LAKE KATHLYN MANAGEMENT PLAN
ROUGH DRAFT #1

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1. Management Plan Goal Statements

The objective of the Lake Kathlyn management plan is to benefit users by improving the quality of the natural environment of the lake (i.e. to slow down or eliminate eutrophication) and thereby improving quality of life. The requirements of the plan must include maintenance of land and water use as well as aquatic and terrestrial wildlife use (plants and animals).

1.1 Strategic Planning/ Systems Design

In order to address the problem of designing a strategic lake management plan for Lake Kathlyn, a systems approach was taken. This approach is warranted due to the complexity of the problem(s) and the variety of the stakeholders. A general discussion of the mechanics and merits of this approach is contained in the companion Tyhee Lake Management Plan.

1.2 Consensus Building

A successful lake management program begins with a lake management plan which has widespread support from stakeholders. It is essential to involve all interested groups and regulatory agencies in the planning process to discuss the issues and work toward achieving a consensus (Gibbons, 1994). People are invited to participate at an early stage of the planning process so that they are more likely to become advocates of the program. This is essential for implementation and perpetuation of the plan (Rast, 1988). Stakeholders include government agencies, lake residents, lake user groups, environmental groups and others. For a complete explanation of the need for consensus in lake management planning, see Sec 1.2 in the Tyhee Plan, and a full list of the stakeholders involved in the Lake Kathlyn Management Plan, see Appendix C.

2. The Nature of the Eutrophication Process

The observed water quality in the lake, reflects in part the cumulative effects of the materials carried in all waters flowing into the waterbody (Rast, 1988). The process of eutrophication can be accelerated through increased materials carried into the lake due to human settlement, clearing of forests and development of farms within the lake's watershed (Rast, 1988). This is generally termed cultural eutrophication (Cooke, 1993). An increased growth rate of the flora and fauna in a lake is associated with a loss in recreational value, and a potentially unsafe water supply (Cooke, 1993).

A lake undergoing cultural eutrophication can be treated so that it will again have water quality more characteristic of the natural eutrophication process (Rast, 1988). If cultural eutrophication is left unmanaged, the result will be significant ecological impacts (such as fish kills) and significant reduction in quality of life for residents and recreational user groups which benefit from the lake. For a complete description of the effects of eutrophication on water quality and the biota, see Section 2.0 of the Tyhee Plan.

2.1 Nutrients: Limiting vs. Non-limiting

It is apparent from past studies that phosphorus is the main nutrient of concern. When assessing the available nutrient levels in the aquatic system, it should be noted that only the dissolved reactive fraction and some portion of the particulate fraction of phosphorus are available to organisms for growth (Cooke, 1993), however in P limited lakes such as Kathlyn, it can be assumed that all P, be it “total”, or dissolved will become available to the plant biota at some time in the nutrient cycle.

Excessive growth of algae and aquatic plants can cause decreased dissolved oxygen levels, decreased recreational value due to odours and aesthetics, and poor habitat conditions for other aquatic organisms such as fish (Wetzel, 1983). A reduction of phosphorus inputs is generally the most effective method to reduce the excessive growth of algae and aquatic plants in a lake that is receiving a continuous loading of nutrients (Wetzel, 1983).

Atmospheric levels of phosphorus are low, as it does not have a gaseous phase and the nutrient is chemically reactive. These two characteristics make phosphorus technologically easier to control and remove from water than nitrogen (Wetzel, 1983). Once external loading to a lake is decreased the lake will require from 2 to 10 years for recovery from eutrophication symptoms such as increased algal growth (Wetzel, 1983).

2.2 Nutrient Sources - Internal versus External Nutrient Loading

Sources of nutrients to a waterbody include external and internal sources such as groundwater seepage and sediments, in various states of chemical equilibria (oxidative and reducing conditions). External nutrient loading consists of point sources and nonpoint sources. Any direct nutrient sources to the lake such as discharges through culverts and storm drains are considered to be point sources whereas, overland flow and groundwater seepage are considered to be nonpoint sources. Internal loading from groundwater seepages, decomposing organisms and sediment contributions can add nutrients to the water column at rates equal to or greater than external loading at some times of the year (Cooke, 1993). If a reduction of total phosphorus in the water column is the objective of the lake management program, the major sources of the nutrient inputs to the lake must be identified and quantified.

2.3 Nutrient Models

Once the limiting nutrient for the lake has been identified, possible sources of influx and outflux of the nutrient should be quantified to construct a nutrient model. The theory and practice of nutrient modeling is discussed in Section 2.4 of the Tyhee Plan

3. Diagnosis of Lake Kathlyn

3.1 Interrelatedness Analysis

In the analysis stage of the plan, three systems (socio-economic, biological, and physical) were identified. The systems are artificial and most likely incomplete but were a systematic attempt at identifying and classifying all the important and controllable aspects of the lake system and it's watershed.

A complete inventory of all components of the lake and watershed was developed. The interrelatedness analysis created an overview of the entire lake ecosystem and it's components and how these relate to social, economic and political factors.

For further information on the method of the interrelatedness analysis, see Appendix A which also contains the systems inventory and the interrelatedness analysis, and for explanations of the intricacies involved in each key component, a more thorough explanation is provided in Section 3.0 of the Tyhee plan. This exercise facilitated the commencement of the plan by allowing the determination of key components relevant to the lake. Every lake will have different key components..

3.1.1 Key Components of the Physical System

3.1.1.1 <u>Flushing Rate</u> - What affects it?

. If the flushing rate is high, algal growth becomes more dependant on this factor and less dependant on nutrient supply (Cooke, 1993). Therefore if the flushing rate can be speeded up through diverting clean water through the lake, it will tend to influence algal and macrophyte blooms. An increased inflow of pristine water low in nutrients may mean an increased flushing rate which may improve the aesthetic and chemical qualities of the lake.

3.1.1.2 <u>Water level</u> - What role does it play?

Through manipulation of the outlet (raising or lowering it), the water level in the lake can be altered. This can be used to advantage if nutrient laden water can be discharged in quantity. One or two opportunities a year may present themselves if a lake level control system can be put in place. At spring freshet there is usually a brief period of destratification. Under these conditions, the nutrient concentration in the lake is relatively uniform, instead of concentrated near the bottom if anoxic conditions on the bottom prevail. The second such condition occurs in the fall, and is accompanied by a period of high precipitation. If stored water can be let go in a brief period when it is uniformly high in nutrients, then less of the nutrients will be present for further cycling within the lake. This will be the premise used as part of the Tabor Lake Management plan (north of Prince George). For a discussion of all the potential considerations associated with such a scenario, see Section 3.1 of the Tyhee Plan.

3.1.1.3 Shoreline and Watershed Erosion as it relates to Sediment Deposition Rates

A slow flushing rate allows sediments a longer time to settle and cause infilling. When the flushing rate is slow, nutrients may concentrate in the lake and not be "flushed" out. This may cause a decrease in water quality and an increase in growth of algae and aquatic plants, if the ratio of suspended sediment to nutrient rich organic matter is low. This may be a key consideration in determining the positive effects of the Club Creek diversion project.

Inflowing streams often carry a high level of nutrients and suspended solids when the rate of flow is high (e.g. during the spring melt) due to mechanical erosion of stream beds and initial flushing of animal waste deposited throughout the winter.

3.1.1.4 Anthropogenic Nutrient Sources

Groundwater or overland runoff which runs into the lake may pick up contaminants from leaking septic systems or gardens (e.g. insecticides, fertilizers) which may cause decreased quality of the water for contact, recreation and consumption. Septic system inputs may carry poisonous or dangerous household products which could alter water quality with respect to human contact and consumption, rendering it unacceptable.

3.1.2 Biological - Chemical System

3.1.2.1 Resources at Risk

A complete inventory and explanation of the resources at risk in each of the Bulkley Valley lakes is contained in Section. 3.1 of the Tyhee Plan.

Sport fishing and recreational uses of the lake can be extremely important to user groups. It is likely that the fisheries potential of the lake if it can be restored to a less eutrophic state will be a major factor in determining the degree to which management efforts are tried.

Wildlife at Lake Kathlyn includes moose, deer, black bear, otter, muskrat and beaver (T. Smith, pers. comm., 1995). A variety of eagles, hawks and owls are also a part of the lake ecosystem. Loons, Canada geese, mallards, golden eye, mergansers, grebes and teal nest and live at the lake (G. Schultz, pers. comm., 1995). Each of these species is a part of the intricate food web that exists at Lake Kathlyn. If eutrophication of Tyhee Lake continues at its present rate, disruption of the natural balancing forces which maintains the aquatic ecosystem in its present form will occur and it is possible that some species will not be able to meet their life cycle requirements in the lake.

In addition to aquatic and terrestrial wildlife resources present, Lake Kathlyn is a source of drinking water for some shoreline residents. It has been a popular recreation area with high swimming and boating activity levels, however, with the recent algal and macrophyte blooms in the lake, these values are vastly diminished.

3.1.2.2 Physical Habitat

The lake has three distinct and interacting biotic communities. These include the wetland-littoral zone and its sediments, the open water pelagic zone and the benthic (deep water) zone and sediments (Cooke, 1993). The three communities are interacting and any symptoms of eutrophication in one zone will affect the other two zones as well. All three zones provide reproductive, feeding, resting and escape habitat for different species of aquatic and terrestrial wildlife. Through eutrophication, the ecosystem is altered and as a result the populations and species of wildlife will change.

New development may destroy shoreline vegetation and wetland areas, thereby destroying habitat for waterfowl. Riparian vegetation is an essential part of waterfowl habitat which is often altered or destroyed by gardening, landscaping and creating views of the lake. Removal of riparian vegetation can also lead to increased shoreline erosion thereby altering feeding, escape and reproductive habitat for fish, waterfowl, and invertebrates.

Wetland areas with emergent macrophytes are vital to fish life cycle requirements as they provide food and hiding areas.

3.1.2.3 Sources of Phosphorus - What makes it available or not?

Poor quality stream inflow, slow flushing rate and complete turnover can all lead to increased available phosphorus within the lake system which in turn leads to an increase in productivity. Improper sewage disposal, overland runoff from agriculture (dairy and horse farms, and cultivation) are land uses likely to result in high phosphorus loading to the lake. An increase in the concentration of phosphorus in the lake may lead to increased algal bloom frequency and duration and excessive growth of aquatic plants.

Shoreline vegetation plays an important role in absorbing nutrients such as phosphorus from the water table which may carry septic field seepage.

3.1.2.4 Phosphorus Concentrating Factors

Phosphorus is concentrated in sediments, hypolimnetic water, plant organic matter and other organisms. Removal or reduction of one of the phosphorus concentrating factors could lead to a significant decrease in phosphorus concentration in the lake.

A low flushing rate causes nutrients to concentrate in the lake rather than being diluted and flushed out. Wind, and other mixing such as that created through macrophyte weed harvesting can cause disturbance of the bottom sediments which allows phosphorus to be liberated into the water column.

3.1.2.5 Ecological Consequences of High Phosphorus - Nutrient Cycles

Resuspension of sediments can increase the concentrations of bioavailable nutrients, leading to algal and macrophyte blooms. When the algae die and decompose, the biochemical reactions require oxygen which leads to a decrease in dissolved oxygen, causing mortality of aquatic life including fish. There is also a significant increase in available phosphorus when algae die off and decompose. Decaying organic matter resulting from algal blooms contributes to sediment buildup which becomes a phosphorus reservoir for later release under anoxic (no oxygen) conditions.

As eutrophication of the lake progresses, species diversity decreases, while populations of some eutrophication tolerant species increase. This has been the case for Lake Kathlyn.

Blooms of cyanobacteria can lead to toxic drinking water. Cyanobacterial toxins can also cause mortality of aquatic and terrestrial life and other animals that consume contaminated lake water (e.g. livestock).

A leaking septic tank or nonfunctional septic field may drain into the groundwater and carry nutrient rich water to the lake. This drainage may also be high in fecal pathogens. Fecal pathogens can be hazardous to the health of many species and decrease the water quality for human consumption and contact recreation.

Sewage disposal directly into the lake may contribute significantly to poor clarity and smell of the lake water.

3.1.3 Socioeconomic System

3.1.3.1 Range of Desired Outcomes of Varied User Groups

Each group of lake users has their own interests to protect. It is likely that residential users have the most at stake in terms of the lake. The value of their land, their quality of life and the water which they drink are all dependant on the state of the water in the lake. Excessive macrophyte and algae growth will lead to deterioration of the water quality for drinking and recreational purposes. Residential users maintain an interest in the viability of waterfowl populations and wish to see them perpetuated to fulfill their vision of the lake. Recreational users include swimmers, tourists, beach users, anglers, and wildlife observers. For all recreational users, high water quality and lake aesthetic quality are a top priority.

3.1.3.2 Potential Changes to Land Use

The effects of overland runoff on eutrophication of the lake depends on land use in the area. Agricultural land use in the watershed with no runoff treatment will lead to increased nutrient loading to the lake and therefore an increased rate of eutrophication. Such uses are likely occurring on one of the creeks which has its headwaters to the north east of the lake, across Highway 16.

Through proper care taken by forest managers, upper reaches of the creeks should remain intact and unaltered to reduce erosion caused by overland runoff.

New development of roads or pipelines could affect fish populations if there is a negative impact on nearby creeks through restriction of access and sedimentation.

Residential land uses include horticulture, gardening and creation of beaches. This development can reduce the area of riparian vegetation which reduces the amount of absorption of nutrients in overland runoff.

3.1.3.3 Financial & Institutional Resources Available

The Volunteer Lake Stewardship Program is a new government initiative which will provide some funding, technical support through the Ministry, monitoring assistance and establish a user group support network which will produce educational materials and provide guidance. The Protection Society has qualified for an initial grant of seventy-five hundred dollars ($7,500) and will have an opportunity to apply for ongoing funding.

Other private initiatives for raising funds include protection society membership dues, fundraising events, donor campaigns and tax based revenue under the newly established Local Improvement District.

3.1.3.4 Regulatory Requirements

As illustrated in Table 2, of the Tyhee Plan, many of the lake components are protected by federal, provincial, regional district or municipal legislation.

4. Watershed & Limnological Background Information

This section of the lake management plan includes a description of the area, including maps and morphometric-hydrologic data, and an accurate summary of all measurement methods and sampling locations.

4.1 Watershed

Lake Kathlyn is located northwest of Smithers in Northern British Columbia (map sheet 93L) as illustrated in Figure 1 (figure from Boyd, 1984). The lake is within the Smithers-Telkwa Official Community Plan area.

The lake is in the Skeena watershed and the catchment basin is outlined in Figure 2 (Skeena GIS, 1995). The approximate size of the catchment basin is 25 km^2 . The catchment basin is determined by the physical height of the land and the boundary outlines the area within which all water flows towards the lake. Of note is the Kathlyn glacier at the headwaters of Club Creek on Hudson Bay Mountain.

4.1.1 Land Use Activities

Land use activities in the Lake Kathlyn Catchment Basin include:

- agriculture -livestock -cultivation/harvesting
- residential
- civic park
- past mineral exploration and development

Figure 1: Location of Kathlyn, Seymour, Round and Tyhee Lakes

Figure 2: Lake Kathlyn Catchment Basin Map (Skeena GIS, 1995)

The percentage of land used for each of these activities can be roughly estimated using aerial photographs.

4.1.2 Zoning

Zoning of the land is determined by the Bulkley Nechako Regional District as a part of the Official Community Plan. The types of land use activities which are taking place in the watershed are restricted by the zoning by-laws. As determined by the Official Community Plan, the catchment basin includes land zoned as follows:

- Rural Residential (Ru-R) minimum parcel size 0.4 ha
- Rural Agricultural (Ru-A) minimum parcel size 2.02 ha
- Commercial (C) no minimum parcel size
- Mineral development (Md) minimum parcel size 7.0 ha

4.1.3 Water Sources (tributaries, groundwater)

Sources of water inflow into the lake include groundwater, creeks, precipitation, and overland runoff (water flowing over the ground following a precipitation event or spring melt). During spring melt, the creeks are at high flow and by the time the summer season arrives, most of the creeks have dried up, with the exception of the club creek diversion. Figure 3 shows the sampling sites, including inflowing creeks and deep station.

4.2 Limnological Characteristics

4.2.1 Morphometric Data

Table 1 summarizes the morphometric data for the lake as described by Ian Boyd (1984).

Figure 3 illustrates the bathymetry of Lake Kathlyn (Boyd, 1984).

Table 1: Summary of Morphometric Data (Boyd, 1984)

Attribute		**Value**	**Units**
Elevation		472	m
Surface area		170	hectares (ha)
Volume		7780	cubic decametres (dam^3)
Mean Depth		4.6	m
Littoral Area (<5m)		30	percentage of lake surface area (%)
Maximum Depth		9.5	m
Perimeter		6130	m
Water Retention time	Mean	1.15	years (yr)
Flushing rate	Mean	.9	years

Figure 3: Bathymetry, Water Licence Point of Diversion, and Water Quality Monitoring Sites for Lake Kathlyn

4.2.2 Physical/Chemical Water Quality Characteristics

4.2.2.1 Temperature Profile

Lake Kathlyn is dimictic. This suggests that turnover occurs twice a year, once in the spring and once in the fall, however, the turnover is not always complete (Portman, 1992).

The lake turnover is complete on the day that the water column is isothermal (uniform temperature at all depths). At the deepest point in the lake (shown in Figure 2), temperature measurements are taken at different depths. If the temperatures at each depth are different, then the lake is said to be thermally stratified.

4.2.2.2 Dissolved Oxygen Profile

. Biochemical and chemical oxygen demand are greater than the oxygen replenishment in Lake Kathlyn. Depletion of dissolved oxygen allows phosphorus release from the sediments into the water column. An increase in phosphorus concentrations leads to increased algal growth and the cycle continues until the anoxic water is replenished with oxygen. For a complete description of the annual changes in the mechanics and chemistry of the D.O. profile in the lake see Section 4.2.2 of the Tyhee Plan.

If anoxic conditions at depth are not completely replenished due to incomplete mixing at turnover, during the summer stratification, the hypolimnion dissolved oxygen depletion occurs much more rapidly, allowing a longer time period for anoxic conditions to persist. Anoxic conditions at the sediment-water interface allows for phosphorus transport from the sediments into the water column, which may lead to more severe algal problems. It is conceivable that increased cold water flows from the Club Creek diversion may have beneficial effects at turnover, by causing increased mixing. This conjecture remains to be tested through temperature profile monitoring in the spring.

4.2.2.3 Nutrients - Phosphorus and Nitrogen

Nitrogen and phosphorus are usually the two limiting nutrients in freshwater systems. Before a lake management action plan can be identified, it is important to determine which is the limiting nutrient in the lake or if the nutrients are co-limiting. If the weight ratio of total nitrogen to total phosphorus in the lake is greater than or equal to 15:1, the plankton growth is limited by the availability of phosphorus and if the weight ratio is less than or equal to 5:1, the plankton growth is limited by nitrogen (Boyd, 1984). In Lake Kathlyn, the weight ratios of nitrogen to phosphorus at the deep station in June, 1995 ranged from 12 at 7.5 m depth to 28 on the surface, averaging above 20. The 15 m depth sample showed a weight ratio of 5, but it is suspected that this sample was contaminated with sediment from the bottom. Data from other years sampling confirm that Lake Kathlyn is indeed P limiting.

The water quality of Lake Kathlyn was reviewed by Boyd et al. in 1984. It was suggested that the total phosphorus concentration at spring overturn should not exceed 0.015mg/L. This objective applies to the average of three samples taken 1 metre below the surface, at mid depth and 1 metre above the bottom at the deep station sampling site.

4.3 Biological Characteristics

4.3.1 Aquatic Plants and Algae

Algal biomass and species diversity are an indicator of trophic status in a lake. An eutrophic lake is usually characterized by high algal biomass and frequent algal blooms, which generally indicates a high level of available forms of nutrients in the water column. Boyd et al (1984) described the pattern of algal growth as follows:

- January - low standing crop (260 cells/ml) dominated by *Anabaena* and *Cryptomonas* (cyanobacteria and green algae)
- May - higher standing crop (300 cells/ml) dominated by *Dinobryon*, *Asterionella*, *Anabaena* and *Chroomonas* - fluctuations in species dominance and standing crop may occur within a few days
- June - high standing crop (6000 cells/ml) dominated by *Anabaena* and *Asterionella*
- July - 1200 cells/ml - dominated by *Gomphosphaeria*, *Chroococcus* ,*Anabaena* (all cyanobacteria) and *Quadrigula* (green algae)
- September - moderately high standing crop (700 cells/ml) dominated by *Gomphosphaeria* and *Coelosphaerium*, (both cyanobacteria)

Corresponding chlorophyll *a* measurements for this period were highest in the summer with a mean and maximum of 5.0 and 9.5 ug/l. (It was suspected by the authors that if the June sample had not been destroyed that a much higher average concentration and maximum would have been measured). These concentrations when compared to an objective of 4 ug/l to avoid nuisance effects point to Lake Kathlyn having a eutrophication problem. The predominance of cyanobacteria also point to eutrophic conditions, and are also indicative of a potential hazard to human health through drinking water and primary contact recreation.

In 1977, Dr. Pat Warrington conducted an aquatic plant survey on Lake Kathlyn. It was found that there were extensive shallow water areas with beds of *Potamogeton* spp., *Lemna minor and Ceratophyllum demersum.* None of these plants are rooted and therefore must obtain nutrients from the water column. This indicates that there are relatively high concentrations of available nutrients in the water column.

It is interesting to note that <u>Elodea</u> <u>canadensis</u>, one of the most abundant aquatic plants in the lake in 1992, was not found in the lake in 1977 (Warrington, pers. comm., 1992). This species is characterized by maximum growth one year followed by a population crash the next and then a slow increase in the growth again (Warrington, pers. comm., 1992). It is a nuisance plant in many lakes in British Columbia because it can rapidly cover the entire surface area of a lake and may block or clog the outlet causing an increase in the water level of the lake.

4.3.2 Zooplankton

The dominant species of zooplankton present in Lake Kathlyn are not presently known. Zooplankton are an important part of the food web in a lake system because they feed on algae. The technique of reversing or controlling eutrophication in lakes through biomanipulation of zooplankton species may in turn control algal biomass (Cooke, 1993).

4.3.3 Fish

Rainbow trout were stocked in Lake Kathlyn in 1958 and 1959 (4000/year) by the Fish and Wildlife Branch, BC Environment. According to the DFO Stream Information System (SIS), coho salmon are known to spawn in Lower Kathlyn Creek and have been observed in Upper Kathlyn Creek. Pink salmon have also been observed in Upper Kathlyn Creek. The Kathlyn Creek system has an escapement of 50 (100 maximum) and 20 (100 maximum) for coho and pink salmon respectively. These figures were derived from a period of record of 1980-89. As late as 1965, 500 fish had been counted in the escapement inventory for this creek system. Management target escapements for the creek system have been set at 350 and 1000 for coho and pink salmon respectively. As of 1991, the SIS shows enhancement releases of Toboggan Creek hatchery coho into Kathlyn Creek and Lake. Other fish which have been identified in the lake include steelhead, peamouth chubb, northern squawfish, longnose sucker, cutthroat trout, and prickly sculpin.

4.3.4 Terrestrial Wildlife and Waterfowl

Nesting waterfowl at the lake include loons, ducks (mergansers, grebes, mallards, golden eye, and teal), and Canada geese (G. Schultz, pers. comm., 1995). Sandhill cranes are among those which use the lake for staging in the spring and fall (I. Sharpe, pers. comm., 1995).

Eagles, hawks, owls, moose, black bears, otters, coyote, fox, muskrat, beavers, and deer also depend on the lake and associated riparian habitat as a part of their life cycle requirements (T. Smith, pers. comm., 1995). In most cases, wildlife are more likely to flourish in the lake and riparian ecosystem if the food web remains somewhat heterogeneous. Although some species of larger wildlife may be able to utilize vast mats of *Elodea*, for food or habitat, most lake dwelling species will be presented with an obstacle that will physically prevent them from feeding (on fish, other aquatic vegetation or benthic invertebrates) or finding suitable habitat (open water for escape from predators, floating nest sites).

5. Water Body Usage Map

The water body usage map provides a visual representation of the specific uses of the lake (Gibbons, 1994). This allows the many different uses to be identified and recognized in the lake management plan.

Specific uses of Lake Kathlyn include a boat launch area, (nonmotorized only) waterfowl nesting and rearing areas (upland and emergent vegetation cover, open “brood” water), wetland areas for a variety of wildlife including furbearers, beaches and swimming areas, a local park, and water supply intakes. These should be drawn on a water body usage map for the next draft of the Lake Kathlyn Management Plan.

6. Discussion of Lake Management Alternatives

For a discussion of the complexities to be considered in identifying, evaluating and choosing lake management options, see Section 6 of the Tyhee Plan.

To assess the lake management alternatives in terms of feasibility for Lake Kathlyn, the advice contained in Boyd et al (1984) and personal communications with R. Nordin and K. Ashley was used as a basis for selecting alternatives for further consideration (a "canvass of the experts" as outlined in Rast, 1988). The list of alternatives tended to fit into 2 distinct categories:

- can do no harm, will most likely cause positive results in reducing eutrophication effects (although not quantified), and can be implemented at low cost (financial, social and ecological). These include freshwater diversion using Club Creek as the source and a Local Improvement Area tax base as the funding source and aquatic weed (*Elodea*) harvesting, using MELP or locally built harvesting equipment and a currently held grant (MELP Lake Stewardship Program) as the funding source. Both options can be implemented immediately.
- may have negative as well as positive effects on eutrophication and/or may have significant financial, social and/or ecological costs. These include hypolimnetic siphoning or aeration (hypolimnetic of destratification type), sediment removal, regulation of lakeshore and creekside development and land use, construction and use of community sewer facilities, remediation of individual onsite sewage disposal systems and water level control. as was done for the Tyhee Lake Plan, a combination of cost-benefit analysis and social-impact ranking matrix should be used to evaluate these options. The ranking objectives to be used should be financial and social cost, ecological cost, ecological benefit and effectiveness in reducing eutrophication. Details of the method to be used are shown in Section 6.2 of the Tyhee Plan. Detailed discussion of these options is included in following sections.

Most of the options which treat the causes of cultural eutrophication involve reducing point and non-point sources of external nutrient and sediment inputs by implementing specific land use management practices. These measures are usually doubly rewarded since any reduction in contaminant loading to a water body as a result of land use management practices usually reduces the nutrients available for internal cycling over the long term and can maintain or extend effectiveness of in-lake controls (Gibbons, 1994).

6.1 The option of doing nothing

It is important to consider the consequences of doing nothing because it offers one basis of comparison with the potential effects of implementing a lake management program (Rast, 1988). In the case of Lake Kathlyn, the anecdotal evidence of gradual deterioration of lake qualities is quite compelling, although it must still be determined whether cultural sources of nutrients to the lake constitute a high enough proportion to expend considerable time and effort on reduction or elimination. In 1986, it was apparent that nutrients from the tanker base were having a significant effect of lake eutrophication and that immediate action was required (Remington, 1986). Now that this drainage has been routed to the Bulkley River watershed, only the remnant nutrients present in the lake sediments remain. Clearly an evaluation of the option of doing nothing helped decide if management was required. With this issue already dealt with, it is difficult but not impossible to estimate the rate of cultural eutrophication from residential, agricultural and internal loading sources. However, this should be done quickly using sediment core analyses (core slicing, lead ^{210} aging, nutrient concentrations and diatom taxonomy to determine eutrophication indicator assemblages), as it is known that a lake exhibiting eutrophication symptoms is likely to become worse over time and if a lake is allowed to deteriorate indefinitely it will decrease the chances for a timely rehabilitation while increasing the cost of restoration (Rast, 1988).

6.2 Inventory of Lake Management Options

For a complete inventory of lake management options available, including those mentioned above and a description of the pros and cons of each, see Section 6.4 of the Tyhee Plan.

6.2.1 *Septic System Failure Definition Remediation/Maintenance*

The amount of nutrient loading to the lake through septic systems can be varied and it is very difficult to estimate the total nutrient contribution to the lake from septic systems. Boyd et al, 1984 discussed this at length, and ended up with a loading estimate of .65 kg of P/household /year on average. This number varied with soil type and distance from the lake (see Boyd, 1984). The efficiency of removal of phosphorus is also directly related to groundwater flow characteristics according to Kerfoot, 1981. They observed a high correlation between location of nutrient rich plumes and attached plant growth. This was also mentioned as being the case at Lake Kathlyn by Boyd et al (1984). Flourometer studies of Lake Kathlyn have corroborated the soils and groundwater assessments made by Boyd et al (1984) to some extent. Results indicate that sewage effluent was present along the shoreline in 4 locations:

- foreshore of 4 lots at SW corner of the lake
- 1 lot at S end of the lake
- inflow from the airport area
- developed shoreline on E side of the lake

In addition to these results, investigations of soil properties indicated that two areas of the lake, the south end and the upland area on the east side have poor suitability for septic systems according to Boyd et al (1984). They recommended that septic systems in these two areas be set back a minimum of 300 metres from the shoreline (1984). This could be addressed through Zoning Bylaws for presently undeveloped or proposed redevelopment of land in this area.

Another approach uses a water budget formulation where input is equal to output (black box model). Other sources of nutrient loading can be measured and the nutrient contribution from septic systems can be estimated indirectly (Cooke, 1993). This modeling exercise is likely to show that septic system discharges comprise only a small percentage of total external and internal loading, however, it may be a large percentage relative to external loading only.

Since this is most likely the case, long term maintenance of septic systems is an important part of reducing cultural eutrophication of Lake Kathlyn. It is a fact that problems associated with septic system failure are difficult to diagnose, therefore it is up to the individual house owner to maintain the system. Often, people do not realize that there is a problem with their system until it has reached a serious failure stage. An additional way of diagnosing failing systems is through the use of a septic leachate detector by the Ministry of Health. The Health Inspector adds a dye to the septic system and then assesses whether any of the dye seeps into the lake (detection of plumes). This process is not always effective and can be time-consuming, but is nonetheless worthwhile.

6.2.2 *Control of Inputs from New Development*

New development within the catchment basin can contribute significant amounts of nutrients and sediments to the lake which would further increase the rate of eutrophication. Ditches used to catch and store nutrient rich runoff may be effective. Management practices which increase retention of overland runoff may be expensive and the associated cost would be borne by developers. Subdivision zoning bylaws specifying acceptable land use management practices could be set in place by the Bulkley Nechako Regional District, through the Official Community Plan.

6.2.3 *Runoff from Agricultural Lands*

Runoff from agricultural land may account for a significant amount of nutrient loading to Lake Kathlyn. Initial indications are that although nutrient inputs from the tanker base operations have been curtailed, some agricultural inputs to the creek(s) on the E side of the lake may be occurring (see Appendix H for water quality information). This will be verified through the proposed monitoring program outlined in Section 7. The Tyhee Plan includes a detailed description of how this type of input may be curtailed .

6.2.4 *Public Education*

Every lake management plan must include a public education program. It will encourage a larger portion of the population to take responsibility for the part they play within the watershed and the perpetuation of the plan. Through education, public involvement, which is essential to implementation and perpetuation of the plan, will result. Public education can also be effectively used to reduce external loading of nutrients and sediments. The public must be informed about land use/management practices to reduce nutrient loadings. This may include using phosphate free detergents, choosing to promote the growth of riparian vegetation and reducing fertilizer use.

6.2.5 *Hypolimnetic Withdrawal*

Hypolimnetic withdrawal involves removal of nutrient rich, oxygen deficient water at depth, replacing the natural outflow of surface water (Cooke, 1993). The ultimate goal of hypolimnetic withdrawal is a decrease in internal loading of phosphorus. This could be accomplished through removal of hypolimnetic water which would be replaced with water higher in dissolved oxygen. The residence time of the hypolimnion would be decreased which would in turn decrease the period of anoxia. Ultimately, the depth of the anoxic boundary would change which would lead to a decrease in phosphorus diffusion from the sediments (Cooke, 1993).

Hypolimnetic water could be removed by siphon and discharged through the outlet and into the Bulkley River via Kathlyn Creek. There is a six week freshet when the water could be siphoned out while maintaining the water level (P. Marquis, pers. comm., 1995).

The hypolimnetic water may have some impact on the creek and the Bulkley River. Increased aquatic vegetation in the stream bed and algal blooms are possible, although discharges restricted to spring freshet would make this unlikely (I. Sharpe, pers. comm., 1995).

6.2.6 *Biomanipulation*

Manipulation of the lake biota can have significant effects on algal biomass and phosphorus concentrations in the lake (Carpenter, 1995). A piscivorous fish is one which feeds on other fish. Addition of piscivorous fish to the lake community causes a decrease in the planktivorous fish populations which, in turn, allows an increase in zooplankton populations. Zooplankton are efficient algal grazers. This is known as “top-down” biomanipulation (Cooke, 1993). Once the piscivorous fish are mature, they are likely to be removed from the lake by anglers. Removal of a fish which weighs several pounds from the lake will remove a significant amount of phosphorus from the system. Effective biomanipulation requires an extensive knowledge of the lake biota and the specific mechanisms of the pelagic food web (Cooke, 1993).

6.2.7 *Sediment Removal*

Even if external phosphorus sources are significantly reduced, lake recovery may not be evident for a period of years until sediment P concentrations from historic loadings are depleted. The reason is that the internal phosphorus cycling may still be high due to internal loading from the sediments under anoxic conditions. It should be noted that there is not a clear indication that this will occur. It was hypothesized by Boyd et al (1984) that sediments were not contributing greatly to the annual P loading. However, sediment P concentrations resulting from spring 1995 sampling were found to be high enough to cause some additional consideration of this issue (see results in Appendix I). This remains to be verified through additional water sampling (leading to a workable P budget) and sediment core sampling (see Section 7). If it is found that significant loading from sediments will still occur, it may be feasible to remove the phosphorus laden sediments from the lake basin using a hydraulic dredge (Cooke, 1993). Before employing this restoration method, the sedimentation rate must be determined to ensure that the technique will be effective over the long term. Indeed in this case, an increased sedimentation rate from diversion of glacial fed (turbid) Club Creek may provide a seal over the P laden sediments which were deposited when airport runoff was entering the lake.

The pros and cons of this management option are discussed in Section 6 of the Tyhee Plan.

7. Monitoring and Evaluation of Lake Quality

7.1 Water Quality

Monitoring data is essential as it allows us to compare the quality of the lake from year to year. An extensive baseline data set is already established for Tyhee Lake, allowing the development of a P budget for the lake and comparison of water quality before and after implementation of lake management techniques A monitoring plan is essential from this point on to ensure aid in decision making. Once a decision to proceed with a management option is made, those parameters which may assist in demonstrating a change (if one occurs) are first summarized and tracked over the implementation period. This allows continuing evaluation of the effectiveness of the actions taken, and provides a basis on which to determine "how much is enough". If it is desired, parameter specific goals such as a 50% reduction in total P concentration at spring turnover can be chosen ahead of time, and used to check original assumptions regarding the costs and benefits of the option.

To establish a nutrient budget for the lake, water chemistry sampling and flow rate data were collected for the inflowing creeks and outlet of the lake Annual monitoring of turnover (approximately two weeks following ice off) concentrations of temperature and dissolved oxygen have occurred for a number of years.

At the precise time of turnover occurrence water samples are taken at 5 meter depth intervals and sampled for concentration of total phosphorus, total nitrogen, nitrates, nitrites, and total Kjeldahl nitrogen. The phosphorus data has been reported and interpreted in the BC Environment Water Quality Objectives Annual Attainment documents for the period of 1987 to 1993. A summary of this data has been provided in an October 1994 Water Quality status Report brochure published by the ministry. Results indicate that throughout this period, the objective related to eutrophication effects caused by phosphorus of .015 mg/l total P has never been met at spring turnover. This spring turnover sampling for nutrients should be continued, and used as the primary indicator of eutrophication effects in the lake on an annual basis.

Sampling of this type requires a dissolved oxygen meter and probe (with a 30 meter cable between meter and probe), Hach DO kit for instrument calibration and Van Doorne water sampler for sampling at 5 m depth intervals. Pre-washed sample bottles and coolers for trans-shipment to the Ministry contract lab are also necessary. It is anticipated that this hardware can be made available to the Protection Society for use at turnover.

7.2 Creek Hydrology and Water Quality

Water survey of Canada has installed a permanent hydrometric station on Kathlyn Creek below the lake. Flow rates for each of the inflowing creeks must be monitored by ministry staff and volunteers to refine the calculation of the flushing rate and total nutrient loading on an annual basis. This information is important in the context of judging the relative contributions of lake management options and the natural effects of annual climatic conditions (wet vs. dry years).

Once decisions regarding external lake management options have been made and implementation is imminent, a schedule of creek monitoring to track the success of nutrient limiting activities may be necessary. This may include a selection of target creeks, based on prior evaluation of anthropogenic nutrient sources. For instance, if those residents keeping livestock within the watershed choose to cooperate in limiting the entry of fecal nutrients into the lake, the success of these measures can be measured through monitoring specific creeks associated with the properties involved.

Tools necessary to continue this type of sampling include pre-washed bottles for grab sampling, plywood, 2x4 and sandbag constructed weirs on the larger creeks and a Parshall flume for periodic measurements of the smaller creeks. Bottles and the flume can be provided at no cost for use by volunteers by the Ministry of Environment. Shipping and lab analytical costs may amount to $3,000 - $5,000 per year for this sampling. It is anticipated that these costs could be cost shared on an equal basis with the MELP EP Program, provided budgets allow. Materials for weirs may cost $200 - $300, depending on the number of creeks monitored.

7.3 Biological Sampling

Of most importance to the potential for implementation of some of the more invasive lake management options is the need to establish whether any rare or endangered species are present and what extraordinary means may be necessary to ensure their protection.

As the lake management plan matures, it will be necessary to conduct inventories of algae, invertebrates and fish to monitor the "health" of the aquatic ecosystem. Inferences regarding the eutrophic status of the lake based on algal and invertebrate species present and their relative abundances can be made, and a warning of any impending changes in fish populations may be possible also.

7.4 Aquatic Macrophytes

Aquatic weed harvesting has been recommended as an immediately implementable management option. Once harvesting has commenced, a running tally of the tonnage of biomass removed is necessary, along with the harvesting locations. Once an annual weight has been calculated, then the weight of P removed can be calculated. This will be accomplished by converting wet weight to dry weight through direct measurement and conversion. Then dry weight P concentrations determined from lab analyses of a few samples can be used in a calculation of total weight of P/wet weight tonne. Sampling of biomass harvested will require no specialized equipment. The MOF lab in Smithers can be used to convert wet to dry weight, and biomass samples can be sent to the BC MELP laboratory for P concentration analyses. Costs for this work will be approximately $200 - $300 / year.

7.5 Sediment

Sediment studies including source identification (part of the inflowing creek studies) and documentation of whether there is a nutrient sink acting as a source of internal nutrient loading within the lake are necessary. Over the past 3 years it has been demonstrated that sediment cores taken from deep depositional zone(s) within eutrophic lakes can be used to make some extremely powerful inferences regarding the relative contributions of anthropogenic and natural nutrient sources. A combination of lead isotope (Pb^{210}) dating, diatom assemblage analysis and nutrient concentration analyses of slices of the sediment cores allows a determination of P loadings in 2 to 3 year intervals, (provided the sedimentation rate is sufficient). Then a comparison of “precontact” loading rates with current rates conclusively determines the impact of settlement over the “post contact’ period.

The apparatus needed for sediment coring is available from the MELP EP Program. The Queens University Biology Department (see appendix J for details) is interested in providing the Pb^{210} dating and diatom assemblage identification and interpretation work. P analyses would be done by the MELP lab. It is estimated that the costs would be $2500. Once it was completed, this work would not need to be repeated in the foreseeable future.

7.6 Populations and land use characteristics of the drainage basin

One of the long range goals of the management plan is to ensure that as few new P loading sources as possible occur. These should be documented through the use of a periodically updated land use map and database. It should include the location and type of every potential loading in the watershed, including livestock pasturing and feedlot locations and number of animals present, onsite sewage disposal systems, and their state of functioning (to be documented on a voluntary basis), and any other discharges such as stormwater runoff from new housing subdivisions in the watershed. This map will then serve as a focus for such things as educational initiatives and loading source monitoring.

8. Implementation - Action Plan

8.1 Short Term

8.1.1 Plan Review and Revision - Testing

A systems design approach is subject to ongoing evaluation and revision, and it is accepted that a portion of the resources allocated to its implementation must be focused on refining it. In the first year of implementation, there should be a review of the plan by lake management experts. The review should also include those regulators who may be called upon to write permits and licenses or cooperate in some way to implement the various management options. Ensuring that this occurs should be the first priority, and could be easily accomplished with assistance from the MELP EP Program.

In addition to aquatic weed harvesting and freshwater diversion, it has also been determined that some other form of inlake management such as sediment dredging or hypolimnetic siphoning may be used to some advantage. This will have to be further researched and vetted by the appropriate authorities and experts prior to an implementation decision. Data collection, documentation and evaluation should occur in the next 2 to 3 years, so that decisions regarding such an option can be made once there is an indication of the level of success of the options which have already been implemented.

8.1.2 Financial Support

To implement the lake management plan, an overall budget is required. Costs may include:

- planning - sending the draft plan out for review to experts in the province and elsewhere
- contracts - hiring contractors to maintain the Club Creek diversion and operate the MELP weed harvester
- equipment - operating the dragline harvesting equipment or shipping of the ministry harvester to Lake Kathlyn and back to Prince George on a yearly basis
- monitoring and evaluation programs - training volunteers and carrying out needed water, sediment and biota monitoring.
- permits - water license fees

Acquiring adequate funding to cover implementation costs will be challenging, therefore a funding strategy must be developed. Once a consensus on the range of management options to be implemented has been reached, the level and duration of funding needed must be identified.

Some options for raising funds include:

- voluntary donations, which should be sought in a systematic manner, such as an appeal campaign
- modifying the lake association to allow the ability to collect revenue in the form of membership dues from interested people other than lakeshore residences

- increasing the levy obtained from taxation. The Lake Kathlyn waterfront property owners voted in a Spring 1995 referendum sponsored by the Regional District of the Bulkley Nechako to form a taxing district. All waterfront property owners will pay a parcel tax each year for five years. The money is collected by the Regional District and will be used to maintain the Club Creek diversion which was originally implemented through volunteer labour, voluntary donations and assistance from the Water Management Branch of BC Environment. A goal of twenty thousand dollars was set and the sum was divided by the number of waterfront property owners over a five year program.
- Application for grants or loans from public agencies. These include options such as the Habitat Conservation Fund, the Public Assistance Conservation Fund, the Water Stewardship Grant, and the BC 21 Program.

Committees should be struck immediately to formulate the financial strategy. Fundraising methods should be inventoried, evaluated and decisions made as to their applicability in this instance.

8.1.3 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 financial and volunteerwise).

Volunteer groups who will assist with the implementation of the plan must be identified. In the Bulkley Valley, this may include, but is not limited to:

- other lake protection Societies
- Friends of the Bulkley
- North American Lake Management Society, BC chapter

Volunteers can also assist with monitoring. One method of ensuring that tasks are completed successfully includes placing the volunteers in groups (committees), delegating tasks to each group and making sure adequate training is provided. Each group consists of one leader and their assistants. Each group is responsible for completing a set of well defined tasks. Examples of volunteer subcommittees are:

- funding
- sampling and monitoring
- land use
- education

To ensure that the tasks are carried out indefinitely, no leadership position is to be vacant in any given year. An evaluation of the group's status should be held at regular intervals.

Lake and inflowing stream monitoring can be carried out by properly trained volunteers. It is recommended that a training program be set up immediately in conjunction with MELP EPP to enable the volunteers to learn proper procedures for the necessary sampling.

8.1.4 Regulatory Agencies

Most of the affected regulatory agencies have been consulted and involved in the development of the lake management plan. 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 priorize incoming applications for approval. Allow sufficient time for the agencies to respond.

The first step towards contacting all the necessary regulatory agencies is to determine the effects of the option. For instance aquatic weed harvesting will affect anadromous fish habitat and therefore DFO would need to be consulted. It would also require storage of harvested biomass, possibly requiring a Waste Management permit from MELP EPP. Using the Table below, identify the agency which has the authority to regulate these effects. Contact the affected agencies and obtain the necessary approvals which may be in the form or a permit, approval, license, or a regulation.

8.1.5 Aquatic Weed Harvesting

It has been accepted by a number of lake management experts that aquatic weed harvesting conducted at a modest scale will at worst do no long term harm, and at best improve esthetics in harvested areas and remove nutrients in the form of biomass from the lake, rendering it unavailable.

It is recommended that aquatic weed harvesting commence as soon as is practical. A multi-year harvesting plan should be developed and executed. This should include harvesting locations and timing as well as a disposal plan that does not impair other waterbodies. This could occur through leaching of nutrients from the stockpiled rotting aquatic vegetation. It is likely that MELP harvesting equipment can be made available for some or all of the harvesting through Mel Maxnuk, head of Aquatic Plant Management in the Vernon office (see appendix E for more details)

Table 2: Activities and Associated Regulatory Agencies

Activity	Regulatory Agency
Land Use Control	• Regional District - Zoning Bylaws • Village of Telkwa - Bylaws • Municipal Affairs - Official Community Plan • Ministry of Transportation and Highways - Highway Planning • Ministry of Forests - Local Resource Management Plans and Cutting Permits • Ministry of Agriculture - ALR
Health	• Ministry of Health - Public Health Inspector • Health and Welfare Canada
Pollutants	• Ministry of Environment, Environmental Protection Program • Ministry of Agriculture - Ag. Waste Regulation
Fish and Wildlife	• Department of Fisheries and Oceans • Ministry of Environment, Fish and Wildlife
Public Land	• Ministry of Environment, Lands and Parks - Crown Lands, Parks • Ministry of Forests - Recreation Branch
Water Management	• Ministry of Environment Lands and Parks Water Management Branch
Land Development	• Ministry of Transportation and Highways - Subdivision Approvals • Ministry of Agriculture - ALR • Ministry of Environment, Lands and Parks - Environment Referral service

8.1.6 External Lake Management Options

All of the external lake management options are implementable immediately.

8.1.6.1 Public Education

The education component could take advantage of a major initiative by the Telkwa Elementary School to bring the science of lake management into the classroom, and the homes of its students. Part of the school program is a public education campaign aimed at a broader audience including other schools and the general public. Funding was provided under the Partners in Science Program of the provincial government. The grant will be spent throughout the period ending in March 1996, although plans are being made by the school to ensure that resources will be available in succeeding years to carry on with the initiative. Participation in this initiative should be a high priority for the Protection Society. It is quite possible that the Lake Kathlyn Elementary School could use the curriculum developed under this program and apply it to Lake Kathlyn.

In addition to the school program, other means of heightening awareness through educational opportunities should be sought. These might include soliciting help from the BC Parks interpretive program staff, promoting environmentally friendly recreational use through signage on and around the lake, provision of brochures to be distributed through public institutions, volunteer run booths at public functions such as the fall fair, promoting public education and membership, making presentations to service clubs, chambers of commerce, town councils, schools, showing the management plan and what progress has been made to date and soliciting media coverage of the implementation of the plan and at milestones within it, such as fundraising targets for installing and maintaining the diversion works.

8.1.6.2 Affecting Inflowing Stream Water Quality

It is apparent from initial stream quality data that some of the inflowing creeks contain nutrient concentrations which should be addressed. Sources will most likely include livestock waste, from across highway 16, hobby farms, around the lake and failing septic systems.

Stream water quality needs to be monitored by trained volunteers during spring freshet for a period of 2 to 3 years to better determine which creeks provide the most nutrients to the lake. This will include sampling of 8 inflowing creeks on 6 occasions evenly spaced through the freshet period. The program will cost approximately $3000/year, and subject to availability of the MELP lab and budget constraints may be cost shared on a 50:50 basis.

Once the database is established, it will have to be analyzed by the Protection Society using local knowledge of land use activities to set priorities for action. Additional creek sampling will be required at intervals to determine whether actions have been effective in limiting nutrient inflow to the lake. Since this will involve private property and individual property owners with limited resources, it is suggested that guidelines for land development and use similar to those published for the Regional District of Fraser-Fort George (Lakeshore Guidelines) be written and distributed to land users in the watershed as a first step. This could be done by a small subcommittee with guidance from the Regional district and MELP EPP.

This should then be followed with a voluntary program promoting participation in efforts to limit nutrient inputs to the lake. The program could include tile field inspections by the Environmental Health Officer, with recommendations for improvement if required on a voluntary "property by property" basis. The current EHO has already expressed a willingness to participate in such a program. Similarly, the District Agriculture Representative could be invited to engage in a similar program for agricultural lands within the watershed. Means of acquiring financial assistance for landowners facing the prospect of major works to eliminate nutrient inputs to the lake should be sought and developed if possible. Hopefully this along with the public education initiatives will provide the impetus for action. If these efforts fall short of the desired effect, then enforcement of pollution control statutes by government should be considered and sought if deemed appropriate.

8.1.6.3 Controlling Nutrient inputs From New Developments

New developments slated for the watershed should be carefully monitored at the earliest stage possible, to ensure that nutrient and other contaminant input concerns are addressed “up front”. This planning function is best done through the incorporation of bylaws into the Smithers/Telkwa Official Community Plan administered by the Bulkley Nechako Regional District. Once discussions with Regional District staff have been initiated, it may become apparent that the local improvement district already established to fund diversion works maintenance will provide additional means of regulating land uses to assist in lake restoration. In addition to this, new environmental protection legislation in the near future may provide new means to regulate land use to reduce or eliminate nutrients and other contaminants entering the lake.
If high density residential development in the watershed is contemplated, then planning for placing these lots on a community sewer system should take place. The Protection society should appoint a member to monitor the development of such plans at the local government level, as well as through MOTH, which holds subdivision approval authority.

8.1.6.4 Preventing Nutrient Inputs Through Forest Management Planning

Although there does not appear to be much forest management in the Lake Kathlyn watershed, representation of the Society on the Local Resource Management Planning (LRMP) committee should be sought. This will provide a link at the appropriate level to alert the Society to any possible changes to the status quo.

8.1.7 Monitoring - Immediate Needs

8.1.7.1 Eutrophic Status Of The Lake

Prior sampling and analysis of water quality and aquatic life (phytoplankton and zooplankton) has established that Lake Kathlyn is quite eutrophic. All of the qualitative evidence available points to the theory that although the lake is naturally eutrophic, human caused inputs of nutrients in the last 80 years has greatly speeded up the rate of eutrophication. This needs to be verified through some additional sampling and analyses. Sediment cores from the deepest part of the lake should be taken and analyzed as follows:

- separate the core into thin slices representing as short an interval as possible (this depends on the sedimentation rate)
- determine the age of each slice of the core using the lead isotope (Pb^{210}) dating technique
- identify the diatom assemblage in each sediment slice, and analyze the assemblages according to their affinity for nutrient enriched living conditions
- analyze the sediment in each core slice for P concentration.

Once the cores have been taken, sliced and frozen, they can be shipped to Cornell University for the appropriate analyses. An assessment of the relative contributions of nutrients to the lake for the period before settlement and for the intervening period to the present will then be returned once the analyses are complete. This work will cost two thousand dollars, and should be funded through the current Lake Stewardship grant (see Appendix F for more details).

In addition to this work, a number of sediment grab samples representative of the range of depths and area of the lake should be taken and subject to lab analyses for P concentration. This will assist in determining the extent of the lake bottom that must be affected by any internal lake management. Sampling should be carried out by volunteers under the supervision of MELP EPP staff. Analyses may be cost shared with EPP depending on budget availability. If any of the Lake Stewardship grant remains after the weed harvesting, monitoring and sediment core work, then it should be focused of these efforts.

8.1.7.2 Extent of Aquatic Weed Infestation

A mapping exercise to determine the approximate extent and locations of the *Elodea canadensis* infestation in the lake is needed. This should be done using a sampling method which provides a rough level of quantification of the biomass of the plant by location. This could be done by setting permanent transects between known landmarks, and measuring the approximate depth of the water and volume occupied by plant material. A conversion to biomass could then be made if a cylindrical sample of known volume could be cut through the mass, and the weight (both wet and dry) of plant material determined. Once this baseline has been established, then the effects of the management options employed on weed biomass can be established in future years.

During harvesting operations an attempt should be made to determine the biomass removed from the lake, so that nutrients sequestered from the lake by this method can be determined. This will assist in ongoing evaluations concerning which lake management options may be causing the greatest effect.

8.1.8 Long Term Needs

8.1.8.1 Spring Turnover Sampling

It is important on a yearly basis to sample the depth profile at the deepest part of the basin. If turnover is detected, and the profile shows uniform P concentrations, then calculations of the instantaneous P loading in the lake are straightforward. If turnover is incomplete, then the added step of documenting P concentrations in each of the depth slices of the lake (defined by the bathymetric profile) must be completed. It is reasonable to expect that MELP EPP will continue to do turnover sampling and analyses for at least in 1996. In future years however, it may be necessary for volunteers to carry out this sampling. Once again, it is expected that budget permitting the costs associated with these analyses would be shared on a 50:50 basis beyond 1996. It is estimated that this program would require $300 - $500 in analysis costs, depending on how many rounds of depth profile sampling are needed to ensure that spring turnover (well mixed conditions) has been sampled.

8.1.8.2 Nutrient Budget - Success Indicator

One of the most difficult tasks in lake management planning is creating a nutrient budget (phosphorus in this case) that provides a high degree of confidence for decision making at an affordable price. Lake Kathlyn has been subject to annual turnover sampling for a number of years, and yet a P budget with a satisfactory level of error has yet to be developed. In an attempt to refine the P budget, at least 2 rounds of inflowing creek sampling should be carried out in 1996 and 1997. This should include both quality and quantity measurements. Consultations with the MELP Water Management Hydrologist will be required to best determine which creeks need to be fitted with constructed flow measurement weirs, and which can be measured using other devices such as a Parshall flume and the Water survey of Canada monitoring station on Lower Kathlyn Creek.

Care will need to be exercised in establishing a database that accounts for the vagaries of weather from one year to the next. Of particular importance in this regard is the timing and frequency of sampling necessary to capture the period of greatest loading.

8.2 Long Term

8.2.1 Hypolimnetic Siphoning Or Sediment Dredging

Sediment sampling and analyses aimed at determining the eutrophic status of the lake have been recommended. If these analyses show that the lake is amenable to hypolimnetic siphoning or sediment dredging, and it has been shown that fresh water diversion and weed harvesting are ineffective alone, then hypolimnetic siphoning or sediment dredging may be considered. If it appears upon review of these options by regulators and lake management experts that one is feasible, an engineering design and specifications for its installation and operation should be developed, along with a cost breakdown and tentative implementation schedule. This will require the expertise of an engineering consultant with relevant recent experience in this application. The design project would have to be funded by a new source of revenue, unless a surplus from the local improvement area taxation fund was available.

Once the system is designed and funds secured for implementation, the system should be installed and operated until the desired effect of reducing internal P loading from bottom sediments is achieved. An appropriate means of objectively measuring movement towards the goal of reducing P concentrations in the water column through sediment and water chemistry measurements, must be defined prior to commencement.

8.2.2 Other Internal Lake Management Options

There may be some advantage to localized use of geotextile fabric on the lake bottom in those areas where shoreline eradication of aquatic macrophytes is desirable. If there is enough demand for its installation, there may be some advantage in bulk purchasing. This should be investigated.

Some new studies of the use of predatory (piscivorous) fish which feed on zooplankton consumers are showing promising results. The premise is that predatory fish feeding on zooplanktivorous fish cause increases in zooplankton which graze on algae. As zooplankton populations increase, there is a corresponding decrease in algae. Studies of this nature, and others focusing on new and novel approaches to eutrophic lake management should be kept track of through the North American lakes Management Society (NALMS), and the newly formed BC Chapter. Information regarding gaining membership should be obtained from Dr. Rick Nordin of MELP Water Quality Branch in Victoria.

8.3 Fish Resources

It is known that Coho salmon spawn in Lower Kathlyn Creek. The extent of this should be documented on an annual basis. If it can be shown that rearing coho use the lake or would use it if the eutrophication problem were put in check, then there may be ample grounds for funding under a variety of salmon enhancement initiatives. Once the extent of utilization of the stream and lake has been established, changes over time which may be associated with lake management initiatives can be documented. Should it be necessary to implement hypolimnetic siphoning then it would be important to understand what potential effects of discharging nutrient enriched lake water during spring freshet down Kathlyn Creek.

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