake.

7.4 Physical & Chemical Water Quality Characteristics

Through a partnership between Water, Land and Air Protection (WLAP), Regional District of Kitimat-Stikine (RDKS) and the LWS, a water quality monitoring program was conducted at Lakelse Lake in the summer of 2002. A total of 9 shoreline sites, 1 deep station site, and 1 site on Upper Williams Creek were sampled throughout the summer. Refer to Figure 8 (pg. 26) for the map locations of the 2002 sampling sites.

The Deep Station Site was sampled in July, August, and September. Grab samples were collected from the surface water, at 6 m depth and from the bottom of the water column. At each depth the following measurements/analysis were performed: temperature and dissolved oxygen (D.O.), pH, specific conductance, total metals, dissolved metals, and various forms of nitrogen and phosphorus. In addition, chlorophyll a samples were collected from 0m, 2m, 4m and 6m depths. Vertical zooplankton hauls to 20 m were also collected at the deep station site.

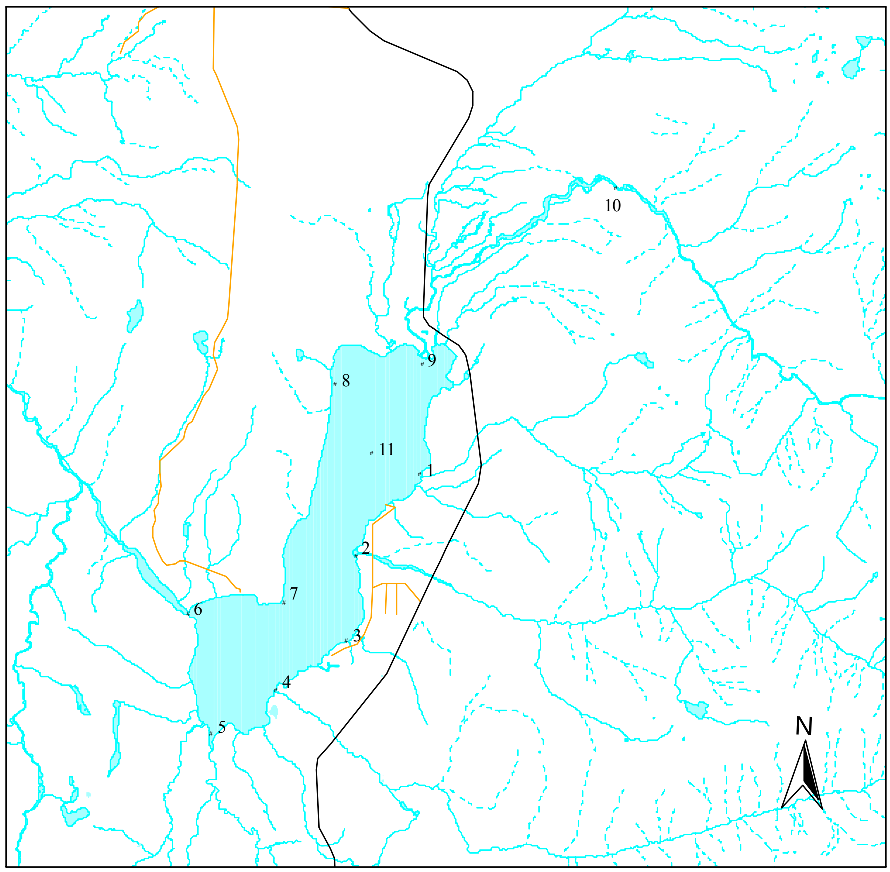
Shoreline and Upper Williams Creek sampling consisted of the same analyses as the Deep Station, but samples were collected from the surface water only (Note: chlorophyll a, zooplankton and temperature/D.O. profiles were not measured). Sampling was conducted in July, August, and October. For further details about the 2002 summer sampling program including a program overview, the data, and the volunteer monitoring guide that was developed, see Appendices C, D and E. (Note: Water quality sampling at Lakelse Lake has continued through the summer of 2003 to further investigate water quality issues. The 2003 sampling program and data to date are also available in Appendices C and D)

Over the years, there have been multiple sampling events on Lakelse Lake (and its tributaries), where physical and chemical water quality measurements have been taken. Table 2 summarizes years when data was gathered, and the data source. (Note: Although this is not a complete list of studies done on Lakelse Lake, these references have been the main sources of background information for this document.)

Table 3. Water Quality Sampling on Lakelse Lake

Year	Source
1944-1948	Brett (1950)
1974	Abelson (1976)
1975	Cleugh et al. (1978)
1986-1992	WLAP (EMS)
2001	Remington (2001)
2002	WLAP

Figure 8. Locations of the 2002 Sampling Sites



1:100,000

1 0 1 Kilometers

Highway
Road
Lake / River/ Tributary

1. E248785 (Furlong Creek outlet)
2. E248786 (Granite Creek outlet)
3. E207319 (Lakelse Lake Ambient Site #4- hot springs main outlet)
4. E248787 (Scully Creek outlet)
5. E248780 (Clearwater Creek outlet)
6. E248781 (Lakelse River)
7. E248782 (Mailbox Point)
8. E248957 (Muller Bay southwest end)
9. E248783 (Willaims Creek outlet)
10. E216313 (Upper Williams Creek)
11. E206616 (Lakelse Lake Deep Station)

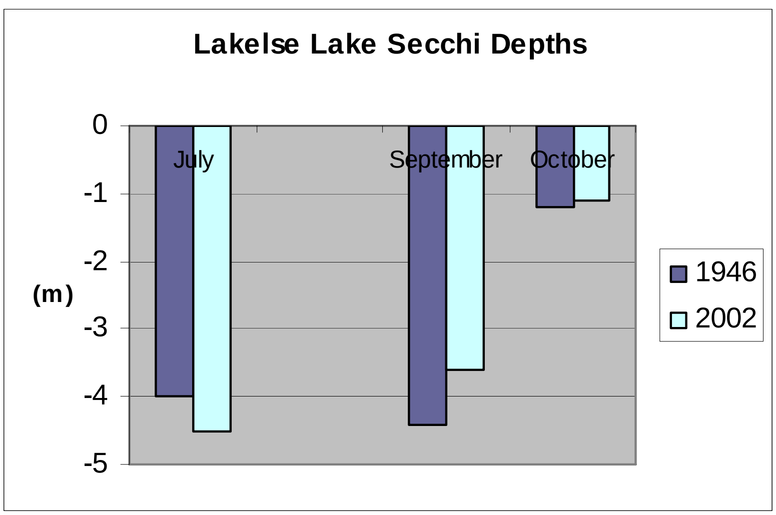
Ministry of Water, Land and Air Protection

Transparency/Secchi Depth

The transparency (or clarity) of a lake is based on the transmission of light through water. It is related to the density of algae and total suspended solids within the water column. Water transparency is usually measured using a black and white Secchi disk. The disk is lowered into the water column to the point where it is no longer visible and the depth is recorded. Another depth is recorded after raising the disk until it just becomes visible and the two depths are then averaged for the *Secchi depth*, or *Secchi transparency* of the lake (Holdren et al., 2001). The assumption is that the greater the Secchi depth, the better the water quality of the lake. Secchi depth measurements can be a generalized indicator of the trophic status of lakes (Michaud, 1991) but it is a difficult parameter to set objectives for. Lakes with a low Secchi values tend to be very productive (eutrophic) while lakes with high values tend to be less productive (oligotrophic).

A comparison of the Secchi depths at Lakelse Lake Deep Station in 1946 and 2002 are shown in Figure 9. According to Table 1 (pg. 17), Lakelse Lake can be classified as oligotrophic based on July and September water clarity measurements. Lower water clarity in October is likely due to fall rains.

Figure 9. Comparison of Lakelse Lake Secchi Depths



Temperature

It is thought that Lakelse Lake is the warmest lake in Northern B.C. A number of hotsprings with temperatures up to 85ºC are found on the eastern shore of the lake (Gottesfeld et al., 2002). Of all the properties of a lake, temperature has the greatest influence on the biology and chemistry of the lake system. The density of water is directly related to temperature. As heat energy from sunlight and the air is directly absorbed by the lake water in the spring, wind action helps to distribute this heat throughout a lake's surface waters. As the surface waters warm, they become lighter than the cooler, denser water at the bottom of the lake. As this process continues, the density

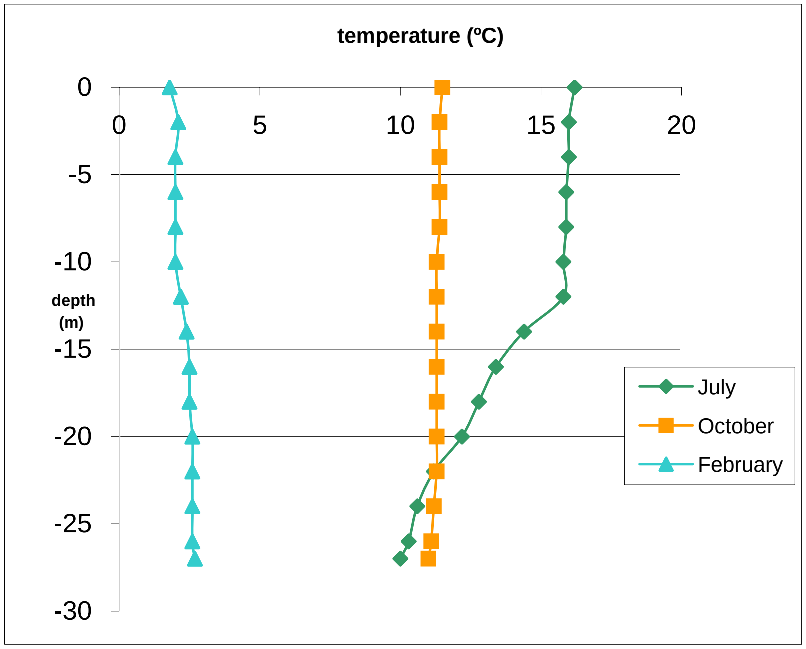
difference between the surface and bottom waters becomes too great for the wind to mix. The occurrence of warm surface waters overlying cold bottom waters is referred to as *thermal stratification*.
Three distinct layers are formed during summer stratification: the *epilimnion* (the upper, warm, and well mixed area), the *metalimnion* (the middle layer of rapidly decreasing water temperature and density), and the *hypolimnion* (the uniformly cold, dense, and unmixed bottom layer). Mixing becomes easier in the fall, as the surface waters cool and the temperature differences between layers decreases. When the water reaches uniform temperatures and density at all depths, this destratification is referred to as *fall turnover*.

Thermal stratification also occurs in the winter months. The temperature in the hypolimnion during the winter is generally around 4° C (at water's maximum density), while the cooler temperatures in the epilimnion are actually less dense. During the winter (when an ice layer forms on top) the water then re-stratifies in reverse order. When the ice layer melts in the spring, the wind action results in another period of circulation which is referred to as *spring turnover* (Holdren et al., 2001).

Temperature profiles reveal whether a lake thermally stratifies (indicated by changes in temperature with depth) and how often and complete the stratification is. Several factors can affect the extent of summertime l stratification within a lake, including lake depth, winds and spring temperatures.

In the case of Lakelse Lake, heavy winds tend to circulate the water in the summertime, resulting in unstable stratification and weak layering during July and August. Limited hours of sunshine in the summer, as well as the rapid flushing rate of the lake are also contributing factors to weak stratification (McKean, 1986). Lake temperature measurements were recorded at the Deep Station Site at regular depth intervals during July and October 2002, and February 2003 to illustrate the summer, fall and winter temperature profiles of Lakelse Lake. Figure 10 shows that Lakelse Lake temperature is weakly stratified in July and uniform (the lake is well mixed) in October. In February, bottom water temperatures were slightly warmer than temperatures near the surface (temperatures closer to 4° C are generally denser).

Figure 10. Lakelse Lake Deep Station Temperature Profiles, 2002/2003



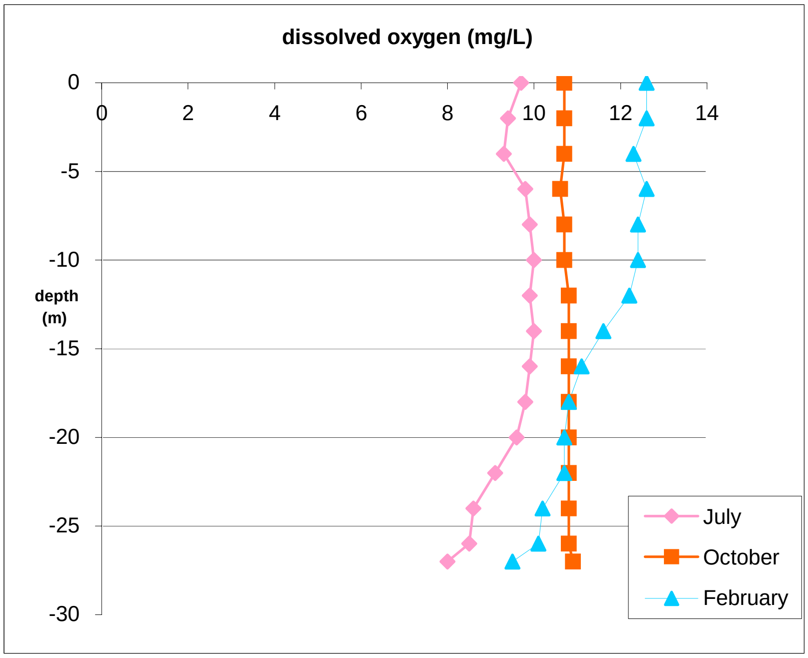
Dissolved Oxygen (D.O.) Profile

The amount of oxygen in the water is an important indicator of overall lake health (Cavanagh et al., 1997). The oxygen enters the water through exchange at the surface waters from wind mixing the epilimnion, photosynthesis and the inflow of oxygen rich water into the lake through streams. Cold water holds more oxygen than warm water, so as the temperature of water increases, oxygen is released to the air (Cooke et al., 1993). When lakes become stratified in the summer and winter, low D.O. levels can cause stress on aquatic organisms and have been attributed to fish kills in severe circumstances. If the water at the lake bottom (hypolimnion) is oxygenated, phosphorus is trapped in the sediments. When D.O. levels are low in the hypolimnion, it encourages the release of phosphorus into the water column. An increase in phosphorus concentration can lead to an increase in algal and macrophyte growth (Holdren et al., 2001). When the plants and algae blooms die, they sink to the bottom of the lake and decompose, further reducing the oxygen content of the water, and creating an ongoing cycle of oxygen depletion.

An objective for the D.O. content of the hypolimnion has been set in Lakelse Lake to ensure the cold water fishery and zooplankton habitat of the lake remains healthy (McKean, 1986). The objective states that D.O. content in the lake should not drop below 6.0 mg/L, at any point greater than 5m above the sediment-water interface. Of the D.O. profiles recorded in 2002/2003, the lowest reading at 5m above sediment was 8.5mg/L in September. Thus all of the D.O. numbers meet the objective. For further information about objectives set for Lakelse Lake see the report *Attainment of Water Quality Objectives for Lakelse Lake, 2002 Update* in Appendix F.

Lakelse Lake is a relatively well-mixed lake due to heavy winds and a rapid flushing rate, which helps to keep the bottom layers oxygenated, even throughout the summer months. D.O. should continue to be measured to monitor and maintain the cold water fishery and zooplankton habitat. D.O. profiles for Lakelse Lake in July, October and February are shown in Figure 11.

Figure 11. Lakelse Lake Deep Station Dissolved Oxygen Profiles, 2002/2003



Nutrients

Aquatic life has several requirements for survival and growth. For algae and aquatic plants (which form the base of the aquatic food web), these requirements include sunlight, oxygen, hydrogen, carbon, nitrogen, phosphorus and other micronutrients. The ratio of carbon (C): nitrogen (N): phosphorus (P) by weight in plants is 40C:7N:1P and this is the ratio that is needed in their environment for growth (Wetzel, 1983). If sunlight and other micronutrients are available for growth, then phosphorus will be the first major nutrient to limit growth. Additional phosphorus that enters the lake environment will result in increased levels of photosynthesis, and growth of algae and aquatic plants. If phosphorus is in excess within the lake, then there will be a high level of photosynthesis until nitrogen becomes scarce and thus the next limiting nutrient (Wetzel, 1983).

An objective of 10µg/L has been set for mean summer concentration of total phosphorus in Lakelse Lake (McKean, 1986). Based on the July, August and September Deep Station sampling, the mean summer concentration in Lakelse Lake is estimated to be 4µg/L. This number is below the objective.

Phosphorus-Limited Lakes

Most lakes in North-Central B.C. are phosphorus-limited, and a few are co-limited by phosphorus and nitrogen. Generally, in waters with N:P ratios of less than 5:1, nitrogen is limited. Ratios of 5-15:1 indicate no limitation or co-limitation and ratios of greater than 15:1 indicate phosphorus limitation (Nordin, 1985). McKean (1986) reported that Lakelse Lake is limited by phosphorus, except possibly during freshet when nitrogen-limiting conditions are approached. Data collected in 2002 has similar indications, though sampling at spring turnover is required to clarify results.

Nutrient Sources: Internal and External Loading

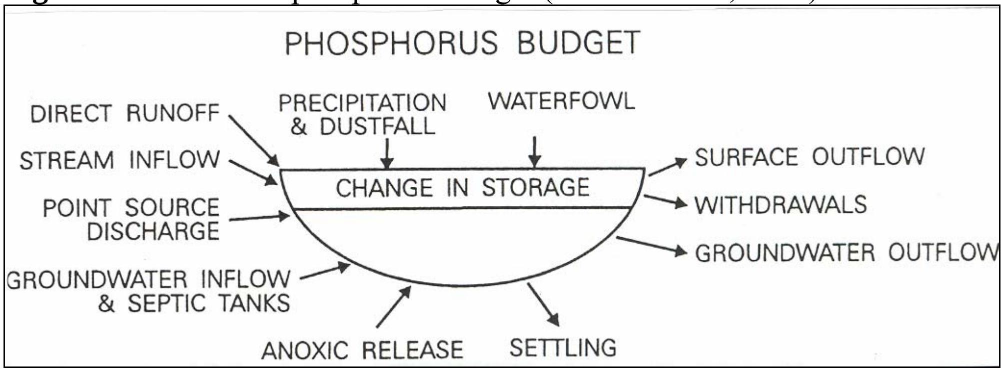
Because phosphorus is the nutrient that regulates the general trophic status of the lake, it is important to determine the internal (in lake) and external (outside the lake) sources of this nutrient. Internal sources of phosphorus include nutrient cycling through plant growth and decay, and sediments. The chemical equilibrium in the lake, and especially at the sediment-water boundary, dictates how much phosphorus is released from the sediments. Phosphorus is re-suspended into the water under reducing (low oxygen) conditions at the sediment-water boundary.

External sources of nutrients can be classified as either “point” or “non-point” sources. Both can contribute significant amounts of nutrients to aquatic systems. Non-point sources cannot be traced to a specific origin or starting point but seem to enter the lake system from many places. There are three major sources of non-point source nutrients: those that are carried by overland flow during ice melt, flood or storm events (often originating from agriculture, forestry, urban development, and mining); those that are deposited from dust in the atmosphere (during rainfall events); and those sources seeping into the lake from deep and shallow groundwater flow (onsite septic system leachate). External point sources include direct discharge into the lake from specific, identifiable pipes, points or outfalls. These sources are generally more readily measurable than non-point nutrient sources (Holdren et al., 2001).

Nutrient Budgets

A nutrient budget is a quantitative assessment of nutrients moving into, being retained in, and moving out of an aquatic system (Holdren et al., 2001). It is a mathematical tool that describes both the sources (and sinks) and quantities of nutrients in aquatic ecosystems. Since phosphorus is central to the productivity of lakes, many nutrient budgets focus on phosphorus loading. Figure 12 illustrates external and internal phosphorus sources that may contribute to the total budget. One way to calculate a budget is by sampling and calculating loading rates from all possible sources of nutrients including atmospheric deposition, streams, septic tanks, agriculture, direct discharges and internal loading (McKean, 1986). This process is labour intensive and costly due to extensive laboratory analyses.

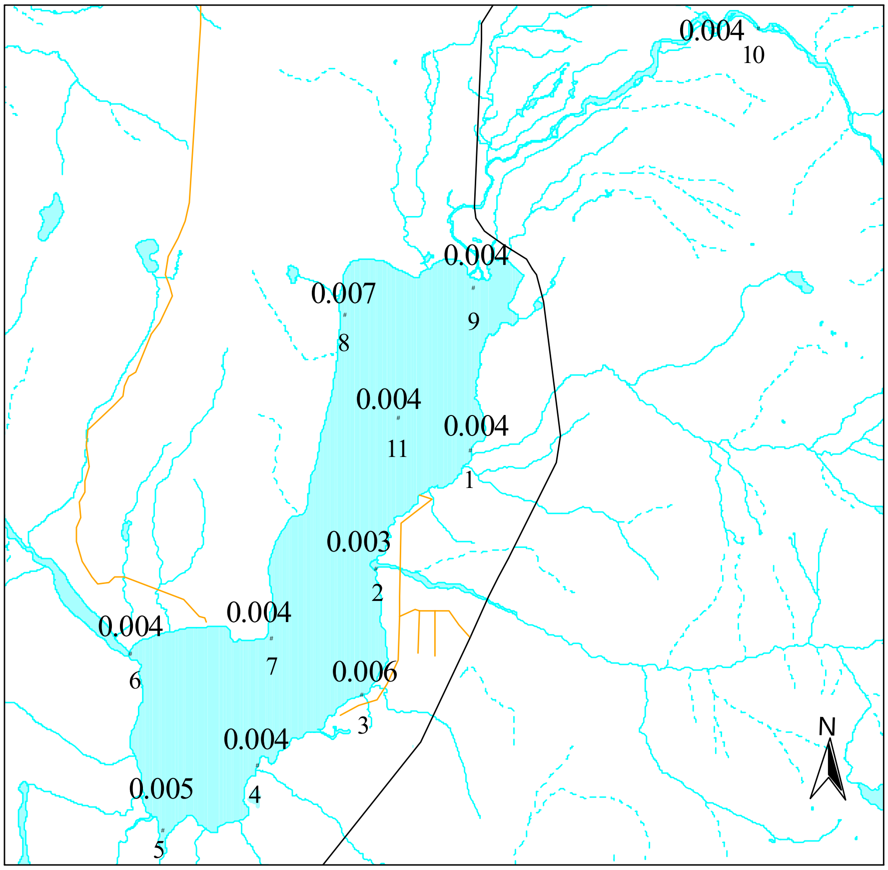
Figure 12. Schematic phosphorus budget (Holdren et al., 2001).



Another method involves the use of models. These models can account for the phosphorus loading due to climate, watershed characteristics and human activities (including land use). The relationship between the land use and the lake trophic quality can be explored and quantified through mathematical modeling (see Rysavy and Sharpe, 1995, sections 2.4 & 4.2.2.5). Once phosphorus concentrations are predicted from a model, it is useful to interpret this prediction in the context of expected water quality characteristics for the lake of interest.

Information regarding phosphorus contributions to Lakelse Lake is insufficient to produce an accurate phosphorus budget or model for the lake. Unknowns include inputs from groundwater, atmospheric deposition, overland flows, septic system infiltration, biological decay and lake bottom sediments. During the summer of 2002, sampling took place near the mouths of many tributaries entering the lake. Total phosphorus values from the three sets of samples have been averaged at each site and are shown in Figure 13 to give a preliminary indication of the nutrient contributions from these sources. Further information is required to create an accurate nutrient budget for Lakelse Lake.

Figure 13. Average total phosphorus concentrations (mg/L) at Lakelse sample sites, 2002



1:68,000

1 0 1 Kilometers

1. Furlong Creek outlet - 0.004 mg/L
2. Granite Creek outlet - 0.003 mg/L
3. Ambient Site #4 (hot springs main outlet) 0.006 mg/L
4. Scully Creek outlet - 0.004 mg/L
5. Clearwater Creek outlet - 0.005 mg/L
6. Lakelse River - 0.004 mg/L
7. Mailbox Point - 0.004 mg/L
8. Muller Bay southwest end - 0.007 mg/L
9. Willaims Creek outlet - 0.004 mg/L
10. Upper Williams Creek - 0.004 mg/L
11. Deep Station - 0.004 mg/L

Ministry of Land,
Water and Air Protection
Skeena Region
March 2, 2003

British Columbia

7.5 Biological Characteristics

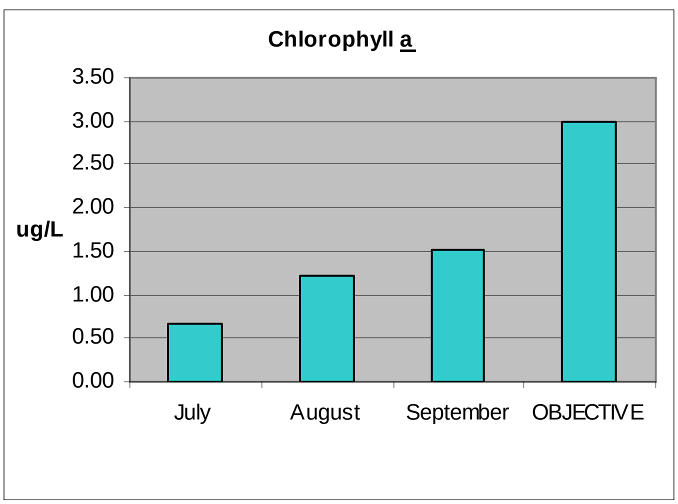
Algae

Algae are single celled, photosynthetic organisms that form the base of aquatic food chains. These organisms are separated into three groups based on where they grow: algae that float on or just below the surface of the water are called *phytoplankton*, mobile algae (flagella or cilia) are called *planktonic,* and those algae that attach themselves to the bottom substrate are called *periphyton* (Holden et al., 2001). Abundance of all forms is primarily a function of light, temperature, and concentration of nutrients.

Algal biomass and species diversity is a good indicator of the trophic status of the lake. The sediment core diatom analysis (discussed in section 7.6) indicates that diatom populations in the lake have been historically dominated by species with affinities for oligotrophic conditions, suggesting that in the past Lakelse Lake has been oligotrophic.

Chlorophyll a measurements are recognized as a useful estimate of algal growth in lakes. Objectives have been set for chlorophyll a to monitor nuisance algal growth in lakes. The objective for mean summer concentration of chlorophyll a in Lakelse Lake is ≤3µg/L (McKean, 1986). Based on the July, August and September Deep Station sampling, the mean summer concentration in Lakelse Lake is estimated to be 1.14µg/L (see Figure 14). This number is significantly below the objective. A chlorophyll a growing season mean of 1.14µg/L indicates Lakelse Lake is oligotrophic (McKean, 1986). For further information about this objective set for Lakelse Lake, see Appendix F. A list of algae species that were present in Lakelse Lake in 1976 can be found in Appendix G.

Figure 14. Concentration of chlorophyll a in Lakelse Lake - July to September 2002



Aquatic Macrophytes

Aquatic macrophytes are vascular plants (plants with conducting cells to transport nutrients through their stems) that provide the most productive and important habitat in a lake. There are different types of growth forms for macrophytes, including submergent, emergent, floating-leaved, and free floating. Macrophyte growth is affected by temperature, light penetration, nutrients, and slope and sediment type (for rooted types). Rooted macrophytes tend to rely primarily on nutrients found in the sediment while free floating forms draw upon nutrients found in the water (Holdren et al., 2001).

Studies suggest that there is an inverse relationship between algae and macrophytes. When there are large algae blooms, there are often fewer macrophytes. Where there is large macrophyte growth, there is usually reduced algae growth (Wetzel, 1983).
A species inventory of aquatic macrophytes in Lakelse Lake was conducted by Dr. P. Warrington in 1984. The list of species is provided below.

Aquatic Plants in Lakelse Lake (Warrington, 1984):

- *Potamogeton richardsonii* (Richardsons Pondweed)
- *Potamogeton gramineus* (Grass-leaved Pondweed)
- *Potamogeton zosterformis* (Flat-stem or Eelgrass Pondweed)
- *Potamogeton robbinsii* (Fern-leaf Pondweed)
- *Potamogeton bercgtoldii/freisii* (Small Pondweed)
- *Potamogeton epihydrus* (Ribbonleaf Pondweed)
- *Potamogeton natans* (Floating-leaved Pondweed)
- *Potamogeton praelongus* (White-stemed Pondweed)
- *Potamogeton pectinatus* (Sago Pondweed)
- *Myriophyllum exalbescens* (Northern Water Milfoil)
- *Myriophyllum verticillatus* (Whorled Water Milfoil)
- *Utricularia vulgaris* (Common Bladderwort)
- *Utricularia intermedia* (Flatleaf or Northern Bladderwort)
- *Ranunculus aquatilis* (White Water Buttercup)
- *Ranunculus flabellaris* (Yellow Water Buttercup)
- *Najas flexilis* (Slender Water Nymph or Naiad)
- *Callitriche heterophylla* (Pursh Two-headed Starwort)
- *Sparganium emersum* (Unbranched Bur-reed)
- *Nuphar polysepalum* (Yellow Pond Lily, Cow Lily, Spatterdock)
- *Equisetum fluviatile* (Water Horse Tail)
- *Typha latifolia* (Common Cattail)
- *Menyanthes trifoliate* (Buck Bean)
- *Hippuris vulgaris* (Mares Tail)
- *Alisma plantago-aquatica* (Common Waterplatain)
- *Scirpus lacustris* (True Bulrush)
- *Scirpus subterminalis* (Water Bulrush)
- *Isoetes sp.*
- *Chara sp.*
- *Carex sp.*
- *Glyceria sp.*
- *Nitella sp.*

It should be noted that *Elodea canadensis* was not included Warrington's list of aquatic plants. Additional information about these species is found in Appendix H, with the inclusion of *Elodea canadensis*. Area residents have only recently (late 1990's) noticed the occurrence and subsequent increase in *Elodea canadensis* in the lake. For further information about macrophytes found in British Columbia see Warrington's *Identification Keys to the Aquatic Plants of British Columbia* on the web at: http://wlapwww.gov.bc.ca/wat/wq/plants/plantkey/key.html.

Zooplankton

Zooplankton are microscopic single- or multi-celled animals that form an integral part of the aquatic ecosystem. Not only do zooplankton form a major food source for fish and invertebrates, they also act like grazers on the algae community. Zooplankton can significantly increase the clarity of the water by feeding on algae (Holdren et al., 2001).

A thorough survey of the zooplankton community of Lakelse Lake was completed between 1949 and 1952 (McMahon, 1954). During this study, two copepods (Cyclops and Epischura) and two cladocerans (Bosmina and Diaphanosoma) dominated the zooplankton community. Because of differing sample methods, subsequent data collected by Abelson (1976) and Cleugh et. al., (1978) are not comparable to McMahon (1954). In 1984 the Regional Waste Management Office also collected data, although it is not as complete. See Appendix I for a list of species collected in Lakelse Lake (Abelson, 1976). Monitoring of the zooplankton community is recommended because of its importance as a food source to sockeye underyearlings, and presumably trout and coho fry in the lake and Lakelse River (McKean, 1986).

In the summer of 2002, three sets of 20 m vertical zooplankton hauls were collected at the Deep Station Site. The samples were sent to Blake Matthews at the University of Victoria, in hopes that the nitrogen isotope composition of the zooplankton can be measured and related to watershed activities and nutrient conditions in the lake. A written proposal for the study is currently underway.

Fish

The Lakelse watershed possesses a very high fisheries value both commercially and recreationally. Lakelse Lake is a shallow lake ideal for rearing fish and is a major producer of sockeye, coho and pink salmon. Steelhead and spring cutthroat populations sustain a healthy sport fishery. Resident species present in the system include rainbow trout, Dolly Varden, mountain whitefish, prickly sculpin, largescale suckers, red-sided shiners, northern pikeminnow, peamouth chub, and threespine stickleback (Gottesfeld et al., 2002). The following paragraphs summarize the current state of various salmonid species and their utilization of the Lakelse watershed system:

Chinook
The chinook population is relatively low in the Lakelse watershed. They enter the system in mid August to early September and spawning generally occurs below the lake outlet. Past studies have documented chinook spawning in low numbers in tributary creeks like Sockeye and Williams Creek (Gottesfeld et al., 2002).

Pink
Within the Skeena system, the Lakelse River is one of the major pink salmon producing rivers. Pink salmon enter the river from August to October, peaking in September. To a lesser extent, the tributaries of the river and Lakelse Lake are utilized by pinks for spawning.

Chum
Like the pinks, chum also enter the Lakelse River from August to October, with the run peaking in September. The run is modest, and escapement data is scarce.

Sockeye
Within the Skeena drainage, Lakelse Lake is one of the major sockeye salmon producers. Sockeye generally enter the Lakelse system in June, and spawning occurs in August. Williams and Scully Creeks are major spawning streams, though fish utilize the lower reaches of many other Lakelse Lake tributaries including Andalas, Clearwater, Hatchery, Granite, Sockeye and Blackwater Creeks.

Coho
Although escapement declined severely by the mid 1970's, the Lakelse coho stock remains one of the most productive coho stocks in the Skeena system. The run enters Lakelse River in September and October with most spawning taking place below the lake outlet. Fish also utilize many Lakelse River and Lakelse Lake tributaries for spawning.

Steelhead
Two distinct runs of steelhead enter the Lakelse watershed: a spring run and winter run. Spawning occurs in a number of areas throughout the Lakelse River mainstem, mainly in a section downstream of the lake outlet. Steelhead have also been known to overwinter in Lakelse Lake.

For more detailed description of Lakelse watershed fish populations and their habitat see *Conserving Skeena Fish Populations and their Habitat* (Gottesfeld et al., 2002).

Terrestrial wildlife and waterfowl

Important wildlife populations are found within the Lakelse watershed. Big game animals in the area include moose, deer, grizzly and black bears, wolves, cougars and goats. The Lakelse Lake - Lakelse River areas are critical habitat for both moose and grizzlies. Kermode bears, a white color phase for a subspecies of black bears, also are found in the area.

Numerous species of furbearers are found throughout the Lakelse watershed. They include fox, porcupine, red squirrel, marten, fisher, mink, otter, short-tailed weasel, wolverines, lynx, coyote, muskrat, snowshoe hare, and beaver. Of all the furbearers, beavers have the greatest influence on the Lakelse watershed, as their numerous dams create important habitat for moose, waterfowl, fish and other species which utilize riparian areas. Small mammals and amphibians such as the spotted frog provide the foundation of the food chain for many furbearers and birds of prey. In addition, seals have been known to follow migrating fish upstream into the Lakelse River and Lakelse Lake (Kerby, 1984).

The Lakelse watershed provides substantial habitat for waterfowl. Lakelse Lake is utilized by various species of migratory geese and ducks. The wetlands and lake provide essential breeding grounds and wintering sites for waterfowl as well. Trumpeter swans currently winter at Lakelse Lake. Birds of prey found in the Lakelse area include bald eagles, osprey, kingfishers, herons, goshawks and marsh hawks. Numerous smaller non-game birds inhabit the area and are an important part of outdoor recreation opportunities in the area. For a more extensive list of species refer to *The Greater Terrace Official Settlement Plan* (Kerby, 1984).

7.6 Inferring Lake History with Sediment Cores

Effective management of aquatic resources requires long-term environmental data so that background conditions can be determined. The results from sediment coring can provide long term data on ecosystem conditions and changes, and can be used to assess and compare past and present ecosystem health. It is therefore very useful to integrate this type of analysis into environmental monitoring and assessment programs.

In February 2002 sediment core samples were obtained from Lakelse Lake north and south basins (Figure 16, pg.40). The sediment cores were separated into 1 cm thin slices and shipped to Dr. Brian Cumming at Queen's University for analysis. The results are summarized in a report entitled *Assessment of Changes in Total Phosphorus in Lakelse Lake, BC: A Paleolimnological Assessment* (see Appendix J). The approximate cost for the analysis of each core was $5,000. Now completed, core sampling and analysis will not need to be repeated in the foreseeable future.

Summary of Lakelse Sediment Core Results

Sediment cores enable the reconstruction of lake productivity levels over time. A combination of lead isotope (Pb 210) dating, diatom assemblage analysis and nutrient concentration analyses of the slices allow for inferences to be made about natural and human influences to the lake. The following is a summary of the results from *Assessment of Changes in Total Phosphorus in Lakelse Lake, BC: A Paleolimnological Assessment* (Cumming, 2002).

Diatom Assemblage Changes and Analysis

Diatoms are single-celled microscopic plants belonging to an algal class. Due to the composition of their cell walls, they are generally well-preserved. Diatom species respond quickly to environmental change, which make them extremely useful in quantifying environmental characteristics to a high degree of certainty. Individual species can be related to variables of interest and can then be used to make environmental inferences (Dixit et al., 1992). Each slice of the Lakelse sediment core was analysed to identify species population abundance. What is known about species affinities for various nutrient regimes was applied to infer the trophic status of the lake over the long term.

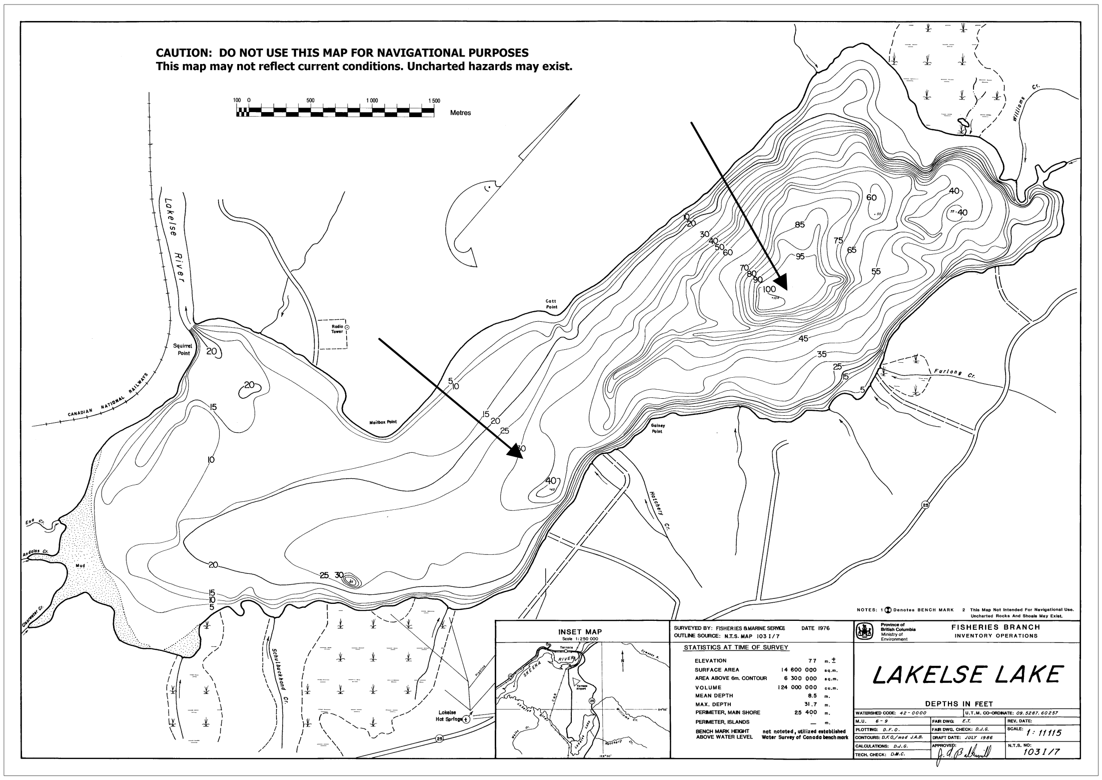
According to Cumming (2002), Lakelse Lake appears to have been oligotrophic to slightly mesotrophic throughout the past several hundred years. This is evident from the dominance of *Cyclotella stelligera* (an oligotrophic planktonic species) throughout the cores. In both the south and north basins, there has been little change in the diatom species composition over the last several hundred years, with only small increases in euthrophic species after approximately 1957. These small changes were not large enough to change the estimated phosphorus levels. The diatom-inferred total phosphorus (TP) estimates indicate that over the past several hundred years the lake has had relatively oligotrophic conditions (TP ranging from ~4 to 8 ug/l, being slightly higher in the shallower south basin).

Sedimentation Rates and Organic Matter

A comparison of pre-settlement sediment loading rates with current rates can determine the impact of human development in an area. The sediment core analysis indicates that, in the north basin, sediment delivery rates began to increase in the 1950's and peaked in 1991. In the south basin, loading was highest between 1967 to 1972 and 1981 to 1984. A historical timeline presented in Appendix K lists the major events and developments around Lakelse Lake within the last 100 years. Significant human activities in the Lakelse watershed began to occur in the 1950's and included sawmill operation on the north end of the lake, increased logging activity, highway construction and subsequent creek diversions and landslides. These activities may be related to the observed increase in sediment delivery.

In the mid to late 1990's, changes in the composition of the inwash to the lake are noted as the % organic matter increased. In other words, a change in the content ratio of the composition occurred. Without increases in sedimentation rates nor inferred increases in phosphorus levels, the recent small increases in percent organic matter suggests that inwash to the lake has changed recently due to either increases in organic matter, or decreases in inorganic material (Cumming, 2002). (Note: Organic matter refers to materials that are non-mineral. Rather, the molecules have originated from plant and animal materials.)

Figure 15. Bathymetric Map and Sediment Core Sample Locations of Lakelse Lake (arrows indicate north and south basin coring locations)



Discussion

The changes in sediment input to the lake between 1950 and 1990 may have contributed to the creation of favourable habitat for *Elodea* colonization. The recent creek diversions in the 1990's may be a contributing factor to the noted increase in organic composition of lake inwash. Further monitoring at creek outlets and analysis of current sediment load composition may help to pinpoint sources of these recent changes.

8.0 Priority Issues in the Lakelse Lake Watershed

Using the Kepner-Tregoe "Situation Appraisal" analysis (for details see Section 5.2), members of the LWS identified a number of specific concerns regarding the quality and health of the Lakelse watershed, that they would like to see addressed in this management plan (also see Appendix A for original document created by LWS). The stakeholder concerns are classified into 11 issues and are ranked from high to low priority (see Table 4, pg. 44). The top seven priority issues are examined below and will be dealt with in this management plan. The issues rated as moderate to low priority are not discussed in the plan, but should be periodically reviewed and re-prioritized as necessary.

Descriptions of the top seven issues, including reasons for the concerns, are included in the sections below. It is important to recognize that the issues are inter-related. Many issues share certain aspects, and change or action taken on one issue can affect others both directly and indirectly.

8.1 Elodea canadensis

The growth of *Elodea canadensis* in Lakelse Lake has recently been noted by lake and watershed residents, and it appears to be steadily increasing. This is particularly alarming as *Elodea canadensis* was not mentioned on the species list of an aquatic plant survey done in Lakelse Lake in 1984 (Warrington, 1986). Through observations and mapping by residents, it is evident that within the last 3 to 4 years the growth of the plant has spread to include much of the littoral zone. Lakelse has a high recreational value, as reported in a 1974 study by Sinclair. The excessive growth of *Elodea* is interfering with recreational pursuits such as swimming and sport fishing and negatively impacting resorts and campground beaches. Area residents are concerned about how the growth will affect lake quality and health, the recreational and fisheries value of the lake, and potentially reduce individual property values. Factors affecting *Elodea* growth are not well known, and the exact link between the *Elodea* infestation and sediment and nutrient inputs to the lake is currently unclear.

8.2 Fish Species

As discussed previously, the Lakelse watershed possesses very high fisheries values. The system provides important spawning and rearing habitat for numerous commercially and recreationally fished species including cutthroat trout, steelhead, pink, sockeye, coho and chinook salmon (Gottesfeld et al., 2002). A species of primary concern in Lakelse Lake is sockeye salmon as they are known lake spawners. The relationship between *Elodea* and sockeye is not well understood, so the possibility that excessive plant growth may inhibit sockeye production should be considered. An *Elodea* infestation can affect the food chain in the lake by displacing algal primary producers and potentially limit sockeye production (Smith, 2002 pers. comm.). Furthermore, decomposition of *Elodea* during the winter may cause harmful oxygen deficits.

The RDKS is concerned about impacts of sewage disposal systems on the lake and streams that provide salmon and trout habitat (Stantec, 2000). Nutrients from these sources may be contributing to the excessive aquatic plant growth. With the increase in aquatic plants and human development, important habitat will be lost and a change in the distribution of fish species may subsequently occur. Working toward the maintenance and restoration of fish habitat and stocks is of high importance to stakeholders around the lake.

8.3 Forestry

Lakelse residents are concerned about accelerated degradation of lake water quality that generally occurs as watershed development increases. The loss of riparian areas from past forestry practices has led to erosion and increased sediment and nutrient inputs to the lake. Sediment core results from Lakelse Lake (see section 7.6, and Appendix J) indicate that increases in sediment delivery rates correspond with the onset of major forestry activities (and infrastructure) in the Lakelse watershed. The possible link between the *Elodea* infestation and sediment and nutrient loading suggests it is important to ensure future forestry practices are improved and monitored.

8.4 Shoreline Development/Modification

The LWS is concerned that lack of public education regarding healthy shoreline living will increase the rate of water quality degradation around the lake. Negative shoreline impacts can result from various commercial, agricultural and residential activities including tree removal, planting lawns and non-native shrubs, using fertilizers, paving areas of property, building docks, and installing on-site sewage disposal systems. When these activities occur around the shoreline, erosion and nutrient inputs to the lake also tend to increase.

The RDKS has expressed concerns about impacts of current sewage disposal systems on drinking water quality and fish habitat in the area (Stantec, 2000). It is well known that the rate of non-point source nutrients entering a lake from septic systems increases when there is no buffer of natural vegetation. In the case of Lakelse Lake this is significant, as 86% of the developments lie within landforms considered moderate to poor for renovating septic effluent (McKean, 1986). The loss of riparian areas from residential land clearing has also led to shoreline erosion and increased sediment inputs to the lake. The possible link between sediment and nutrient inputs, *Elodea* growth and fish habitat degradation, suggests the importance of practicing low impact activities around the lake.

8.5 Stream Modification

One of the most significant stream modifications is the alteration of the total surface flow of Scully Creek through straight, man-made ditches below the highway. In addition to the serious impact on sockeye, the sloughing clay banks are causing massive influx of clay deposits to the lake. Furthermore, channel modifications on various other tributaries have created problems with slope failures, and likely amplified sediment delivery rates from these streams. The loss of riparian areas around Lakelse tributaries, from residential land clearing and forestry practices, has also contributed to stream erosion and increased sediment inputs to the lake. Increases in sediment delivery will impact overall water quality in the lake. Lakelse drinking water intakes have high turbidity readings (Downie, 2003 in prep.), possibly resulting from stream sediment loading. The modifications may also be degrading valuable fisheries habitat and spawning areas.

8.6 Water Level Changes & Effects

High water may contribute to greater inwash of sediments to the lake: as residential land clearing is common practice, the riparian vegetation that used to act as a protective barrier is no longer supporting the land, resulting in erosion and loss of property.
Some residents have suggested that high water levels in Lakelse Lake persist for much longer than they used to, and they are concerned about why this is occurring and how it is affecting water quality. Factors changing the natural variation and duration of water levels may contribute to changes in the lake's trophic status. The *Terms of Reference* for RDKS's Liquid Waste Management Plan (LWMP), states that "during high water a number of disposal fields are under water and no doubt contaminate the lake" (Stantec, 2000). If water levels remain high it is likely that the level of contamination increases.

8.7 Drinking Water Quality

Lakelse Lake is a popular drinking water source for seasonal and permanent residences along the lakeshore. Although many lakeshore residences have abandoned their lake intakes in favour of groundwater wells and creek intakes, a number of individual homes and at least one resort still draw water from Lakelse Lake. Recent drinking water quality studies have noted source quality concerns at Lakelse Lake (Remington, 2002; Zimmerling et al., 2001; Downie, 2003 in prep.). It has been noted that the water table is only a few feet below the ground surface on the east side of the lake, and that during flood conditions, a number of disposal fields are submerged. Other non-point sources of contamination may include commercial and agricultural development around the lake. Logging in watersheds that drain into the lake also poses a threat to drinking water quality.

The RDKS has recognized that Lakelse Lake septic tanks and disposal fields discharge to ground and surface water sources which may be the water supply for residences. As part of its LWMP, it will evaluate whether it should institute any particular regulations or controls on the existing systems, or investigate the opportunity to construct a community water supply system for health reasons (Stantec, 2000).

Table 4. Summary of Priority Issues and Reasons for Concern

Issue	**Serious-ness**	**Urg-ency**	**Reason for Concern**
1. *Elodea canadensis*	Very High	Very High	Excessive growth has negative impacts on recreational, fisheries & property values
2. Fish Sustainability	Very High	Very High	Commercial and recreational fish values are high; it is important to maintain and restore these stocks and habitat
3. Forestry	Very High	Very High	Logging activities are potential sources of silt / nutrients
4. Shoreline Development and Modifications	High	High	Increased sediment & nutrients enter lake following shoreline modification and loss of riparian areas (erosion, septic seepage, fertilizers)
5. Stream Modifications	High	High	Increased sediment & nutrients enter lake following creek disturbances; present possible disturbance to fish habitat
6. Water Level Changes and Effects	High	Mod	High water levels along with other factors result in shoreline erosion/ loss of property; increased sediment & nutrients enter lake when lake levels are high
7. Drinking Water Quality	High	High	Human health is at risk; sampling shows contamination
8. 1st Ave Salts and Fines	Mod	Mod	Increased sediment & nutrients entering lake possibly harm fish
9. Wintering Swans	Mod	Low	Interference with natural migration and behavior of swans
10. Power Boats and PWC's	Mod	Low	Can cause Elodea fragmentation & spread and wave induced shore erosion
11. Others (acid rain, beavers)	Very Low	Very Low	

9.0 Lake Management Goals

Based on the priority issues identified in the Lakelse system, four goals were established by LWS to provide direction for their overall mission "to preserve and protect the health of the Lakelse watershed." The management goals were important to provide context and direction throughout the management planning process. They helped the management planner and stakeholders translate the priority issues into management approaches with potential remedial actions. The management goals used in the planning process include the following:

Goal 1: Identify current and potential sources of water quality degradation affecting the Lakelse system.

Goal 2: Monitor, preserve and enhance the quality and health of fish in the Lakelse Watershed.

Goal 3: Provide workable options for managing the causes of accelerated lake degradation due to human impact.

Goal 4: Increase public awareness of lake health issues by promoting activities, developments and uses around the lake which do not compromise the quality and health of the system.

To preserve and protect the quality and health of Lakelse watershed, a successful management solution must include investigation of the causes of accelerated eutrophication (nutrient and sediment inputs) as well as symptoms (excessive weed growth). The *Elodea canadensis* infestation may have emerged as a result of human-related activities within the watershed and along the lakeshore. Managing the infestation and protecting the values of the lake requires a good understanding of the lake system and identifying causes of the symptoms. Protecting the recreational, fisheries and property values of Lakelse watershed relates largely to public education and providing individuals with the tools and knowledge to practice low impact activities and sustainable waterfront living. Public education is a cornerstone to successful lake stewardship, and has been identified as a primary goal in the lake management plan. Together, these 4 goals form the basis for deciding upon which remedial actions will best address the priority issues in the watershed.

10.0 Lake Management Approaches and Remedial Actions

The first half of this management plan describes Lakelse Lake and its watershed, and identified priority issues in the watershed from the perspectives of LWS and other stakeholders. A series of four management goals were also defined. The remaining sections of this plan will identify **optional** management approaches and remedial actions that can be implemented to protect and enhance the quality of the watershed. For the purpose of this document, management approaches are higher level strategies to describe general types of actions that could be used to address an issue of concern. For each approach, there are a variety of specific remedial actions that can be implemented. Desirable management approaches and actions are those that will address the priority issues and goals of the plan, and can be implemented given local constraints. Each approach (and actions within the approach) has pros and cons, and must consider ecological concerns and financial restrictions.

10.1 Defining Potential Approaches and Actions

The Option of Doing Nothing

Before presenting the list of potential lake management approaches and remedial actions for the Lakelse Lake watershed, it is important to note that "Do nothing" is a viable management approach in certain circumstances. Planners should always consider the consequences of doing nothing because it offers one basis of comparison for the potential effects of implementing a lake management program (Rast and Holland, 1988). The "Do nothing" option helps highlight cases where a management program is desirable, and other cases where a program may not be required or should be postponed until further information permits a better analysis of options.

Other Lake Management Options

Lake management approaches may treat the symptoms of a problem, or can treat the causes, in an attempt to restore lake conditions. When the symptoms are treated without any effort to identify and correct the problem and its causes, the treatment will only be temporary. Until the problem is identified and causes of the problem are addressed, the symptoms will continually reappear.

One reoccurring theme in this lake management plan is the need to identify current and potential sources of water quality degradation. This involves implementing a reliable base of volunteer monitors to test, observe and record the changes occurring in Lakelse Lake. In most cases, sources of lake degradation must be identified before internal remedial actions are considered (Rysavy and Sharpe, 1995). Approaches for identifying and then improving watershed management practices are therefore very important in the early stages of lake management. Other actions that will help to protect the health of the Lakelse watershed focus on increasing public awareness of these and other lake health issues. Increasing public awareness on all aspects of the Lakelse ecosystem is key to bringing about a positive change. Overall, a combination of lake management approaches and remedial actions are required to maximize the effectiveness of lake preservation and protection.

10.2 Analysis of Potential Approaches

In this management plan, the evaluation process began by investigating a range of approaches to address each priority issue. Table 5 summarizes the management approaches that were considered for each issue.

Table 5: Priority Issues and Potential Lake Management Approaches

Issue	Potential Lake Management Approaches
1. *Elodea canadensis*	1.1 Monitor and identify trends in *Elodea canadensis* growth. 1.2 Continue water monitoring program on Lakelse Lake to gain a better understanding of the watershed system and *Elodea* 1.3 Remove excessive *Elodea* plants from Lakelse Lake 1.4 Reduce non-point source nutrient inputs to the lake 1.5 Reduce sediment inputs resulting from human activities within the watershed
2. Fish Sustainability	2.1 Promote fisheries research and data collection 2.2 Improve fish habitat
3. Forestry	3.1 Encourage improved forestry practices in the watershed to minimize impacts and support remediation activities on conditions that impact the lake
4. Shoreline Development	4.1. Examine trends via shore and water monitoring programs 4.2 Encourage development and activities that minimize nutrient and sediment inputs to the lake system
5. Stream Modifications	5.1 Identify and monitor stream sources of sediments entering the lake 5.2 Work to minimize impacts of watershed activities on streams and encourage remediation work to mitigate problem conditions
6. Water Levels	6.1 Initiate a hydrology study of Lakelse Lake 6.2 Improve general public awareness about the watershed system
7. Drinking Water Quality	7.1 Work with local and provincial governments to improve drinking water quality 7.2 Improve public awareness about drinking water issues in the Lakelse watershed

The next step in the process was to develop an extensive list of specific remedial actions for each approach. The actions were thoroughly researched, and the advantages and disadvantages of each were recorded in a chart. The chart included in section 10.3. Note that the actions in the chart represent a range of lake management approaches and remedial actions that were **considered** and not necessarily recommended for the Lakelse Lake watershed. To evaluate the potential approaches and remedial actions, LWS examined the advantages and disadvantages of each alternative. Considered here was the notion of long-term sustainability and effectiveness of any activities chosen. Experts were consulted and other Lake Management Plans were researched to determine the importance of various actions.

The next section of this plan describes the management approaches and remedial actions that were explored for the Lakelse Lake watershed.

10.3 Analysis of Potential Remedial Actions under Various Management Approaches (MA)

MA 1.1 Monitor and identify trends in *Elodea canadensis* growth.

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Volunteer inventory of *Elodea* in Lakelse Lake	• Conduct an inventory of aquatic macrophytes(with a focus on *Elodea*) via a formal volunteer monitoring program; involves direct observations and recording of aquatic plants by volunteers using boats and/or wading.	• Low cost for equipment and development of program protocol • No cost for data collection if volunteer labour can be used	• Inexpensive • Provides better understanding of *Elodea* distribution (small scale, within lake) • Can be repeated to monitor growth trends over time • Lobbying support from other agencies will be more effective with background data • Collection process can be public educational tool; will help build community capacity to manage watershed	• Requires sample design protocol to be created before any program is started; technical assistance may be needed to develop protocol and train volunteers • Need to repeat survey in future to monitor change • Takes time to create a useful data set • Does not actually reduce the amount of *Elodea* in the lake	• Improved data is needed about *Elodea* distribution to track annual changes/ make comparisons with other water quality data • Improved knowledge and data allows appropriate recommendations to be made
B. Aerial Photos & Interpretation of *Elodea* and other aquatic plants	• Conduct an inventory of aquatic macrophytes (with a focus on *Elodea*) via aerial photography and interpretation • To see aquatic plants in the lake, infared (IR) photos must be used	• High cost for equipment, • Technical assistance ($1000's)	• Provides better understanding of *Elodea* distribution (small scale, within lake) • Can be repeated to monitor growth trends over time • Lobbying support from other agencies will be more effective with background data • Don't need to recruit and organize large group of people	• Expensive equipment is required; need to find $ for this. • Technical assistance required • Need to repeat survey in future to monitor change • Takes time to create a useful data set • Does not actually reduce the amount of *Elodea* in the lake	• Improved data is needed about *Elodea* distribution to track annual changes/ make comparisons with other water quality data • Improved knowledge and data allows appropriate recommendations to be made
C. Investigate if *Elodea* appears at other local lakes	• Extend the above-mentioned inventory of aquatic macrophytes (focus on *Elodea*) via volunteer monitoring program to nearby lakes. (Onion, Clearwater, West, End, Ena, Herman and Hai Lakes) • (See above for details)	• Low cost for equipment and development of program protocol • No cost for data collection if volunteer labour can be used	• Provides better understanding of *Elodea* distribution (large-scale, region-wide) • May provide insight into possible effects from uncontrollable factors (climate, etc.)	• Does not actually reduce the amount of *Elodea* in the lake • Access to some lakes may be difficult	• Improved data is needed about *Elodea* distribution to track annual changes/ make comparisons with other water quality data
D. Distribute questionnaire to other Highway 16 lakes to identify trends in *Elodea* growth patterns	• Create and distribute questionnaire to various Highway 16 lake societies and residents to collect information about *Elodea* growth patterns	• Low cost	• Provides better understanding of *Elodea* distribution (large-scale, region-wide) • Questionnaire already distributed • May provide insight into possible effects from uncontrollable factors (climate, etc.) • Very little effort required by LWS	• Need to repeat survey in future to monitor change • Takes time to create a useful data set • Does not actually reduce the amount of *Elodea* in the lake	• Knowing how external factors like climate may be affecting *Elodea* growth is helpful for making management decisions

MA 1.2 Continue water monitoring program on Lakelse Lake to gain a better understanding of the watershed system and *Elodea*

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Implement a volunteer monitoring program to collect water quality data	• Implement a volunteer lake (water quality) monitoring program to efficiently and cost effectively provide credible information on lake conditions • Lobby for volunteers to collect data, and make use of knowledge and experience of past volunteers, guides, staff (WLAP and NWSS) to assist with lake monitoring, provide equipment etc.	• Relatively low cost for equipment and development of program protocol • No cost for data collection with volunteer labour • Possible small cost for lab analysis	• Inexpensive (equipment can be borrowed) • Will provide a valuable data set • Will help to understand the system so appropriate recommendations can be made • Collection process can be public educational tool; will help build community capacity to manage watershed • Protocols already created for some sampling methods • Some volunteer training already in place	• Does not actually reduce amount Elodea in the lake or sediment & nutrient inputs to the system • Need to purchase or borrow equipment and find money (or in-kind support) for lab analysis • Some protocols still need to be created • Takes time to create a useful data set	• Improved data may provide insight to the Elodea question, and illuminate sources of nutrients and sediment to Lakelse Lake • Improved knowledge and data allows appropriate recommendations to be made
B. Conduct spring overturn water quality sampling in 2003	• Conduct deep station sampling at surface, middle and bottom depths to obtain P data before uptake begins	• 1 set of sampling costs ~ $350 • WLAP can fund and provide equipment	• Inexpensive (WLAP will fund; can use volunteers/ Katimavik participant) • Will provide a complete data set, which is valuable • Collection process can be public educational tool; will help build community capacity to manage watershed • Sampling protocols already created	•	• Improved data may provide insight to the Elodea question, and illuminate sources of nutrients and sediment to Lakelse Lake • Improved knowledge and data allows appropriate recommendations to be made
C. Monitor and identify sources of nutrients entering the lake so that a phosphorus budget can be created	• Collect data to determine the extent of nutrient inputs from various sources • Work with WLAP to continue and expand the shoreline sampling program; will likely involve establishing new sampling sites in the creeks instead of at their mouths, and monitoring P concentrations and streamflow extensively over the year; consider the use of students or volunteers for sampling	• No cost for data collection with volunteer labour • Cost for lab analysis in 2003 was $1300 per round (9 sites); requires many more sites and more frequent tests	• Will provide a valuable data set • Will help to understand the system so appropriate recommendations can be made • Collection process can be public educational tool; will help build community capacity to manage watershed • Some volunteer training already in place (water quality aspects)	• Moderately expensive (lab analysis may be costly) • Need to purchase or borrow equipment and find money (or in-kind support) for lab analysis • Need to develop protocol and train samplers to collect streamflow measurements • Does not actually reduce nutrient inputs to the system • Requires a year-long commitment to create a useful data set	• Improved data may provide insight to the Elodea question, and illuminate sources of nutrients to Lakelse Lake • Improved knowledge and data allows appropriate recommendations to be made
D. Monitor and identify sources of sediments entering the lake	• Obtain more data to determine the extent of sediment inputs from various sources, which likely influence Elodea growth. • Inexpensive methods include sediment traps, Secchi disk monitoring; consider use of students or volunteers to implement monitoring programs	• Relatively low cost for equipment and development of program protocol • No cost for data collection with volunteer labour • Possible small cost	• Inexpensive • Will provide a valuable data set • Will help to understand the system so appropriate recommendations can be made • Collection process can be public educational tool; will help build community capacity to manage	• Takes time to create a useful data set • May need to purchase or borrow equipment and find money (or in-kind support) for lab analysis; this depends on the type of monitoring done • Does not actually reduce sediment inputs to the system	• Improved data may provide insight to the Elodea question, and illuminate sources of sediments to Lakelse Lake • Improved knowledge and data allows

	• Investigate both stream sources, and lakeside sources	if lab analysis required	watershed • Some sample design protocol already created • Have knowledge of previous volunteers (some monitoring has already begun)		appropriate recommendations to be made

MA 1.3 Remove excessive *Elodea* plants from Lakelse Lake

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Remove *Elodea* via physical control methods	• Install benthic barriers: cover aquatic plants with a layer of growth-inhibiting substance; the water column above the sediments is then free of rooted plants	• Expensive and variable costs, depending on material used: \$0.15-\$0.75/sq ft for material; \$0.25-0.50 sq ft to install (USD)	• Prevents plant growth, and is proven effective at beaches in North-central B.C. (BC Parks); may be left for multi-year control • Barriers are not visible; no water use restrictions • Relatively easy to install; and can provide longer-term control with maintenance • Can be removed; materials may be reusable • Can improve fish habitat	• Non selective control; after removal, plants re-colonize quickly • Very expensive, when applied on larger scale • Installation may be difficult where there are bottom obstructions, over dense stands; maintenance may be required (and new plants may establish on top) • Significant impacts to benthic community; may impact spawning or feeding by some fish	• Appropriate for small-scale, high use areas (<1acre) only; too expensive for large areas
B. Remove *Elodea* via chemical control methods	• Apply chemicals to the water to get rid of aquatic plants. Possible chemicals include Diquat (use aquatic herbicide "Reward" manufactured by Syngenta) or Fluridone (use aquatic herbicide "Sonar" manufactured by SePRO)	• Expensive: \$700-1000/acre (USD)	• Chemicals have been shown to effectively control *Elodea canadensis*; selective control can be achieved with correct application rate and time • Some chemicals provide effective control for up to 5 yrs • Most "modern" chemicals have no restrictions on swimming and fishing after application; low or non-toxic, and safe and easy to use • Some chemicals work slowly so decomposing weeds do not deplete oxygen and kill fish; others provide faster action.	• Some chemicals don't actually kill the plant (no effect on roots) so species may re-grow rapidly; others do kill the plant • Some chemicals have restrictions for drinking water (3 days) and irrigation (3 days) • For fast-acting chemicals, water quality concerns may arise from release of nutrients and possible DO depletion when plants die • Fluridone not yet registered in Canada; may require extensive research and permitting process before moving ahead • Application will need to be done by trained professionals	• Different chemicals appropriate for different-sized lakes. Lakelse is quite large with a high flushing rate, so it may be difficult to apply treatements to selected areas and achieve sufficient contact time; weed growth is not widespread enough, and waterbody is too large to treat entire lake
C. Remove *Elodea* via low tech. mechanical control methods	• Perform mechanical control using hand cutters (scythes, knives), rakes or bare hands. This can be done in deeper areas by a snorkeler or diver who surveys the area and pulls out plants by hand	• Low or no cost for labour if done by volunteers. • Minimal cost for tools. May be expensive if divers need to be hired	• Control can be selective to target *Elodea* • Relatively inexpensive, especially if volunteers are used • Can be applied at any control intensity • Immediate removal of plants • Widely used technique for localized nuisance problems (by lakeshore owners) • No water use restrictions	• Labour intensive, tedious • Cost is labour-based and may be higher if paid workers are used • May generate turbidity • Fragmentation may occur, leading to further spread of *Elodea* • May impact aquatic fauna	• Appropriate for small scale, localized problems or in sensitive environments like spawning grounds

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
D. Remove *Elodea* via high tech. mechanical control methods	• **Aquatic weed harvester** – use machine to cut the vegetation and collect the plant material. Then, transport the materials to the shore and transfer to disposal vehicles (ie. dump trucks) which take the plant material away • See Chapter 12 in Cooke et. al. (1993) for a details **Note: other methods are mentioned below, but harvesting is the most practical and advantages and disadvantages are listed for harvesting only.** • **Diver-operated suction harvesting -** a vacuum system is used to remove plant stems, roots, and leaves. Divers dig out the material, which is then sucked up through a hose to a barge. The sediments are left in place. • **De-rooting methods** such as rototilling - a cultivator on a long arm is used for tilling aquatic sediments and destroying root crowns. The root masses are buried, or dislodged, and buoyant root crowns and stems float to the surface and can be collected • There are many different types of machines available. See Chapter 12 in Cooke et. al. (1993) details	• Expensive • Harvester - $50,000 to purchase and in BC $650-$1200/ha to operate (based on 1980's info) • Diver suction – equip cost expensive but unknown and in BC $4250-$16000/ha to operate (based on 0.03-0.05ha/day) • De-rooting – equip cost expensive but unknown and in BC $1000-2500/ha to operate	(HARVESTING ONLY): • Widespread use, including control of *Elodea canadensis* in North-Central B.C. lakes • Minimal bottom disturbance; no water use restrictions and only minor interference with other lake uses (recreation) • Removes plant biomass from the lake, which may improve oxygen levels and decrease nutrient levels • Easy to regulate treatment area • Harvested product may be beneficial to someone	(HARVESTING ONLY) • Non-selective control • Control is short-term because roots are not removed; 1 harvest/yr often not enough • Fragments are produced, leading to possible spreading of the infestation • High initial capital cost; and relatively expensive to operate (fuel, operator wages, equip. maintenance) • Operating depth limited; limited access to confined places • May be significant "by-catch" of fish, invertebrates, and other organisms • In shallow areas, possible re-suspension of sediments and release of nutrients/other compounds • Disposal of plant material requires labour and disposal location • Must be done in summer; may create public dissatisfaction	(HARVESTING ONLY) • Has been used for larger scale treatments, but best for short-term localized clearing • Appropriate for cosmetic concerns and to eliminate weed interference with recreation; not appropriate in newly infested areas because it spreads fragments; may not be appropriate for Lakelse because there are areas of the littoral zone that are not yet infested.

MA 1.4 Reduce non-point source nutrient inputs to the lake

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Monitor and identify sources of nutrients entering the lake so that a phosphorus budget can be created	• Implement Action C under MA 1.2	• See Action C under MA 1.2			
B. Improve public awareness regarding relationship between human activities and lake quality	• Improve general public awareness about the watershed, and suggest ways residents can help restore or improve watershed quality and health; consider brochures, guest speakers, workshops, trade fair, presentations to Terrace/Kitimat schools and/or implementation of lake curriculum in schools • Focus on "friendly" shoreline practices that will help limit nutrient inputs to lake, and proper sewage system upkeep (construction, maintenance, and alternative practices)	• Relatively inexpensive, but variable depending on activity (small printing and distribution costs for brochures, possible costs for guest speakers, booth rentals)	• Relatively inexpensive • A step towards a long-term solution • Kids programs target future watershed residents at a young age; and helps promote long-term stewardship attitudes • Can be very effective; healthy shorelines and working sewage systems substantially reduce P inputs • Educational materials are readily available from a variety of sources; school science curriculum already exists for Tyhee Lake and other materials area available	• Must come across as informative and not preach to the residents • Need to implement this slowly, and may require a long time for resident acceptance • Difficult to measure the success of the program or for residents to see specific results (improved water quality, etc.) • School curriculum requires acceptance of teachers and school board	• Relevant educational materials are readily available • A large number of Lakelse residents practice land clearing and have sewage systems, so potential impacts from these may be large • Likely to be most effective if educational materials are delivered in "small doses"
C. Northern Health Authority (NHA) staff should continue to work with the community toward compliance to the Health Act for on site waste water systems	• A Health Officer can speak about current problems with compliance issues around the lake. One issue is lack compliance verification to NHA statutes. NHA and RDKS need to promote a unified approach to building inspection and issuing of health permits in the Lakelse area.	• High cost to agencies involved	• Will raise public awareness on the issue • Will result in better regulation & compliance • Human health will be better protected	• May create public dissatisfaction	• The lack of building inspectors in the Lakelse area is creating a problem for NHA compliance issues.
D. Participate in regional planning initiatives (including the RDKS's LWMP)	• Cooperate in regional land use planning and zoning initiatives to ensure that Lakelse Lake watershed quality issues are considered; ensure that planning processes endorse activities that do not contribute to extra nutrients entering Lakelse watershed • Support the RDKS in its plan to develop a LWMP by being active in public review and consultation process; if possible and if appropriate, advocate options for improving water and waste disposal services/facilities to lakeside lots and outlying subdivisions (including JPF)	• Inexpensive for LWS to *support* initiatives (Note: LWMP project is expensive but costs are paid by regional government)	• No cost to LWS for supporting initiatives and getting involved in consultation/review • Most initiatives will likely only require a small time commitment by one or two people • LWMP is an ideal initiative to get involved with as it includes areas that directly influence Lakelse Lake • Improved infrastructure will significantly reduce impacts to lake, and help protect human health; sewage disposal permitting, monitoring, maintenance, enforcement etc. much easier with one disposal system	• Requires commitment and cooperation from the RDKS • LWS members may not have technical expertise to provide useful/adequate feedback on reviews, etc. • Difficult to measure success of the program or for residents to see specific results (improved water quality, etc.) • Improved infrastructure requires significant capital cost and acceptance by local residents (may result in increased property taxes; also, physical disturbance of land to install infrastructure)	• Sewage is likely entering the lake system from subdivisions, causing environmental damage and risks to human health; because LWMP is aimed at protecting health, it is a priority of many agencies/governments • Studies for Liquid Waste management plan have already begun • Funding for infrastructure may be available through cost-sharing programs
E. WLAP staff need to inventory sewage discharges which may	• WLAP staff should review existing sewage permit files, and conduct a survey for possible unauthorized		• Will result in improved regulation & compliance • May come across others who need to	• WLAP facing time/ budget constraints, may take time to get personnel on the case	• Last file review was in 2001, capacity and discharges may have

influence water quality and which are under WLAP jurisdiction	discharges		catch up on permit applications etc.		changed since
F. Encourage improved agricultural practices in the watershed to minimize impacts	• Encourage Best Management Practices (BMP's) for agricultural operations in the watershed (hobby farms etc.); there are many agricultural practices that preserve the quality of aquatic systems without diminishing agricultural return. • LWS should provide input to peer advisory groups	• No cost to *encourage* BMP's or to provide input to peer advisory groups (Note: costs to agricultural operators vary with management strategy)	• Very little cost to LWS • Many "sustainable" agricultural practices do not minimize agricultural returns • Some practices are very effective at reducing P inputs	• BMP's rely heavily on voluntary compliance; legislation would be needed to ensure total compliance • Requires acceptance by agricultural operators	• Agriculture is known to contribute significant amounts of nutrients to waterbodies.
G. Encourage improved forestry practices in the watershed to minimize nutrient delivery to lake	• Implement actions listed under MA 3.1 (to reduce nutrient inputs from forestry)	• See actions under MA 3.1			• Forestry is known to contribute significant amounts of nutrients to waterbodies; forestry is widespread in the Lakelse watershed, and impacts may be significant

MA 1.5 Reduce sediment inputs resulting from human activities within the watershed

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Monitor and identify sources of sediment entering the lake	• Implement Action D under MA 1.2	• See Action D under MA 1.2			
B. Improve public awareness regarding relationship between human activities and lake quality	• (Similar to Action B under MA 1.4 – can be implemented together) • Improve general public awareness about the watershed, and suggest ways residents can help restore or improve watershed quality and health; consider brochures, guest speakers, workshops, trade fair, presentations to Terrace/Kitimat schools and/or implementation of lake curriculum in schools • Focus on "friendly" shoreline practices that will help limit sediment inputs to lake, factors that contribute to erosion, and benefits of riparian areas	• See Action B under MA 1.4			
C. Participate in regional planning initiatives	• Implement Action D under MA 1.4 • Ensure that planning processes endorse activities that do not contribute to increased sediment delivery in the Lakelse watershed	• See Action D under MA 1.4			
D. Encourage improved forestry practices in the watershed to minimize sediment delivery to the lake	• Implement actions listed under MA 3.1 (to reduce sediment inputs from forestry)	• See actions under MA 3.1			

MA 2.1 Promote fisheries research and data collection

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Support initiatives that will improve knowledge of fisheries issues and identify areas of concern	• Encourage qualified fisheries biologists to conduct an assessment of existing fish populations; work with DFO on data collection; maintain representation in WFSP program; continue to support WLAP cutthroat trout study; promote studies to identify affects of Elodea on salmonid (sockeye) production; encourage DFO attention toward Scully, Williams, etc. • Support development of a Management Strategy (supported by scientific literature) prior to initiating any restorative, rehabilitation, or enhancement activities	• Inexpensive for LWS to *support* initiatives	• Management Strategy provides much-needed direction • Formal assessments and scientific studies produce much more comprehensive data set • Less responsibility and fewer resources required (from LWS)	• Requires support and initiative from BC Government fisheries biologists, DFO, or other technical experts • Management strategy is expensive, but necessary; studies that rely on voluntary participation (like Creel Surveys) do not normally produce useful results • Does not actually improve fish habitat and increase fish populations	• Greater knowledge is needed before restorative, rehabilitation, or enhancement activities are initiated; a management strategy provides useful direction • Techniques to enhance fish stocks will be much more effective if the system is understood • With background data, lobbying support form other agencies will be more effective
B. Undertake projects that will improve knowledge of fisheries issues and identify areas of concern	• Undertake data collection projects such as fish counting/recording, record local knowledge etc. • Continue D.O. monitoring in *Elodea* mats • In consultation with DFO and WLAP, Identify other projects to carry out	• Variable costs, depending on the project and the amount of labour and materials that are donated (vs. purchased)	• Carefully designed projects can produce useful data • Small scale projects are manageable; costs can be kept relatively low with volunteers and donations • Getting volunteers involved improves public awareness and serves as an educational tool	• Technical assistance required to develop monitoring protocol, and interpret results • May need to find money for equipment • Large-scale projects likely beyond the scope of LWS, which may lack resources, expertise, and manpower • Does not actually improve fish habitat and increase fish populations	• Greater knowledge is needed before restorative, rehabilitation, or enhancement activities are initiated • Techniques to enhance fish stocks will be much more effective if the system is understood; • LWS may lack resources, expertise and manpower; should focus work on smaller, manageable projects

MA 2.2 Improve fish habitat

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Support initiatives that will improve fish habitat in the Lakelse watershed	• Work with qualified fisheries biologists to conduct restoration activities; support restoration projects implemented by DFO, NWSS, WLAP, and projects recommended through WFSP program	• Inexpensive for LWS to *support* initiatives	• Larger agencies have better access to resources, knowledge, manpower, etc. • Less responsibility and fewer resources required (from LWS)	• Requires support from BC Government fisheries biologists, DFO or other technical experts • Experience has brought frustration to volunteers (e.g. lack of progress in Scully Creek)	• Rearing and spawning habitat is the most important factor that influences the size and health of fish populations • Improved salmonid habitat may actually increase salmonid recruitment and survivability, and improve population size and health • Reinforced and re-vegetated streambanks serve other purposes: act as buffers, may help reduce nutrient and pollutant inputs from land use activities
B. Undertake projects that will improve fish habitat in the Lakelse watershed	• Undertake restoration projects around the lake. • Involve public in restoration initiatives, get school groups/other local community groups involved to increase knowledge of fisheries issues; make presentations and show educational videos; create and distribute assorted manuals, brochures, and pamphlets. • Make relevant fisheries data (eg. Fisheries Inventory Summary System, FISS) more readily available to the public.	• Variable costs, depending on the rehabilitation project, and the amount of labour and materials that are donated (vs. purchased) • Public education initiatives are inexpensive (small printing and distribution costs for materials)	• Small scale projects are manageable; costs can be kept relatively low with volunteers and donations; many enhancement projects can be done with donated materials and volunteer labour (little or no capital cost) • Getting volunteers involved improves public awareness and serves as an educational tool	• Variable costs; costs can be expensive if materials need to be purchased and paid labour is used • Technical assistance required to develop protocol • May need to find money for equipment • Large-scale projects likely beyond the scope of LWS, which may lack resources, expertise, and manpower	• Rearing and spawning habitat is the most important factor that influences the size and health of fish populations • Improved salmonid habitat will most certainly increase salmonid recruitment and survivability, and improve population size and health • Reinforced and re-vegetated streambanks serve other purposes: act as buffers, may help reduce nutrient and pollutant inputs from land use activities

3.1 Encourage improved forestry practices in the watershed to minimize impacts and support remediation activities on conditions that impact the lake.

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Encourage Best Management Practices (BMP's) to help reduce sediment and nutrient-rich runoff entering into the lake system or its tributaries.	• Encourage Best Management Practices (BMP's) for forestry operations in the watershed; concentrate on those outlined in the Forest Practices Code • As forest licensees embark on certification, LWS should participate in meetings as they develop criteria and indicators for protecting the aquatic environment	• No cost to *encourage* BMP's or to participate in certification planning • Costs to forest companies vary with management strategy	• Very little cost to LWS • BMP's are capable of reducing the impacts of forestry or resource extraction activities in the watershed • Certification programs will likely be more effective than voluntary programs	• BMP's rely heavily on voluntary compliance; legislation would be needed to ensure total compliance • Requires acceptance by forestry companies	• A large portion of the Lakelse watershed is forest cover so potential impacts from forestry may be large
B. Undertake projects that will reduce nutrient and sediment inputs to the watershed and improve fish habitat.	• Implement Actions under MA 1.4, 1.5 and 2.2				

MA 4.1 Examine trends via shoreline and water monitoring programs

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Monitor and identify lakeside sources of nutrients and sediments to gain a better understanding of the watershed system	• Implement Actions C and D under MA 1.2 • Concentrate on lakeside sources of nutrients and sediments	• See Actions C and D under MA 1.2			
B. Conduct lakeshore land use survey and recommend alternative low-impact activities	• Conduct a survey of lakeshore development practices to identify trends that may impair lake water quality; summarize the findings, the related problems and list solutions. Encourage property owners to undertake alternatives to limit aquatic impairment	• Low cost if implemented through volunteer monitoring program or in partnership with government agency	• Data would be useful to illustrate where problem areas are grouped • May shed light on Elodea issue (does it correspond to developed areas?) • Low cost to LWS, especially if volunteers are used • Survey can be public educational tool; sharing results will be an opportunity to suggest alternative activities designed to limit aquatic impacts	• May create public dissatisfaction; must be performed in a manner that does not point fingers (results reported in a general fashion) • Will need to repeat survey in future to detect any development change	• A large number of residents are unaware of impact their activities have on the lake, this could be a public education opportunity

MA 4.2 Encourage development and activities that minimize nutrient and sediment inputs to the lake system

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Educate the public about healthy shoreline living	• Implement Action B under MA 1.4 and Action B under MA 1.5	• See Actions B under MA 1.4 and 1.5			

MA 5.1 Identify and monitor stream sources of sediments entering the lake

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Identify and monitor stream sources of sediments entering the lake to gain a better understanding of sediment loading rates in the watershed	• Implement Action D under MA 1.2 • Concentrate on stream sources rather than lakeside sources	• See Action D under MA 1.2			

5.2 Work to minimize impacts of watershed activities on streams and encourage remediation work to mitigate problem conditions

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Encourage forestry sector to adopt BMP's	• Implement Action D under MA 1 • Concentrate on BMP's outlined in Forest Practices Code Riparian Management Guidebook to keep streams protected	• See Action D under MA 1			
B. Participate in riparian restoration initiatives	• Implement Action A under MA 2.2 • *Scully Creek Restoration Feasibility Study* lists possible remediation activities.				

MA 6.1 Initiate a hydrology study of Lakelse Lake

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Repeat Water Management Branch 1988 lake-outlet profile survey.	• Collect historical data about previous studies; using the same benchmark as previous surveys of 1988 and 1979, resurvey the area around Herman creek bar.	• Hiring a consultant would cost approx $2-5000. • Free if surveyed by volunteers	• Will allow for comparison to previous study	• Potentially expensive • Finding background information from past studies may be difficult as previous surveyors have retired/quit • Any further action would have to be approved.	• Any factors that impede flushing rate may contribute to increasing lake trophic status….but water level changes are likely as much a result of increased inflow as decreased outflow
B. Establish a lake level gauge	• Contact Water Survey of Canada staff to get hydrological advice, assistance with installation, training etc. • Delegate task of recording to available a committed volunteer.	• Install Staff gauge: • Monitor via WSC: + $5000 start up, and $10000/yr. • volunteer monitoring (free) or /$1000/yr if employee hired	• Inexpensive (if volunteer run) • Will provide a data set • Collection process can be public educational tool	• Takes time to create a useful data set • Requires cooperation from Water Survey of Canada, and needs committed volunteer for regular/long term monitoring • Does not actually alleviate water level concern	• Data collection useful for background information, future comparisons

MA 6.2 Improve general public awareness about the watershed system

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Educate residents about effects of high water and preventing shoreline erosion through 'friendly' shoreline living	• Implement Actions B under MA 1.4 and 1.5	• See Actions B under MA 1.4 and 1.5			

MA 7.1 Work with local and provincial governments to improve drinking water quality

(See Appendix L for Summary of Jurisdiction for Authorizing Sewage Discharges in B.C.)

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Northern Health Authority (NHA) staff need to work toward determining compliance to the Health Act for on site waste water systems	• Implement Action C under MA 1.4 •				• There may be homes around the lake that require improvement of their septic system
B. Support RDKS in its implementation of a LWMP for Lakelse area	• Implement Action D under MA 1.4 • In particular, advocate options for improving water and waste disposal services/facilities to lakeside lots and outlying subdivisions (JPF) to protect human health	• Inexpensive for LWS to *support* initiatives (Note: LWMP project is expensive but costs are paid by regional government) • Potential user costs associated with new infrastructure	• Low cost to LWS • LWMP may result in construction of sewage collection, treatment and disposal systems for densely built up areas	• Potential user costs associated with new infrastructure	• Protecting human health is an important concern and government priority • Septic leakage may also be coming into contact with and contaminating drinking water.
C. WLAP staff need to inventory sewage discharges which may influence water quality and which are under WLAP jurisdiction	• Implement Action E under MA 1.4				• Protecting human health is an important concern and government priority • (Last file review was in 2001, capacity and discharges may have changed since)
D. Support initiatives to implement recommendations listed in WLAP's 2002 Drinking Water Source Quality Monitoring & Water Quality Objectives Attainment reports	• Work with WLAP to help bring future monitoring and recommendations to fruition. Continue volunteer monitoring program to assist in field work activities, support WLAP funding proposals to continue monitoring.	• Inexpensive for LWS to *support* initiatives	• Human health will be better protected • Low cost to LWS • Provides useful information for RDKS LWMP	• Funding for future WLAP projects not yet secured	• Protecting human health is an important concern and government priority • Drinking water quality issues have been identified around Lakelse Lake

MA 7.2 Improve public awareness about drinking water issues in the Lakelse watershed

Remedial Action	Description	Cost Estimate ($)	Advantages	Disadvantages	Appropriate?
A. Make data related to drinking water issues more accessible to the public	• Ensure water quality reports are accessible to the public. (make copies of these reports available at public meetings, trade show etc.)	• Inexpensive (small printing and distribution costs for materials)	• Will improve public health awareness • Get community motivated to make a change and begin implementing options from 7.1	• Changes will not likely be seen for a number a years	• Protecting human health is an important concern and government priority

11.0 Recommendations

Members of LWS, government and environmental groups were given the opportunity to review the tables describing the advantages and disadvantages of each remedial action. They were asked to consider the effectiveness, social acceptability, financial cost, environmental concerns and long term sustainability of each action. LWS looked at the applicability and feasibility of each action as it pertains to the Lakelse watershed.

This section recommends the remedial actions that are most likely to address the priority issues identified, and provides direction for achieving the recommendation. The recommendations are based on input from government and environmental agencies and on an "action plan" developed by LWS (based on the K-T "Situation Appraisal" process).

11.1 Recommendations and Actions

1. Monitor and identify trends in *Elodea canadensis* growth in Lakelse Lake by conducting a volunteer inventory of aquatic plants

Aquatic plants are an integral part of a balanced aquatic ecosystem, and they perform a wide variety of ecological functions. However, under certain conditions, aquatic plants can be problematic. The solution to problem plant growth lies in careful management. To achieve this, the ability to track annual changes in the *Elodea* distribution, and make comparisons with other water quality data is critical.

Conducting a volunteer inventory is a realistic and cost-effective technique to gather information about aquatic plant growth. If volunteers are properly trained and survey techniques are well designed and carefully implemented, a volunteer survey can produce accurate and useful information. Furthermore, once a monitoring protocol is created the survey can be easily repeated with little or no financial cost. In addition to providing much needed information in the short term, it will offer the long-term direction needed for managing aquatic plant growth in the Lakelse Lake watershed. The information will allow appropriate recommendations to be made so that water quality, fisheries health and the aesthetic value of the lake is protected.

LWS Action

An aquatic plant inventory at Lakelse Lake should take place as soon as possible (summer 2003). LWS should establish a sub-committee to organize the survey and delegate tasks including:

- Gathering resource materials such as:
  Gibbons, M. V., H. L. Gibbons and M. D. Sytsma. 1994. A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans. Washington State Department of Ecology. http://www.ecy.wa.gov/programs/wq/plants/management/manual/index.html
- Researching a sampling and recording protocol
- Rallying and training volunteers

- Holding a pre-sampling workshop (may include '*Elodea* expert' guest speaker)
- Enlisting NWCC students to assist with the survey
- Mobilizing equipment (grapples, GPS's, boats, guides, maps)

2. Investigate if *Elodea canadensis* appears at other local lakes

To help understand the factors affecting its growth, the LWS should attempt to identify whether *Elodea* is present in nearby lakes and streams. Tracking the *Elodea* distribution in the watershed will affect future lake management activities. It is important to protect all of the ecosystems in the Lakelse watershed from potential infestation so that water quality, fisheries health and the aesthetic value of the watershed is maintained. A public education campaign aimed at preventing the spread of the plant may be a desirable management approach.

LWS Action

LWS will need to consider the following factors before extending the *Elodea* monitoring survey to the other local lakes:

- What resources are available for further investigation (labour, equipment, time)
- Which lakes are easily accessible, most likely infested, are vulnerable to infestation, and/or pose the greatest risk to infesting other lakes in the area. (prioritize which lakes to sample: Onion, Clearwater, West, End, Ena, Herman and Hai Lakes)

3. Continue volunteer water monitoring program on Lakelse Lake

Volunteer monitoring provides an efficient and cost-effective means of data collection. It can supply a valuable data set, illuminate sources of nutrients and sediment to Lakelse Lake, and may provide insight to the factors affecting *Elodea* growth. Understanding the system is necessary before many other remedial actions can be effectively implemented. The collection process can be a public educational tool and will help build community capacity to manage the watershed.

The short term focus should be on conducting spring turnover sampling in 2003. LWS volunteers should also continue to work with WLAP to maintain and expand the shoreline sampling program, to investigate both stream sources, and lakeside sources of nutrients. This will likely involve establishing new sampling sites in the creeks instead of at their mouths, and monitoring phosphorus concentrations and stream flow extensively over the year. Water sampling within Lakelse Lake tributary streams will help quantify the extent of nutrient inputs from these sources.

Long term monitoring should include gathering data on sediment delivery, to determine the extent of inputs from various sources. Sedimentation in Lakelse Lake is likely an important factor influencing *Elodea* growth, and understanding the primary sediment sources will likely be a crucial part of defining an effective aquatic plant management approach. Sediment monitoring should continue with those methods already in place, including sediment traps, and Secchi disk monitoring at tributaries.

LWS Action

WLAP staff will be very busy in the spring, and to ensure that spring turnover is not missed in 2003, an immediate LWS volunteer is required to monitor D.O. and temperature profiles every few days after ice off. This will allow volunteers and WLAP staff to be notified and mobilized when the lake is turning over, and ensure that this critical sample is not missed. Following turnover, LWS should begin building membership toward volunteer water quality monitoring, so that individuals are readily available throughout the summer. Again, the use of students for sampling should be considered. LWS should also plan to continue sediment monitoring, and should budget for possible costs of sediment analysis.

4. Improve general awareness and public education relating to human influences on lake quality and health

Watershed education is the most cost effective method of instigating change in the way lake residents use, perceive, and value the natural environment. Education and awareness is a useful tool for highlighting the interaction between human land use and its effects on lakes and watersheds. Educational materials should describe ecosystem components, interactions and functions, and include ideas for individuals, families or the community to help restore or maintain the quality of the watershed. Information can be circulated to residents through multiple media sources: television, radio, newspaper, websites, pamphlets, brochures, workshops and meetings.

LWS Action

To raise public awareness, LWS can invite local media to lakeshore events and invite *Living by Waters* to put on workshops throughout the summer. Selecting workshops that focus on the following will facilitate attainment of goals 3 and 4:

- Shoreline restoration practices that will help limit nutrient inputs to lake
- Proper sewage system upkeep (proper construction and maintenance, regulations, how to minimize environmental impacts from sewage disposal systems, alternatives available when proper sewage disposal systems cannot be installed (sand filters, biological digesters, etc.))

To educate present and future lake users and provide long term solutions to water quality issues, LWS can also:

- Distribute the current LWS brochure and update it if required
- Bring public education displays (already created) to tradeshows etc.

- Run a newspaper column
- Work with BC Parks on public education signs and fliers for distribution at Lakelse Lake Provincial Park
- Involve school groups in lake activities and events

5. Support initiatives for fisheries research and data collection and initiatives that will improve fish habitat

Data about fish populations and habitat is needed so that appropriate remedial actions can be recommended. Data is often much more useful when it is collected by (or in cooperation with) a professional biologist. If not already done, qualified fisheries biologists need to conduct assessments of existing fish populations to improve knowledge of fisheries issues and identify areas of concern. Techniques to enhance fish stocks will be much more effective if fish populations, and current influences on them, are understood.

Any mechanical restoration work should only be considered feasible if it does not require ongoing maintenance. Rehabilitating spawning areas with marginal or reduced value will most certainly help local salmonid populations by increasing recruitment rates (Watershed Restoration Technical Circular No. 9, 1997). Rearing and spawning habitat is the most important factor that influences the size and health of fish populations. Reinforced and re-vegetated stream banks also serve other purposes; they act as buffers and may help reduce nutrient and pollutant inputs from land use activities.

Funding for rehabilitation initiatives may come from local non-government agencies and clubs or through federal/provincial funding sources (such as DFO). Materials, labour, and equipment for habitat construction projects can be donated from within the local community to keep costs to a minimum. Getting volunteers involved improves public awareness and serves as an educational tool. Fisheries education will help all community residents and resource users acquire an awareness of fish and their habitat requirements. It will help cultivate social and technical skills necessary for solving local fisheries management problems. Public education resources that may be helpful to LWS include:

- Canadian Wildlife Federation “Fish Ways” (http://www.wildeducation.org/programs/fish_ways/fishways.asp)
- Fisheries Information Summary System (http://www.bcfisheries.gov.bc.ca/fishinv/fiss.html)

LWS Action

Since most fisheries projects are too large for LWS to implement alone, the society should play a supporting role for any research or rehabilitation activities. LWS should continue to support a proposed WLAP cutthroat trout study and promote studies to identify effects of *Elodea* on salmonid (sockeye) production. LWS should work with qualified fisheries biologists to conduct restoration activities and support restoration projects. LWS volunteers can work with DFO on data collection and encourage attention toward Scully Creek concerns.

6. Gather Information on the Water Management Branch 1988 lake-outlet profile survey to investigate the viability of a repeat survey

A Lakelse River profile survey was conducted in 1979 and again in 1988. The section of interest for LWS is located where Herman Creek enters the Lakelse River. Due to concerns that the bar created at Herman Creek is impeding water passage, a repeat of the original survey is desired to compare any change in the channel since 1988. Collecting historical data about the previous studies will involve extensive data searches (may include contacting WLAP in Victoria). In order to repeat this study, the same benchmark used in the previous surveys must be located. An exact repeat of the survey will indicate if any change has occurred in the channel.

LWS Action

LWS should form a sub-committee to undertake the background research required for this activity. Information should be reported back to LWS directors, and viability of the survey discussed further at this time.

7. Establish a lake level gauge

Some residents have suggested that high water levels in Lakelse Lake persist for much longer than they used to. Installing a gauge will allow a large number of people to track the level of Lakelse Lake, will keep the community informed about highs and lows for the year, and future comparisons can be made. It is an inexpensive collection process that can be used as a public educational tool.

LWS Action

LWS should contact Water Survey of Canada staff to get hydrological advice, assistance with installation, and training on how to read and record lake levels. This is a long term project, and the task of recording should be delegated to a properly trained and committed volunteer(s).

8. Encourage a multi-agency approach for effective wastewater management

Water, Land and Air Protection (WLAP), Regional District of Kitimat-Stikine (RDKS), Northern Health Authority (NHA) and Lakelse Watershed Society (LWS) all play a role in encouraging effective wastewater management. These agencies are currently collaborating to develop a Liquid Waste Management Plan (LWMP) which will provide much-needed direction for wastewater management in the Lakelse Lake area.

In the meantime, WLAP staff should inventory sewage discharges which may influence water quality and which are under their jurisdiction (see Appendix K for a Summary of Jurisdiction for Authorizing Sewage Discharges in B.C.). WLAP staff should review existing sewage permit files, and investigate any possible unauthorized discharges.

NHA staff should continue to work with the community to ensure that on-site wastewater systems under their jurisdiction are in compliance with the Health Act. NHA and RDKS need to promote a unified approach to building inspection and the issuing of health permits in the Lakelse area. Increasing public awareness on the issue can help increase compliance and make people aware of the human health issues involved with malfunctioning septic disposal fields.

LWS Action

LWS should be active in the public review and consultation process of the LWMP, and if appropriate, advocate options for improving water and waste disposal services/facilities to lakeside lots and outlying subdivisions (including Jackpine Flats). Improved infrastructure will significantly reduce impacts to lake, and help protect human health.

9. Participate in regional planning initiatives

Watershed activities are known to significantly affect lake water quality and thus managing sediment and nutrient inputs to lakes involves managing the activities that create them. Regional land use planning and zoning initiatives provide avenues to affect changes in watershed activities at the regulatory level. It is important for Lakelse Lake watershed quality issues to be considered in these planning initiatives to ensure that they do not endorse activities that contribute to extra nutrients entering the lake.

LWS Action

LWS should make it known to RDKS (and other agencies) that it would like to provide input to future land use planning and zoning initiatives.

10. Support initiatives to implement recommendations listed in WLAP's *Drinking Water Source Quality Monitoring Program: Lakelse Lake & Jackpine Flats Draft Final Report* & *Attainment of Water Quality Objectives for Lakelse Lake, 2002 Update- Draft*

The report titled *Drinking Water Source Quality Monitoring Program: Lakelse Lake & Jackpine Flats Draft Final Report* (Appendix M) outlines drinking water quality monitoring that was conducted around Lakelse Lake and presents the results of this work. It also makes recommendations for future drinking water source quality monitoring in the area. Information contained in this report will be especially useful to the RDKS as it continues development of its LWMP.

Recommendations in the report include:

- Monitoring of Lakelse Lake continue at the established sampling sites to determine if the recent results suggest a trend in deteriorating water quality.
- Monitoring of Jackpine Flats groundwater continue at the established sampling sites, and at other sites in the subdivision, to gather data that will help determine the extent and risks of possible surface water influences on groundwater supplies.
- Additional sampling be conducted at all locations during the late winter/early spring (and other seasons) to investigate seasonal variation in water quality.

The document titled *Attainment of Water Quality Objectives for Lakelse Lake 2002 Update* (Appendix F) presents a water quality objectives update for Lakelse Lake. It summarizes levels of attainment in 2001 and 2002, and makes recommendations for updating the original objectives. The report recommended that an objective for Enterococci be added to the set of water quality objectives for Lakelse Lake, and that monitoring continues and the lake be re-assessed at least every five years to determine if any of the objectives need to be updated.

LWS Action

LWS can help make possible future sampling programs that are recommended, by providing input during program design (for example, providing advice on sample site selection). Also, LWS can continue to provide volunteer time to assist with sampling.

11.2 Summary of Recommendations

The recommendations listed above were chosen because they were deemed to be practical actions for LWS (and other agencies) to pursue as they begin to address the priority issues identified earlier in the plan. Due to the complex and interrelated nature of the watershed system, many of the recommendations address multiple issues, and every issue is addressed by at least one recommendation. The following table (Table 6, pg.71) illustrates the relationship between the priority issues and recommendations.

Table 6. Issues and Recommendations

Issue	Recommendation									
	1 *Elodea* mapping	2 other lakes	3 monitor water	4 public ed.	5 fish	6 outlet profile	7 lake gauge	8 waste-water	9 regional planning	10 drinking water
Elodea canadensis	●	●	●	●						
Fish Species				●	●					
Forestry				●	●					
Shoreline Development/ Modification			●	●				●	●	
Stream Modification			●	●	●					
Water Level Changes & Effects				●		●	●			
Drinking Water Quality								●	●	●

12.0 Management Plan Implementation

12.1 Immediate and Short-Term Actions

Although they will not yield immediate results, the data collection and volunteer monitoring recommendations should be initiated as soon as possible because they will provide the information needed to make effective decisions in the future. LWS should make every effort to participate in activities and continue advocating for conditions that will facilitate the long term goals and recommendations in this plan. It is important for the society to set achievable short-term goals, and monitor its progress on an ongoing basis.

12.2 Resources

Financial Support

For long term sustainability of the Lake Management Plan goals, a strategy must be developed to gain adequate funding to cover implementation costs. Once a consensus on the management actions and monitoring strategies has been reached, the level and duration of funding needed must be identified. When the LWS membership permits such action, a committee should be struck to formulate the financial strategy. Fundraising methods should be inventoried, evaluated and decisions made as to their applicability for the LWS.

Some options for raising funds include:

- Relating projects to current government programs (the provincial government's emphasis on drinking water source protection may equate to increased funding for water quality monitoring)
- Department of Fisheries and Oceans community fund
- Appling for grants or loans from public agencies and other organizations
- Voluntary donation, from individuals and businesses (should be sought in a systematic manner such as an appeal campaign)
- Collecting revenue in the form of membership dues from individuals and businesses
- Entering into partnerships with corporations and organizations
- Conducting fund-raising events, selling merchandise, etc.

Visit the following website further funding possibilities:
http://www.ec.gc.ca/ecoaction/grnsrc/index_e.cfm

Volunteer Groups

Committed volunteers are essential to the success of the plan. Managing a lake is an ongoing process, and a mechanism is needed to keep the plan in motion after it is written. Therefore, an aggressive membership program is needed that is flexible enough to accommodate more than one level of participation (both volunteers and financial contributions). In addition to lakeshore residents, other volunteer groups can assist with implementation of the plan. For the Lakelse Lake Management Plan this may include, but is not limited to:

- Other Lake Protection Societies in the region
- Youth and service clubs
- The Salmonid sub-committee of the Lakelse Community Association.
- Northwest Community College Students in relevant diploma courses (for example Forest Ecosystem Technology Diploma -Smithers Campus)
- Professional associations and groups
- B.C. Lake Stewardship Society (BCLSS)
- Northwest Stewardship Society

Sub-Committees

One method of ensuring that tasks are completed successfully includes placing the volunteers in groups (sub-committees), delegating tasks to each group and making sure adequate training is provided. The sub-committees consist of a leader (chair) and their assistants. Each sub-committee is responsible for completing a set of well-defined tasks. Examples of volunteer sub-committees are:

- Fundraising
- Sampling and Monitoring
- General Advocacy
- Public Education
- Membership Advocacy

To ensure that the tasks are carried out indefinitely, no leadership position should be vacant in any given year. Election of new sub-committee chair positions should occur every 2-3 years. An evaluation of the group's status should be held at regular intervals.

Regulatory Agencies

Most of the affected regulatory agencies have been consulted and involved during the lake management planning process. These agencies should be kept informed of activities around Lakelse Lake as the Lake Management Plan is implemented. In addition, prior to undertaking specific activities, it is essential to identify all affected regulatory agencies and obtain the necessary approvals and permits. When applying for permits and approvals, it is helpful to include a deadline for which the approval is needed as it will allow the agency to prioritise incoming applications for approval. Sufficient time should be allowed for the agencies to respond.

12.3 Plan Review and Revisions

This document does not indicate completion of the lake management planning process. As recommendations in the plan are implemented, the planning process will continue in a cyclical nature with assessments and revisions occurring on an ongoing basis. It is hoped that the LWS will continue to generate support in the community and gather resources to undertake activities recommended in the plan.

In the first year of implementation, there should be a review of the plan by lake management experts. The reviewers should include regulators who may be called upon to write permits and licenses, or cooperate in some way to implement the various management recommendations. Ensuring that this occurs should be the first priority, and could be accomplished with assistance from the WLAP, Environmental Protection division.

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