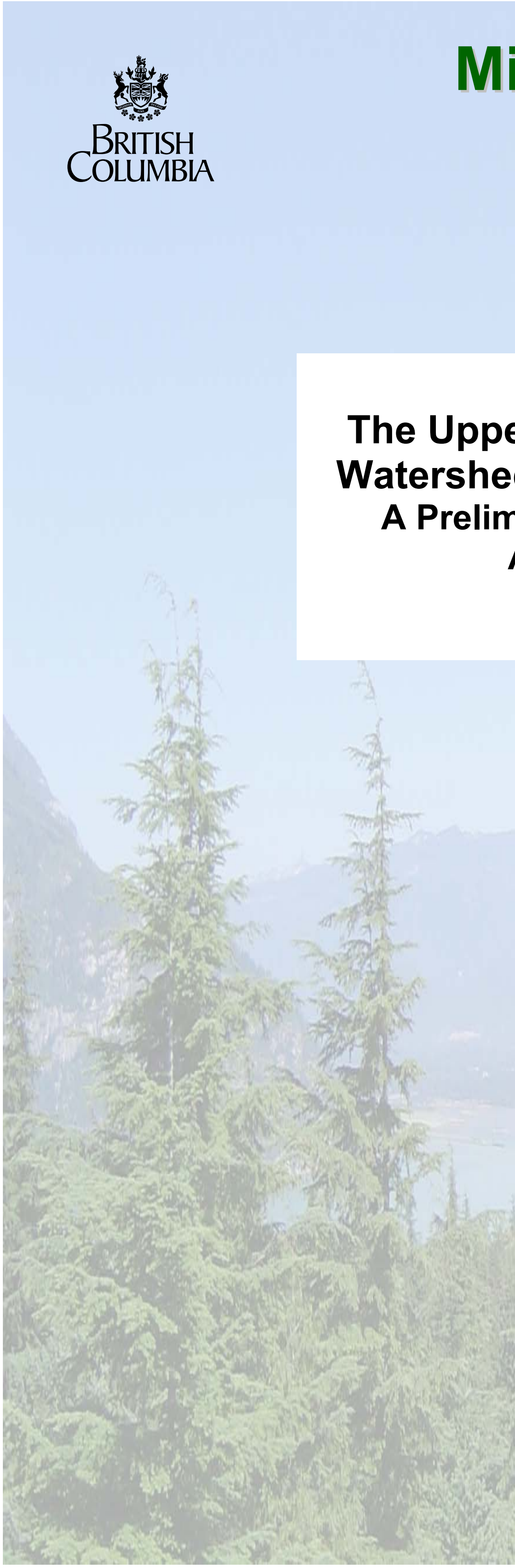

BRITISH COLUMBIA

Ministry of Water, Land & Air Protection

LOWER MAINLAND REGION

The Upper Birkenhead River Watershed, British Columbia:

A Preliminary Water Quality Assessment

ENVIRONMENTAL QUALITY

The Upper Birkenhead River Watershed, British Columbia:
A Preliminary Water Quality Assessment

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Preface

This report is one in a series of water, groundwater, and air quality reports that are being issued by the Lower Mainland Regional Office in fiscal year 2004/05. It is the intention of the Regional Office to publish water, groundwater and air quality reports on our website (http://wlapwww.gov.bc.ca/sry/p2/eq/index.htm) in order to provide the information to industry and local government, other stakeholders and the public at large. By providing such information in a readily understood format, and on an ongoing basis, it is hoped that local environmental quality conditions can be better understood, and better decisions regarding water, groundwater and air quality management can be made.

Acknowledgements

The Upper Birkenhead Watershed Stewardship Group and the Ministry of Water, Land and Air Protection would like to thank the many dedicated individuals who are committed to maintaining Birkenhead Lake and the surrounding watercourses in their natural condition. The authors would like to thank Brent Moore for his review of this report and for providing valuable comments during the preparation of this report. Bob Thompson provided historical information while he and Liz Kolouch both provided access to monitoring sites on Phelix Creek.

The following members of the Upper Birkenhead Watershed Stewardship Group were involved in the water quality sampling or information gathering for this report: Tom Shollen, Ted Wheeler, Bunny and John Magdalenich, Lisa Zetterberg, Margret and John Foskett, Paddy Rodney, Allana and Fred Thompson, Cathy, Leo and Mark Belisle, Fred , Bill and Dana Wallace, Thom and Stephania Gibb, Breanne and Roslyn Johnson. Patrik Zetterberg provided ample time and patience while assisting with the location of fisheries information. Ross Wetzel has been important for his ongoing support in the UBWSG initiatives and has provided the assistance of the Environmental Youth Team which he supervised. This project was funded through grants from Fisheries and Oceans Canada and Fisheries Renewal British Columbia. With the exception of two photographs, all others were taken by Rhonda Johnson.

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1.0 INTRODUCTION

The Ministry of Water, Land and Air Protection (MWLAP) assists stewardship groups gathering water quality monitoring data and supporting local watershed initiatives. The Upper Birkenhead Watershed Stewardship Group (UBWSG) approached the MWLAP to partner on a project to examine water quality in the upper Birkenhead watershed. The UBWSG was formed in 2000 and consists of Birkenhead Lake Estates landowners who are concerned about water quality and fisheries habitat. The group hopes to use public education to help minimize the potential impacts of land and water use on both water quality and fisheries habitat. Their mission statement is *"to preserve and protect Birkenhead Lake and its surrounding area from damage to its ecological balance or visual beauty through cooperation, coordination and education"*.

Initially, the stewardship group wanted to collect information and data which related to the Birkenhead watershed, and compile this into a report in order to assist future efforts. The group also wanted to conduct an assessment of whether certain local activities (forest harvesting, agriculture and recreation) may be impacting on the water quality in the upper Birkenhead watershed. The Ministry of Water, Land and Air Protection partnered with the Upper Birkenhead Watershed Stewardship Group by supporting these initiatives. This report represents a compilation of the background information collected on the Birkenhead watershed, as well as presenting the limited water quality data in the appendix.

2.0 PHYSICAL GEOGRAPHY

2.1 Location

The Birkenhead watershed is part of the Fraser River watershed which drains 60% of BC. The watershed is located near the northern end of the Sea-to-Sky corridor in the vicinity of Mount Currie and Pemberton. The upper Birkenhead River watershed is located on the leeward side of the Coast Mountain Range in south-western British Columbia (Figure 1). The rugged terrain of the upper watershed was shaped by periods of volcanism and glaciation (BC Parks 1999). This area has deeply incised mountains, U-shaped valleys and fast flowing creeks.

The upper Birkenhead watershed encompasses the major creeks draining into the Birkenhead River, as well as into and out of Birkenhead Lake (Figure 2). Birkenhead Lake is north of both Whistler and Pemberton (57 kilometres north of Pemberton). The lake is protected in the Birkenhead Lake Provincial Park, which also encompasses some of the forested land surrounding the lake. Phelix Creek and Sockeye Creek are the two largest creeks that flow into Birkenhead Lake, while Taillefer Creek flows out of the lake and into the Birkenhead River. Other large creeks that flow into the upper Birkenhead River include Tenas Creek and Tenquille Creek. Many other small headwater and intermittent streams also flow into the Birkenhead River. The river flows from its headwaters, over falls and cascades in the Birkenhead canyon and then past the town of Mount Currie which is located along the lower reaches (Bussanich 1999). The river then flows into Lillooet Lake, the Lillooet River, then into Harrison Lake and ultimately to the Fraser River via the Harrison River.

The area of interest for this report is the Upper Birkenhead watershed which has been defined as the area upstream of the falls in the Birkenhead Canyon. These falls are approximately 25 kilometres upstream from the mouth of the river. In order to give a general overview of the watershed, however, some discussion of the entire watershed is included.

2.2 Climate

Birkenhead Lake Provincial Park is located in a transitional forest ecosystem. The area is influenced by both dry interior and coastal climatic factors (BC Parks 1999). The climate of this area can generally be characterized as having warm, dry summers and cool, moist winters. Although the Birkenhead Lake area falls within the rain shadow of the Coast Mountains, Pacific frontal systems bring a substantial amount of precipitation to the area (BC Parks 1998). A weather station located in Birkenhead Lake Provincial Park

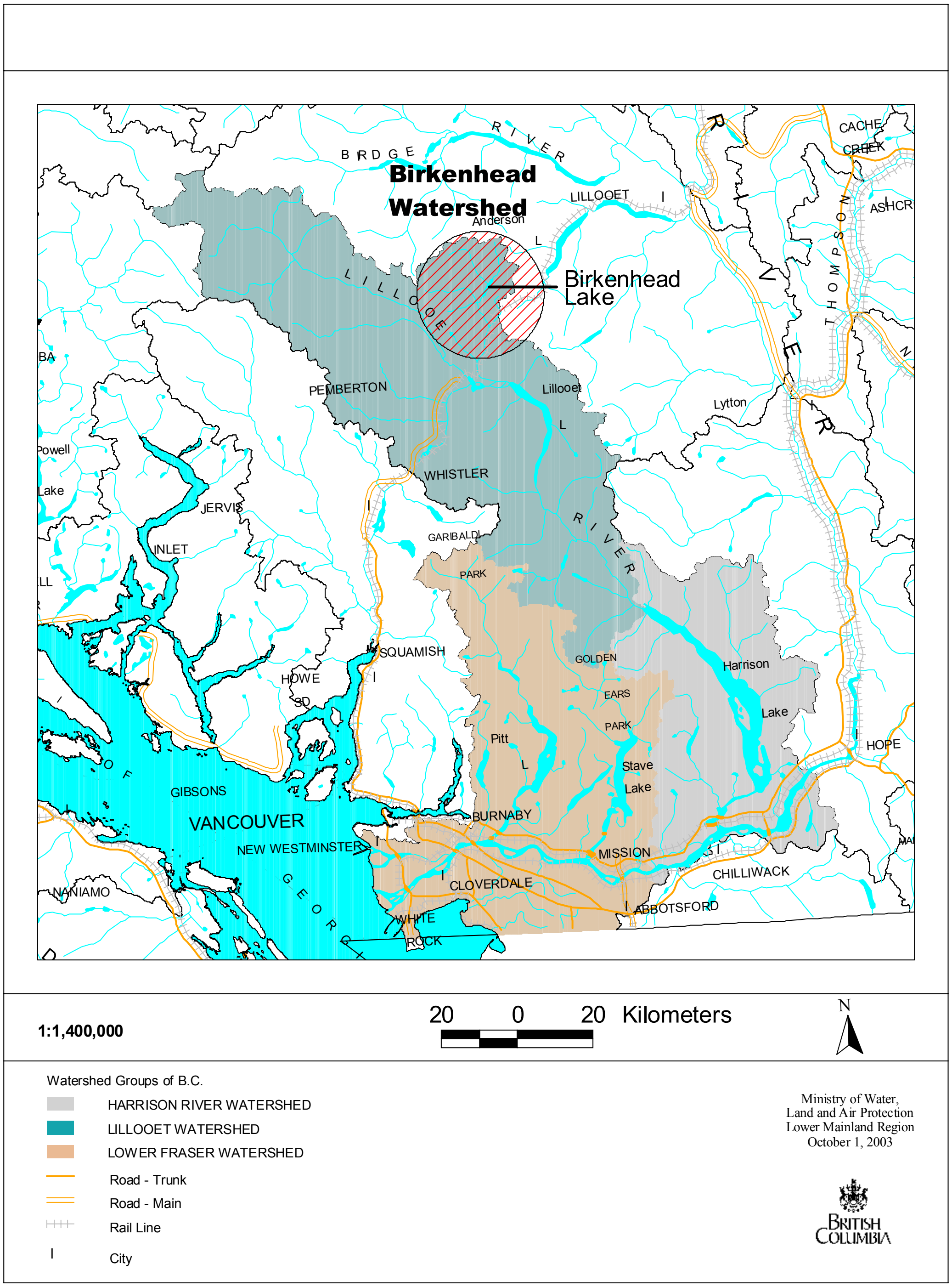

Figure 1: Location of Birkenhead Lake and watershed.

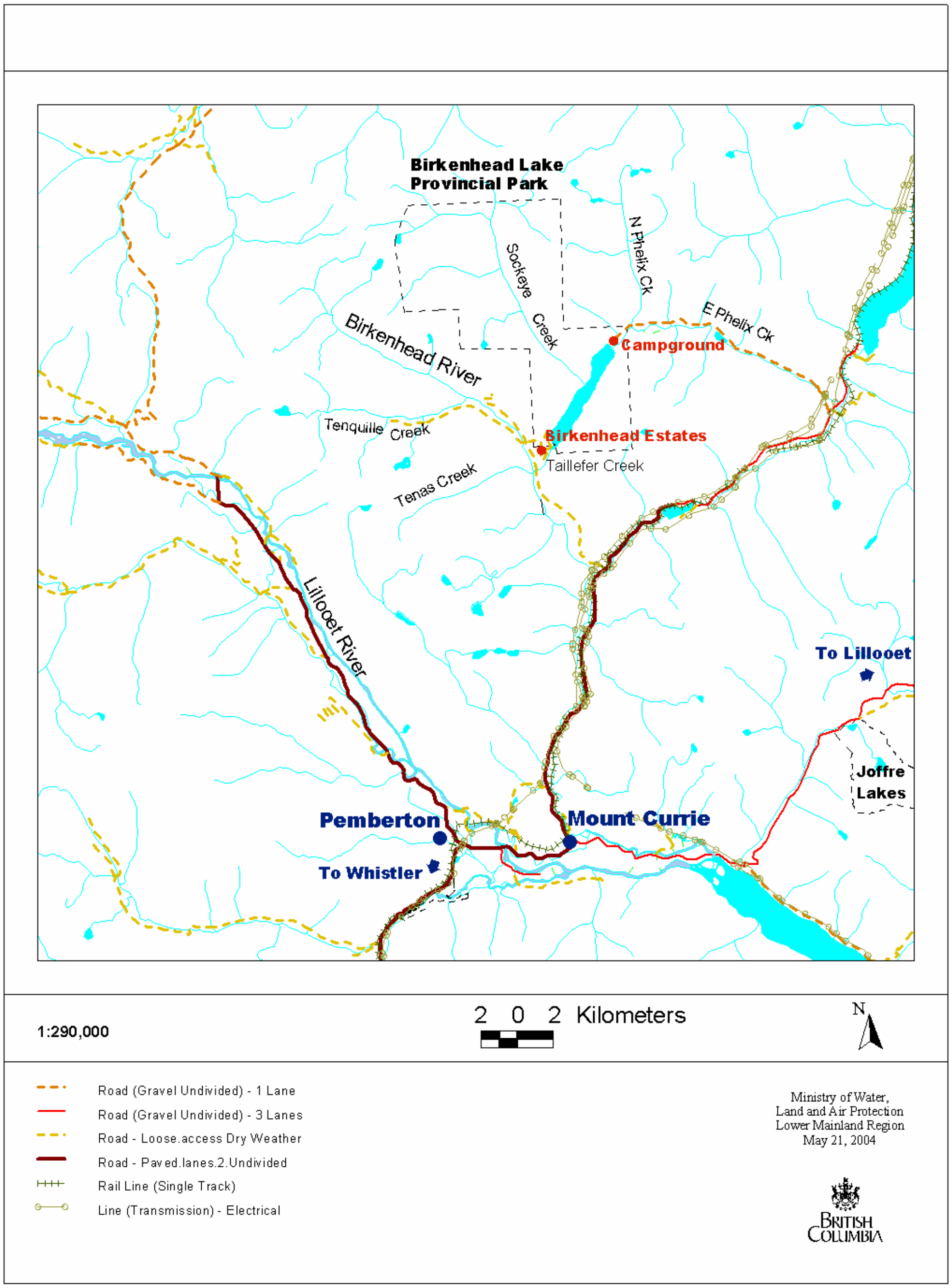

Figure 2: Location of Birkenhead Provincial Park and the Birkenhead Estates.

at an elevation of 715 meters collected meteorological data between July 1983 and July 1985. From this data, the mean annual precipitation was determined to be 791.4 mm (BC Parks 1998). The greatest monthly precipitation occurred in the months of October and November when over 180 millimeters of precipitation fell. The month to receive the least precipitation was highly variable although the summer months were generally drier (total monthly precipitation during the months of July and August ranged between 10 and 95 millimetres) (BC Parks 1998). The warmest month of the year in the park is July, when the maximum temperatures can reach over 30ºC. Despite these high daytime temperatures, minimum night temperatures during the summer can drop to near freezing under the clear skies associated with high pressure systems. The coldest temperatures occur during the winter months of November through February when temperatures can drop to -30ºC. Snow can consequently be expected to accumulate on the ground from late October to early April (BC Parks 1998).

3.0 ECOLOGY

3.1 Vegetation

As the upper Birkenhead watershed is characterized by a transitional forest ecosystem the landscape is representative of both coastal and interior regions (BC Parks 1999). Tree species found in the area include: western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*). Above 1200 meters, Engleman spruce (*Picea engelmann*) dominate the landscape, while subalpine firs are found at the higher elevations. At higher elevations and in previously burnt areas, lodgepole pine (*Pinus contorta*) is a common tree species (BC Parks 1999).

Old growth forests are found in the Sockeye Creek drainage and in the upper Birkenhead River watershed. Approximately 40% of the mature forest in Birkenhead Provincial Park is considered old growth (BC Parks 1999). These old growth stands are composed of fir, cedar and hemlock in the lower drainage, and balsam and spruce in the upper drainage. A few old growth stands composed primarily of fir are located in the Phelix Creek drainage (BC Parks 1998).

There has recently been two pest outbreaks in the Birkenhead area forests. Infestation of the mountain pine beetle (*Dendroctonus ponderosae Hopkins*) since the 1980's has resulted in a large accumulation of fuel (dead trees), creating a potential fire hazard in the area (BC Parks 1999). In order to protect natural resources and to reduce the likelihood of a large forest fire, management initiatives have been put in place. To control the beetle infestation, spot cutting and burning of small infestation pockets has been conducted. This was discontinued, however, due to its ineffectiveness (BC Parks 1999). The Ministry of Forests, BC Parks and Birkenhead Estate landowners have also taken measures to reduce the large fuel build up. Since 1997, dead and dying trees have been removed from the Park and adjacent Crown lands (BC Parks 1999).

Currently there is an infestation of the Western spruce budworm (*Choristoneura occidentalis*) in the forests. The larval stage of this insect feeds on douglas fir needles. To date, the spruce budworm outbreaks in the Birkenhead /D'arcy areas have so far not resulted in large tree mortalities (Heppner 2002, pers.comm.).

3.2 Wildlife

The upper Birkenhead watershed supports a diversity of birds and mammals including both red and blue listed species. The Ministry of Water, Land and Air Protection's red and blue lists identify and rank species that are classified as vulnerable by scientists and experts in the province. The provincial red list includes species formally designated under the BC Wildlife Act or the Federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC). These designations include 'endangered', 'threatened', 'extirpated', or those being considered for these formal designations (MSRM 2002). Blue listed species are at a lower level of risk than are red listed species (Harper *et al*. 1994). The blue list includes species not immediately 'threatened' but those considered to be 'vulnerable' in British Columbia. Vulnerable species are of special concern because of characteristics that make them particularly sensitive to human activities or natural events.

Some of the bird species which use the Birkenhead watershed include: owls (great horned, great grey and barred owl), woodpeckers (pileated, hairy and downy woodpeckers), the red tailed hawks, American kestrels, bald eagles, osprey, white-tailed ptarmigans, sapsuckers, flickers, warblers, jays, swifts, sparrows and grouse. A red listed bird species previously found in the area is the spotted owl (*Strix occidentalis caurina*). The spotted owl is red listed due to its dependence on old-growth forests that are being lost due to forestry activities.

Figure 3: Tailed frog found in Tenas Creek.

There are many other animals found in the Birkenhead watershed. These include black bears, blue listed grizzly bears, cougars, blue listed wolverines, grey wolves, bobcats, hoary marmots, pine martin, pikas, flying squirrels and shrews. Ungulates that can be found in the watershed include moose, mountain goat and the Columbian Black-tailed deer. Amphibians are also present including the blue listed tailed frog (*Ascaphus trueii*) which has been seen in both Ogre Lake and Tenas Creek (Figure 3). This frog favours fast flowing, cold, clean mountain streams.

3.3 Fisheries

3.3.1 Fish Distributions

Figure 5: First set of waterfalls in Birkenhead Canyon.

Historically, the Birkenhead watershed has supported a diversity of aquatic resources including anadromous and resident salmon, trout, char, suckers and whitefish (Bell-Irving 2002, pers.comm.). Approximately 25 kilometres upstream from the mouth of the Birkenhead River, the presence of five waterfalls and a cascade in the Birkenhead Canyon act as potential barriers to fish passage and thus restrict anadramous salmon presence (Figure 4) (FISS 2002). The upper Birkenhead watershed thus mainly supports resident fish species although anadramous salmon have occasionally been reported. In September 1975 an adult female chinook was found above the falls in Birkenhead Lake (Bailey 1979), while in 1977 a few salmon carcasses were observed along Taillefer Creek (Magdalenich 2002, pers.comm.). More recently, in 1998 several chinook were observed at the mouth of Birkenhead Lake in Taillefer Creek (Wetzel 2000, pers.comm.). In 2003, a live chinook salmon was seen near the mouth of Taillefer Creek and another in Birkenhead Lake, while two carcasses were seen in Taillefer Creek (Figure 5). Possibly when the appropriate hydrological conditions prevail, the strongest swimming chinook, coho or steelhead may be able to migrate upstream of the waterfalls in Birkenhead Canyon (Bussanich 1999).

Figure 4: Chinook salmon carcass alongside Taillefer Creek, Sept.

The lower reaches of the Birkenhead watershed support anadromous salmon species as well as resident fish species. Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*) and kokanee salmon (*O. nerka*), steelhead, rainbow (*O. mykiss*) and cutthroat trout (*S. clarki*), the blue listed Dolly Varden char (*Salvelinus malma*), lamprey (*Lampetra sp.*) and sculpin (*Cottus sp.*) have all been observed in the lower reaches of the watershed (Bussanich 1999).

There are at least six resident fish species found in Birkenhead Lake and/or the surrounding creeks. Resident fish species include the blue listed bull trout (*Salvelinus confluentus*), dolly varden char, kokanee and rainbow trout, mountain whitefish (*Prosopium williamsoni*), northern pike minnow (*Ptychocheilus oregonensis*) and large-scale sucker (*Catostomus macrocheilus*).

3.3.2 Historical Fisheries Information

Pacific salmon were the Lillooet First Nation people's most important food source. Salmon provided a rich source of protein, fat, vitamins and minerals with sockeye being the richest and most valued. The iodine content of sockeye prevented natives from suffering from goiter which plagued many of the settlers of this area (Decker *et al*. 1978). In order to catch fish, native people set nets in the lakes, and bag nets and traps in the streams. Favoured fishing locations were Skookumchuck rapids, the upper end of Lillooet Lake, the Birkenhead River and the lower Lillooet River (Decker *et al*. 1978).

3.3.3 Recent Fisheries Data

The Birkenhead River has been a significant producer of sockeye salmon and to a lesser degree coho and chinook salmon. Unfortunately, there is a lack of reliable escapement data for most of the Birkenhead River fisheries resources as a result of sporadic data collection in recent decades. Escapement records from 1951-1985 indicate relatively consistent returns for sockeye stocks, however more recent data is not available.

The current status of coho stocks in the Birkenhead River is unknown due also to inconsistent data collection (Naylor 2002, pers.comm.). If coho stocks are declining in the Birkenhead River as they are elsewhere in the Pacific Northwest, there could be many causes. Declines in marine survival rates and high exploitation rates are thought to be the major factors affecting coho abundances in recent years (Holtby 1998). Average marine survival rates (smolt to adult) for coho in the Strait of Georgia have declined sharply in recent decades. Data from the late 1970's indicate that marine survival rates were in the 15 - 25% range. By the late 1980's that dropped to between 8 - 14%, and then to 1% or less for many stocks by 1998 (DFO 2002).

From the data available, chinook stocks do not appear to be as abundant as they may have been in the past. The chinook run in the Birkenhead River was previously large enough to support a recreational fishery. Available data, however, indicate that chinook stocks declined by 70% between 1951 – 1985. A Department of Fisheries and Oceans (DFO) management plan for the once large chinook run put a protective closure in place in 1976. This closure was still in place as of 2002.

In November 2002 chum salmon were seen schooling in significant numbers up the Lillooet and Birkenhead Rivers (Sam 2002, pers.comm). Historic information regarding the abundance of chum in the watershed could not be found.

Figure 6: Kokanee salmon in Phelix Creek. (Photograph taken by Liz Jones.)

Previously, highly productive resident fish populations were reported in the upper Birkenhead watershed, however, these populations appear to have declined. One local landowner recalls that in the past Phelix Creek could appear solid red due to the abundance of red spawning kokanee (Giguere 2002, pers.comm.). These large numbers of kokanee seen previously no longer return to Phelix Creek (Figure 6). It has been suggested that the cumulative effects of rainbow trout stocking in Birkenhead Lake between 1983 and 1988, and a landslide on a logging road bordering Phelix Creek in the mid-1980's, have detrimentally impacted the kokanee population (Giguere 2002, pers.comm.; Thompson 2001, pers.comm.). The landslide washing clay into the creek occurred in the spring when kokanee alevin emerge. As of 2002, kokanee runs were estimated to be 20% of what they were prior to the slide (Giguere 2002, pers.comm.; Thompson 2001, pers.comm.). In 2002 the kokanee numbers were approximated to be the same as they were in 2001, with approximately 5000 kokanee spawners in the first 500m of Phelix Creek (Jesson 2001).

3.3.4 Birkenhead Hatchery

There has been substantial fisheries interest in the Birkenhead River likely due to the large escapements of sockeye. The federal Fisheries Service operated a sockeye hatchery at the mouth of Owl Creek between 1905 and 1936. Hatchery data suggests that it was not successful at increasing adult sockeye returns (Bailey 1979). The hatchery was also an incubation and distribution site for rainbow trout eggs obtained from Lloyds Creek Station near Kamloops. The Owl Lakes, Green Lake, Alta Lake, Tenquille Lake, Gates Lake, as well as other lakes in the area were all stocked with rainbow trout fry from this hatchery (Bailey 1979). As well, during the operation of this hatchery, adult chinook were intermittently captured for their eggs at Tenas Rapids on the Lower Lillooet River. Between 1906 and 1919, 30,000 - 50,000 eggs were taken, and between 27,000 – 120,000 chinook fry were released (Bailey 1979).

A hatchery is currently operating on the lower Birkenhead River. Between 1977 and 1985 this hatchery was run by DFO in order to enhance chinook salmon populations. Since 1991 the Pemberton Sportsmen's Wildlife Association and the DFO have been jointly responsible for the Birkenhead Hatchery. Currently, the main species of focus at the hatchery are coho and chinook salmon. Volunteers working at the hatchery, supported through a federal Public Involvement Program (PIP) grant, also administer and provide local area school programs with fry, conduct stock and habitat assessments, provide local agricultural liaison, and organize Salmon Celebration days (Bell-Irving 2002, pers.comm.).

3.3.5 Birkenhead Bull Trout

Bull trout are top predators in the aquatic food chain and are considered to be an indicator species of ecosystem health. They are designated as a blue listed species by the provincial Conservation Data Center. This officially identifies them as a species of special concern as they are throughout their range in western North America. Human activities that lead to changes in temperature, substrate composition, habitat complexity, channel stability and migration routes threaten bull trout populations (Rieman and McIntyre 1993).

Figure 7: Bulltrout counting fence in Phelix Creek. (Photograph by Liz Jones.)

A genetically distinct bull trout population is found in Birkenhead Lake (Jesson 2001). Information collected over the past 20 years suggests that the bull trout population in Birkenhead Lake has declined (Jesson 2001). The catch per unit effort (CPUE) for bull trout has declined from a reported 0.5 fish/angler day in 1980 to 0.1 fish/angler day during the 2000-2001 angler survey (Scott Resource Services Inc 2001). This trend was reaffirmed in 2001 with the results from the operation of a bulltrout spawning fence and trap which caught 70 bull trout spawners returning to Phelix Creek (Figure 7) (N'Quaqua in prep). Phelix Creek provides important spawning and rearing habitat and is the primary producer of bull trout for Birkenhead Lake. Fisheries biologists suspect that the decline in the Birkenhead bull trout population is due to a combination of overfishing and poor land use practices bordering Phelix Creek which have harmed spawning habitat (Jesson 2001). In an effort to increase the bull trout population, the Ministry of Water, Land and Air Protection implemented a new catch and release regulation on the fishery in 2001.

4.0 WATER QUALITY

Water quality sampling may be employed to examine the state of water quality conditions in a watershed and to assess the real or potential impacts of various land activities on water quality. Pollutants such as pesticides, metals and petroleum products may be introduced by human activities. As well, human activities may alter natural constituents of water such as suspended sediments and nutrients, which may consequently have detrimental impacts on the aquatic environment. Water quality monitoring or sampling involves measuring these physical and chemical components of the water. The results may provide information about whether conditions exist that are potentially lethal to aquatic organisms or that may harm people's use of the water.

The Ministry of Water, Land and Air Protection develops province-wide ambient water quality (WQ) guidelines for variables that are important in the surface waters of British Columbia (Nordin and Pommen 1986). WQ guidelines are considered safe levels and are set to protect various water uses such as for drinking, recreating, irrigating and aquatic life (Cadmus Group Inc. and MacDonald Environmental Sciences Ltd. 1999). Guidelines are set after researching the scientific literature, guidelines from other jurisdictions, and the general conditions in British Columbia (Pommen 1986). Site specific WQ objectives may then be set for a specific waterbody after a comprehensive monitoring program has been conducted and information on the watershed has been collected.

There are no site specific water quality objectives set for any of the waterbodies in the Birkenhead area. Consequently, results from sampling programs in the local area may be compared to the provincial guidelines or criteria in order to assess the conditions. Water quality parameters which are commonly measured in monitoring programs include dissolved oxygen, temperature, pH, nutrients and suspended solids.

4.1 Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen dissolved in water. Dissolved oxygen (DO) is essential to the respiratory metabolism of most aquatic organisms and is consumed during the decomposition of organic matter. Low oxygen levels may have severe consequences for stream biota such as causing physiological stress, harming salmon migrations and when severe, killing fish. Different life stages of some aquatic organisms vary in their DO requirements and DO ranges suitable for optimal health. They may also have different susceptibilities to stress outside of these DO ranges. Reproductive stages of fish tend to be more sensitive than adult fish.

Natural sources of dissolved oxygen include aquatic plant photosynthesis and natural re-aeration from the atmosphere in turbulent water areas such as waterfalls and rapids. The amount of oxygen dissolvable in water varies with temperature and consequently, DO concentrations are subject to daily and seasonal fluctuations. Photosynthetic activity and discharges into a water body may also influence dissolved oxygen concentrations. Oligotrophic or low nutrient lakes tend to have higher DO concentrations in deeper waters relative to more shallow waters.

Low dissolved oxygen concentrations in creeks and lakes may be an indication of elevated organic matter. Some common organic pollutants which may lead to depressed dissolved oxygen concentrations include septic effluent, manure and fertilizer, as a large amount of oxygen may be utilized during the decomposition of the organic matter in such wastes. Within the upper Birkenhead watershed, inputs of organic matter may originate from the agricultural activities bordering Phelix Creek, improperly maintained septic fields in the Birkenhead Estates, or from the improper disposal of wastes generated by other recreational users. Dissolved oxygen levels at a sampling site in the lower Birkenhead River in the 1970's ranged between 9.8 – 13.1mg/L (Table 5 in Appendix B). The lowest of these readings occurred during August, likely when low flow conditions were present. These levels are not likely a significant concern for aquatic life.

4.2 Temperature

Temperature governs the rates of biological and chemical processes and affects the oxygen content of water. There are therefore differences in the temperature ranges which afford different aquatic species optimal health. Organisms living outside of these temperature ranges may experience physiological stress. Benthic macroinvertebrates and fish are sensitive to changes in water temperature and thus mobile stages of these organisms may move to seek out favourable temperatures. Similar to dissolved oxygen requirements, different life stages of aquatic organisms may have different temperature requirements and different susceptibilities to stress outside of these ranges. The reproductive and juvenile stages of fish tend to be more sensitive than adult fish.

Temperature varies naturally with the depth and width of a waterbody. Water temperature is also influenced by the origin of the water (whether from a glacier or lake), and by the input of discharges and/or groundwater. Data from 1970's collected in the lower Birkenhead River showed low temperatures of 3°C in winter (November – March) and higher temperatures of 15°C in August (Appendix B, Table 5). Sampling conducted in the Lillooet River watershed in 1994 and 1995 showed similar results (Table 1). This study in the Lillooet watershed found that the Birkenhead River tended to have some of the highest water temperatures in both winter and summer (Freyman 1996). This trend was attributed to natural conditions since the river receives discharge water from the lake rather than directly from icefields as do other nearby waterbodies. The lake would discharge waters warmer than those received directly from icefields. Water temperature is also influenced by the removal of riparian vegetation alongside waterbodies which may elevate water temperatures due to a lack of shade. The removal of riparian trees and vegetation has occurred within the upper Birkenhead watershed mainly as a result of forestry and agricultural activities.

Table 1: Water chemistry data collected by the Ministry of Water, Land and Air Protection in the lower Birkenhead River in 1994 and 1995. (Data displayed are geometric means of all of the samples.) (Freyman 1995).

Sampling Period	Sample Size	Temperature (°C)	pH	Nitrate + Nitrite (µg/L)	Ortho-phosphate (µg/L)	Turbidity (NTU)
July - September 1994	7	15	7.1	46	3.5	2.2
February 1, 1995	1	1	6.8	75	1	3.1
May - June 1995	4	7.5	7	83	2.7	0.6
August - September 1995	4	11.4	6.6	33	3.5	0.5
November - December 1995	4	2.6	6.9	33	4.9	1.4

4.3 pH

pH indicates the alkalinity or acidity of a substance. It is measured on a scale between 0 and 14 with 7 being considered neutral. As the pH gets lower (below 7), acidity increases and as the pH increases (above 7), alkalinity increases.

pH affects many chemical and biological processes in the aquatic environment. Lethal effects of pH on aquatic life may occur at high and low pH values. Aquatic organisms tend to have optimal pH ranges just as they have optimal temperature and DO ranges. Changes in pH may affect some physiological functions of aquatic organisms as well water chemistry. The pH of the surface waters and/or of precipitation influences the amount of chemicals that will dissolve in water. A reduction in pH can allow toxic elements to become more bioavailable for uptake by plants and animals. High pH values tend to facilitate the solubilization of ammonia, heavy metals and salts.

Sampling in the Birkenhead River showed pH ranging between 6.9 – 7.9 (Appendix B, Table 5). Results from sampling in the Lillooet River watershed in 1994 and 1995 suggest that the pH is near neutral in most waterbodes in the area, including in the Birkenhead River (6.6 - 7.1) (Freyman 1996). Some other tributaries in the Lillooet River did have slightly more acidic or basic conditions. This was attributed to the influence of bedrock geology on stream chemistry as there are two different rock types in the study area which could cause these differences.

4.4 Nutrients

4.4.1 Nitrogen

Nitrate is the most oxidized and stable form of nitrogen in water and the primary form of nitrogen used by plants. Excess nitrates and phosphorus may cause water quality problems by accelerating eutrophication. Eutrophication is the proliferation or excessive growth of aquatic plants and algae. Although excessive planktonic and/or periphytic growths maintain high dissolved oxygen levels, once the plants and algae die, their decomposition uses up the available oxygen in the water, and the dissolved oxygen concentration plummets. This may result in the problems associated with low oxygen levels in water such as physiological stress and fish kills when severe. Nitrate has also been shown to be toxic to some amphibians (Nagpal *et al*. 1998)

Human health may also be affected by elevated concentration of nitrate in drinking water. When consumed by babies, nitrate gets converted to nitrite in the incompletely developed digestive tracts of babies. Nitrite can then combine with hemoglobin in the blood to form methemoglobin. Methemoglobin does not bind oxygen and consequently the blood is less capable of absorbing oxygen (Nordin and Pommen 1986). This lack of oxygen can be fatal to infants in what has been referred to as 'blue baby syndrome.'

Nitrite is an intermediate form of nitrogen which is readily oxidized. It can be used as a nutrient source by plants and is normally present in only minute quantities in surface waters. Therefore, when nitrite concentrations are elevated, it may cause eutrophication. At relatively low concentrations, nitrite is also directly toxic to aquatic life.

Ammonia is the most reduced inorganic form of nitrogen in water and is found in two forms, dissolved ammonia and the ammonium ion. Dissolved ammonia is highly toxic to fish. The presence of these two forms of ammonia is controlled by temperature, dissolved oxygen and pH. Higher temperatures, higher pH, and lower DO increase the amount of un-ionized ammonia in water, and thus the toxicity to fish. Ammonia may be naturally present in watercourses due to the decomposition of organic matter. Excess ammonia however, may result in eutrophication and the resulting environmental problems. Ammonia concentrations in the Birkenhead River in the 1970's were very low (<0.005 – 0.009 mg/L; App. B, Table 5) and were well below levels set to protect aquatic life (11.7 – 15.2 mg/L depending upon pH and temperature).

Nitrogen concentrations measured in the 1970's in the Birkenhead River (App. B, Table 5) were below levels where any impacts on aquatic life or recreation and aesthetics would be anticipated. Nitrate and nitrite concentrations measured in the Birkenhead River in 1994 and 1995 were also low, ranging between 33 – 83 ug/L. These levels are well below any levels where detrimental impacts would be expected. A nutrient sensitivity test conducted in the Birkenhead River in 1994 did not, however, clearly indicate whether nitrogen or phosphorus limitation was occurring (Freyman 1996). Birkenhead Lake is oligotrophic meaning that it would also be naturally low in nutrients and organic material (BC Parks 1999). Common sources of nutrients to surface waters which may be found in the upper Birkenhead watershed include animal manure, fertilizers, drainage from agricultural lands, discharges from improperly maintained septic tanks in the estate properties, and wastes from other recreational users.

4.4.3 Phosphorous

Phosphorus is an essential plant nutrient, is often the most limiting nutrient to plant growth in freshwater systems and is rarely found in significant concentrations in surface waters. As a result, even small increases in phosphorus may lead to extreme proliferations of plant and algal growths. Consequently, inputs of phosphorus are the prime factors contributing to eutrophication in most freshwater systems. Orthophosphate concentrations in the Birkenhead River in the 1970's were all undetectable (<3 µg/L) while in1994-1995 they ranged between 1.0 - 4.9 ug/L. Nutrient sensitivity tests conducted in 1995 suggest that the Birkenhead River may be phosphorus-limited however the data from tests conducted in 1994 was not conclusive (Freyman 1996). If the Birkenhead River is phosphorus limited, any additional inputs of phosphorus into the system in the future may lead to eutrophication and the corresponding water quality problems.

4.5 Fecal Coliform Bacteria

Fecal coliforms are microscopic organisms which are common in the intestines of humans and other warm-blooded animals. Fecal coliforms are the indicator traditionally examined to determine bacterial contamination in freshwaters. Microbial indicators are bacteria that indicate the risk of disease from pathogenic organisms (Warrington 1988). Presence of the bacteria in a water sample indicates that other harmful disease-causing organisms which also originate in human and animal digestive systems may be present. Consequently, swimming in contaminated water or eating shellfish growing in contaminated water may present a health risk. Recreation in fecal contaminated waters may cause gastrointestinal illnesses from ingestion, and/or skin, ear or eye infections from immersion. As well, fecal contaminated water may pose a threat to the use of the water for drinking, livestock watering or irrigating.

Bacterial concentrations in surface waters are strongly correlated with rainfall. Rainfall runoff over land can carry fecal matter such as pet feces and manure into surface waters such as lakes and creeks, as well as into the groundwater (depending on the local geology). Groundwater may also be contaminated if contaminated surface water flows into well heads.

Samples collected in the 1970's were all non-detectable for bacterial contamination (App. B, Table 5). Sources of fecal contamination include wastes from humans, pets, farm animals and wildlife. Failing septic systems on the recreational properties bordering Birkenhead Lake and Taillefer Creek, or runoff from manure piles or fertilized fields in agricultural areas bordering Phelix Creek could result in bacterial contamination of surrounding surface waterbodies.

4.6 Sediment

4.6.1 TSS and Turbidity

There are direct and indirect methods of quantifying the amount of sediment in water. A direct method is to measure total suspended solids (TSS). TSS is alternately referred to as non-filterable residue (NFR) and is a measure of particulate matter suspended within the water column. Conversely,turbidity measures water clarity by determining how much the passage of light through the water decreases with suspended material. Turbidity is reported in nephelometric turbidity units (NTUs).

Figure 8: Confluence of the clear flowing Taillefer Creek into the turbid Birkenhead River.

Suspended sediment in watercourses may come from natural and/or anthropogenic sources and often varies with season and weather. Snowmelt and storm events often result in elevated sediment in surface waters. Some systems, such as those that are glacially fed, are often naturally turbid for at least part of the year. This elevated turbidity due to glacial melt is visible in the Lillooet River (Freyman 1996). An examination of water quality in the Lillooet River watershed found that during the spring and summer when there is more glacial flour in the waters, turbidity was naturally

elevated. Sampling in the lower Birkenhead River at this time, however, found turbidity to be low (0.5 – 2.2 NTUs), with turbidity levels below or slightly above those measured in the control system, the Cheakamus River (0.4 – 3.3 NTUs) (Freyman 1996). Sampling in the 1970's also showed low total suspended sediment levels in the Birkenhead River (App. B, Table 5).
Figure 8 shows the suspended sediment in the Birkenhead River at its confluence with Taillefer Creek in June 2001. The elevated turbidity levels could be a result of a natural failure upstream (landslide etc) or could be a consequence of human activities upstream. Land activities such as agriculture, forestry and mining can contribute large amounts of suspended sediment into surface waters. Stormwater runoff from rain events pick up particles on the land and transport them into streams therefore elevating suspended sediments. Sedimentation into the upper Birkenhead watercourses from anthropogenic activities would likely be greatest from agricultural activities in the Phelix Creek watershed and forestry activities throughout the watershed. Forestry activities can also result in large scale landslide events and road failures which may have severe consequences on water quality and habitat.

The clear flowing conditions in Taillefer Creek may result from the influence of Birkenhead Lake. The glacial flour present in tributaries into the lake may settle in the lake resulting in the lower turbidity of discharging surface waters. Turbidity in other local lakes has been found to be lower in creeks flowing out of lakes than in creeks entering the lakes (Freyman 1996).

Water quality in much of the Lillooet River watershed may reflect natural background conditions that native fish and other aquatic organism populations are adapted to (Freyman 1996). Detrimental effects of elevations in suspended sediment in water may occur when the amount of sediment input increases, the timing it occurs at changes, the frequency with which sediment loading occurs at changes, or the duration of the loading increases. High concentrations of suspended sediment in the water column may have many detrimental impacts. In fish, it can induce physiological stress, clog gills, increase respiration rates, reduce feeding rates or success, or cause the abandonment of cover areas. Sediment-laden water can also destroy spawning grounds, smother fish eggs, restrict light from reaching aquatic plants and harm aquatic invertebrates by reducing their feeding rates and success, causing increased drift and changing the community structure. Sediment pulses into water can also interfere with water disinfection technologies and be aesthetically unappealing.

In the Lillooet River, the heavy loadings of glacial flour from May-September clear up in the winter when some anadromous fish runs enter the Lillooet system (Freyman 1996). Although the cessation of glacial melt results in lower turbidity in the Lillooet River mainstem, the onset of late autumn storms results in elevated turbidity in some of its tributaries (Freyman 1994-1996). These elevations during storms are likely an indication of turbidity arising from soil and vegetation disruption due to land disturbance. This was seen in the more heavily developed Green River which had elevated turbidity levels in the fall. The results from sampling downstream in the Birkenhead River in November to December and February 1995, however, did not show turbidity levels greatly above the summer turbidity levels (Freyman 1996).

Figure 9: Secchi disc reading in Birkenhead Lake.

4.6.2 Water Clarity

A secchi disc measurement is an alternate means of examining the amount of suspended material in water. The secchi disc is commonly used to measure water transparency or clarity in lakes (Figure 9). Water clarity is affected mainly by three factors: primary productivity (algae), suspended sediment and water colour. Algal blooms resulting from excess nutrients may reduce water clarity. Sediment loading due to runoff from land activities may also reduce water clarity. Water clarity is especially important for visual feeders such as salmon and trout as well as for the photosynthesis of aquatic plants.

Secchi disc sampling in Birkenhead Lake in 1969 showed a depth of 6.0m at the south end of the lake (Harding and Offin 1969). Sampling in 2001 showed similar conditions in August at the same site (Appendix A, Figure 23). The August sampling also coincided with the warmest measured water temperatures. An algal bloom was visible at the north end of Birkenhead Lake in August 2001 which also coincided with the shallowest secchi disc measurement. This is the second year that such a bloom has been noticed. Prior to this, blooms were not observed on the lake.

5.0 IMPACTS OF LAND USE ON WATER QUALITY

There are two broad types of water pollution resulting from anthropogenic land use. One is pollution from a single, clearly identifiable point discharge, such as from an industrial or sewer pipe, and the other is from non-point source discharges. Non-point source (NPS) pollution can result from surface water flowing over an altered landscape and then entering a waterbody. The runoff picks up contaminants deposited on fields or on impervious surfaces (such as concrete or pavement), and carries them into local waters. Land use in a watershed thus affects the amount and type of NPS pollution. NPS pollution is more difficult to control than point source discharges as it is intermittent, variable and widely dispersed (Freyman 1997).

The Birkenhead River watershed differs from many other watersheds in the Lower Mainland region which are threatened by urban and industrial development as the Upper Birkenhead watershed has fewer of these activities within it. As there are no permitted point sources discharging into the Birkenhead River, pollution in the Birkenhead watershed arises mainly from non-point source pollution. As significant urban development has not yet occurred, other activities contributing to NPS pollution such as forestry, agriculture and recreation, likely pose the greatest threat to water quality in this watershed at this time.

5.1 Forestry

The Birkenhead watershed is located in the Squamish Forest District. Forestry activities throughout the watershed are considered moderate to heavy, with significant logging previously occurring in the upper watershed reaches (FISS 2002; Magee 2002, pers.comm.). However, as a consequence of a poor lumber market, a reduction in harvesting activities has occurred and is expected to continue for the immediate future.

The loss of forest cover due to harvesting activities may have many detrimental impacts on surface waterbodies such as the:

- Changes in periphyton (stream-bottom algae) due to increased sunlight,
- Elevation of water temperatures due to a lack of shading,
- Alteration of the aquatic food web due to a reduction in leaf and needle inputs which form a food source for some aquatic invertebrates,
- Increase in bank instability resulting in erosion events due to the loss of root structure,
- Loss of coarse woody debris (CWD) entering the stream ecosystem in the future due to the lack of riparian trees. CWD in streams provides cover for aquatic organisms, creates pools for fish retreat in both fast-flowing conditions and when water levels drop, and dissipates water energy, and
- Alteration in water flow due to soil compaction, road drainage and the lack of water uptake by the trees for photosynthesis. The result may be flashier hydrological patterns which can contribute to changes in channel morphology and stream bank erosion.

To prevent some of these detrimental impacts of forest harvesting on fish-bearing watercourses, current forestry practices require riparian buffer zones be left around salmonid-bearing streams. Riparian buffer zones can help with the recruitment of CWD into watercourses, provide shade and provide an input of organic matter. Riparian areas also slow surface water runoff during storms which decreases the flashiness of creeks and thereby reduces bank erosion.

5.2 Recreation and Development

Rapid population growth and development has occurred in the Sea-to-Sky corridor including in the towns of Squamish, Whistler and Pemberton. Urban development in the Birkenhead watershed is quite minimal and is concentrated in the lower reaches of the Birkenhead River near Pemberton (FISS 2002). With the growing population in close vicinity to the watershed, however, the area is expected to see an increase in both development and recreational users. The 2010 Winter Olympic games to be held in Whistler and Vancouver will likely also attract more development and recreational users to the area.

Urbanization and development are known to contribute to changes in watershed hydrology, channel morphology and water quality due to land clearing, soil disturbance and modifications to surface water drainages. As the amount of impermeable surface area increases, both habitat features and water quality tend to deteriorate (Paul and Meyer 2001). With more impervious surface cover (e.g. concrete), less precipitation infiltrates into the ground and more stormwater runoff results. This stormwater carries contaminants in it that have accumulated on impervious surfaces. These contaminants, such as metals and hydrocarbons, get washed into local waterways with the runoff. In the water they may effect the reproduction, growth or development of aquatic organisms, or be lethal at high concentrations. Contaminants may also accumulate in sediments, harming or altering the aquatic community associated with the sediment. Runoff from urbanized surfaces can thus lead to consistent declines in richness of algal, invertebrate and fish communities (Paul and Meyer 2001). Runoff from such areas can also cause stream channel scouring and increase the variability of stream flows which can alter temperature and suspended sediment loads. As there is very little impervious surface area in the upper Birkenhead watershed, these types of water quality impacts are not anticipated without further development.

Other development in the area includes four BC Hydro powerlines which run adjacent to the Birkenhead River between Owl Creek and Poole Creek (Bailey 1979). The BC Rail railway and provincial highway also pass through the lower Birkenhead watershed and are in close proximity to the Birkenhead River for approximately 21 kilometers. Herbicides may be used to control vegetation on these right-of-ways.

5.2.1 Birkenhead Lake Provincial Park

Figure 10: Camping in the Birkenhead Provincial Park.

Birkenhead Lake Provincial Park was established in 1963 and encompasses most of the lake and the Sockeye Creek Valley. The park boundaries extend high up the sides of the mountains that surround the lake. The park is busy during the summer with an estimated 25,000 visits to the park in 1999 (BC Parks 1999). At the north end of the lake is a sandy beach, picnic area, boat launch, pit toilets and 100 campsites (Figure 10). Camping is also allowed along the lakeshore at a wilderness camping site. In the park, visitors may rent canoes or take horse back rides. The Big Sky bike trail from D'arcy to Squamish also passes through the park, following the length of the lake on the west shore.

High angler use of Birkenhead Lake is supported by the many fish species present in the lake. The lake is popular among sports fishermen for its rainbow trout (BC Parks 1999). With the development of the picnic site and campground at the north end of the lake in 1974, fishing pressure on the lake has increased. From 1983 to 1988, the lake was stocked with rainbow trout; however, this stocking was halted in 1989 (FISS 2002). The lake now supports a popular rainbow trout recreational fishery, with an estimated 5000 anglers each year (BC Parks 1998).

5.2.2 Birkenhead Lake Estates

Birkenhead Lake Estates are located at the west end of the lake and consist of 100 private properties. Twenty-two of these recreational properties are on the lakefront and 32 border Taillefer Creek. The estates are surrounded by park land and crown land.

Recreational use of the areas surrounding the lake may have various environmental impacts. Water quality may be impacted by waste generated from the recreational property users and campers in the area. Septic systems that are not properly maintained may result in bacterial and nutrient contamination of nearby waters. Nutrient enrichment in the lake may lead to algae blooms or eutrophication.

5.3 Agriculture

Agricultural land use in the upper Birkenhead watershed occurs in the lowlands around East Phelix Creek which drains into the northern end of the lake. Residents in this large valley have farmed this land since before the Birkenhead Lake provincial park was created in 1963. This valley has been cleared of trees and the wetlands have been drained (Thompson 2001, pers.comm.). The valley is now mostly grass and fenced fields with a series of drainage ditches and channels which drain into Phelix Creek. Some of the farms have cattle and horses while one farm has tried diversifying by growing trees for the paper industry and operating a driving range. This farm was sold in 2002 to a horse trail riding company.

Agricultural land use may have negative impacts on surface waterbodies. Removal of riparian vegetation reduces shading, increases water temperatures and reduces habitat complexity. As well, if livestock have access to the water, they may cause bank erosion, sedimentation and habitat destruction, and may excrete their wastes directly into the watercourse. Runoff from agricultural lands may also contaminate surface waters. Runoff contaminated with manure or fertilizers can lead to nutrient enrichment. Excess nutrients contribute to eutrophication and ultimately can depress stream dissolved oxygen levels. As well, toxic concentrations of ammonia and nitrite from manure contaminated runoff may cause fish kills while the bacterial contamination of waterways can impair people's use of the water for irrigation, livestock watering and recreation.

Impacts to Phelix Creek water quality due to sedimentation, and to fish habitat due to riparian removal and channelization, have occurred in the past as a result of agricultural activities (Jessen 2001, pers.comm.; Pique 2001). The decline in bull trout and kokanee populations in the area have been partially attributed to these types of impacts (Jessen 2001, pers.comm.).

5.4 Mining

Historically, mining activities were common in the Lillooet watershed. Some exploration mines are present in the watershed, however, there are currently no producing mines (FISS 2002). The Birkenhead Lake area, formerly the Blackwater Lake area, was explored during the gold rush of the 1850-60's when an alternate route to reach the BC Interior for the gold rush was sought. The Fraser River was not navigable during the spring, and the Columbia River (the main route to the interior) had been taken over by Americans. This alternate route was thus established by the provincial government in 1858. It ran from the Fraser River, up Harrrison Lake and Lillooet Lake, followed the Birkenhead River to Anderson Lake and Seton Lake, and returned to the Fraser River at Lillooet.

In 1924, a staff member from the Geological Survey of Canada, investigated the Pemberton area. At the time, the copper content of local mineral deposits was of chief interest and there were $50 rewards for claims (Decker 1998). The Birkenhead area was explored again in the 1930's when a mining company assessed the area. The company went bankrupt, however, and abandoned the prospecting (Decker 1998). There are some remnants from these historical prospecting activities in the area. A small mine shaft has been located close to a logging road in the Tenas Creek watershed.

6.0 SUMMARY

Based on the information collected, the following is a summary of the conclusions drawn:

1. Since the Birkenhead watershed is not yet too developed, attention should focus on preventing conditions from deteriorating in the future and on tracking changes in the environmental quality. There is a need to continue to track the secchi disc measurements in Birkenhead Lake and to record observations about algal blooms. For relatively little effort and cost, this continued secchi disc data

would allow changes in water clarity to be tracked over the long term and trends to be assessed. This may provide information about changing conditions, new or growing nutrient inputs, or climate change. The measurement is easy to take and understand and is cost-effective. It also provides a cumulative measure of the impacts of multiple activities on Birkenhead Lake.

2. With the 2010 Winter Olympics set to take place in Vancouver and Whistler, more development is anticipated in the Sea-to-Sky corridor. Population growth in Squamish, Whistler and Pemberton is also anticipated to continue. Consequently, there will be more people living in closer proximity to the Birkenhead watershed and recreational use of the watershed is thus anticipated to expand. Therefore, possibly the greatest future water quality concern may arise from any deterioration to the aesthetic or tourism values of the lake. Continued involvement of the local people in environmental stewardship will assist in tracking changes in the watershed.

3. Non-point source pollution is likely the greatest threat to water quality in the Upper Birkenhead watershed at this time. In order to address NPS pollution, a more comprehensive monitoring strategy would be necessary as there is the need to differentiate between natural and anthropogenically induced changes in water quality parameters (i.e. forestry effects on turbidity). Such activities investigating the impacts of water quality need large scale monitoring programs to account for seasonal variability which occurs (i.e. increased turbidity naturally at certain times of year). To do this would require a larger scale program to collect samples frequently and year-round. Sampling would need to capture events (storms, freshet), and occur at multiple locations in order to identify problem areas or inputs.

4. Continuation of the Upper Birkenhead Watershed Stewardship Group outreach programs (newsletters, pamphlets, workshops and visits to local landowners) would assist in educating local users about the potential impacts of their land activities on local water quality conditions such as the importance of the maintenance of their septic systems. The UBWSG should continue their membership in the British Columbia Lake Stewardship Society in order to access the resources and technical expertise available through this group.

5. The greatest of the potential impacts of the local activities on the Birkenhead watershed environmental quality, however is likely from habitat degradation rather than water quality deterioration. Alteration and destruction of spawning and rearing habitat has already occurred. As habitat alterations are likely to result in more detrimental impacts to fisheries resources in this large system than water quality conditions, the efforts of the UBWSG may have positive results from working on such issues. Partnership efforts with other local groups (i.e. local first nations groups, BC Parks, BC Fisheries and Department of Fisheries and Oceans) may assist in protecting, preserving and rehabilitating the spawning and rearing habitat of local rainbow trout, kokanee salmon and the threatened bull trout populations.

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Appendix A: 2001 PRELIMINARY WATER QUALITY INVESTIGATION

1.0 OBJECTIVES

The Upper Birkenhead Watershed Stewardship Group (UBWSG) is concerned about the current state of the Birkenhead watershed, as well as the future of the watershed. Individually or cumulatively, the types of activities occurring in the watershed have the potential to be detrimental to water quality and fish habitat. Concern over these activities, and the anticipated increase in some of these pressures, spurred the group to begin a preliminary water quality investigation. The UBWSG initiated a project to begin to assess the effects of: recreational users on Birkenhead Lake and Taillefer Creek, agricultural land use bordering Phelix Creek and forestry activity along the Upper Birkenhead River, Tenquille Creek and Tenas Creek. Prior to this, no extensive water quality data has been collected in the upper Birkenhead watershed. It was hoped that this collection of data would provide some information, or baseline data about the current conditions in the watershed.

2.0 FIELD SAMPLING METHODOLOGY

2.1 Grab Sampling

All discrete water quality sampling was conducted according to standards outlined in the *Ambient Fresh Water and Effluent Sampling Manual* (Resources Inventory Committee 1994). Samples for pH, turbidity and nutrients were collected in 1L polyethylene bottles. Non-filterable residue samples were submitted in separate 1L polyethylene bottles. Each bottle was labeled with a unique identifier and the date. The time of sampling and current weather conditions were recorded in field notes.

Figure 11: Water sample collection in Phelix Creek.

Sampling locations were chosen to be representative of the area and where a safe access point was available. The sampler stood either in the creek or on the bank, depending upon the water conditions, and reached upstream into an area of flowing water to collect the sample (Figure 11). Bottles were held at the base and plunged into the water below the surface to fill. Samples for pH, turbidity and nutrient analyses were rinsed with water from the respective water body three times before being filled. All samples were stored in coolers with ice and couriered to laboratories in the Lower Mainland for analyses. Samples were shipped overnight to Pacific Environmental Science Centre and arrived at the laboratory within 24 hours of collection.

Bacterial samples were collected in sterilized 500mL polyethylene bottles which were not pre-rinsed. Samples were stored in coolers on ice and dropped off at CanTest Ltd. on the same day that they were collected.

2.2 Dissolved Oxygen

A Yellow Springs Instrument (YSI) (Model 51B) multi-meter was used to measure dissolved oxygen (DO). At the beginning of each sample day the probe membrane was checked for wrinkles and air bubbles and the meter was calibrated. If the membrane was damaged or the meter would not calibrate, a new membrane was placed on the probe with new electrolyte solution. In the lake, the DO was measured from a boat. In order to measure the dissolved oxygen at depth in the lake, a Niskin bottle was used to collect water samples. The person sampling from the boat sent a messenger down the line to trigger the closing mechanism on the bottle when it was at the desired depth in the water. The bottle was then pulled up from the measured depth, and DO and temperature readings were taken on the water collected in the sample bottle.

2.3 Temperature

Water temperature in the lake was measured with the YSI dissolved oxygen meter (Model 51B). Temperature measurements in the streams were taken using a thermometer submerged in the water.

2.4 Water Transparency

A secchi disc was used to measure water transparency in the lake. The disc is lowered into the water until it is no longer visible and it is then pulled back up until it reappears. This value is termed the extinction depth, or the secchi disc depth. Measurements were consistently taken between 10:00AM and 2:00PM so that the light rays from the sun were at a similar angle in the sky each time a reading was taken. The reading was taken on the shady side of the boat with sunglasses removed from the reader. The readings were taken once per week, avoiding choppy rough water conditions. The readings were taken in the deepest portion of the lake (as determined by a bathymetric map) at both the north end (Birkenhead Lake North) and the south end (Birkenhead Lake South).

3.0 LIMITATIONS

Due to a lack of time available by the volunteer samplers and this being the stewardship group’s first foray into water quality sampling, a limited number of samples were collected in 2001. For most parameters, only one sample was collected at each site, on one sampling date. There were also few QAQC samples included in the program. Only distilled water blanks as blind samples to the laboratories were included for quality assurance purposes. The small sample size does not indicate whether there may be conditions which may be exerting chronic stress on the system. The lack of sampling over various conditions (wet, dry) and in different seasons also limits the interpretation of the data since many water quality parameters show natural seasonal variation.

While the resulting small dataset may suggest that a certain condition exists in the watershed, it would be inaccurate to draw conclusions from this minimal amount of data. Consequently, the dataset available is very limited and interpretation must proceed with caution. The data collected has thus been interpreted mainly to identify any readily apparent water quality concerns. Any conditions of concern would require additional sampling and data in order to more adequately examine and characterize.

4.0 SAMPLING LOCATIONS

4.1 Birkenhead River

The Birkenhead River is 57.3 km long and flows from headwater streams in pristine alpine areas to an increasingly developed valley where it enters Lillooet Lake (Fishwizard 2001). The Birkenhead canyon falls gradient is steep (6%), and is comprised mainly of cascades and pools. From the falls to the headwaters, the river ranges from 5% gradient with cascades, to a 2% gradient with riffle pools where Taillefer Creek enters. The substrate is mostly boulder and cobble in these areas. Channel discharge measurements were 8.5 - 12.4 m^3/s at Taillefer Creek ,and 6.9 - 12.6 m^3/s at the falls (Bussanich 1999). Water velocity measurements range from 0.6 - 1.4 m/s at Taillefer Creek to 0.9 - 1.3 m/s at the falls (Bussanich 1999).

There are many different activities occurring in the Birkenhead River watershed. Forest harvesting activities have occurred in the watershed over many years and have been heavy in the upper reaches (FISS 2002). Recently, a new road has been built to provide access to the extreme upper reaches of the Birkenhead River watershed. The undisturbed area which this road provides access to was previously inaccessible by vehicle. Mining exploration has also occurred in the watershed, however, there are no producing mines (FISS 2002). The lower reaches of the river face a greater diversity of land use. There is

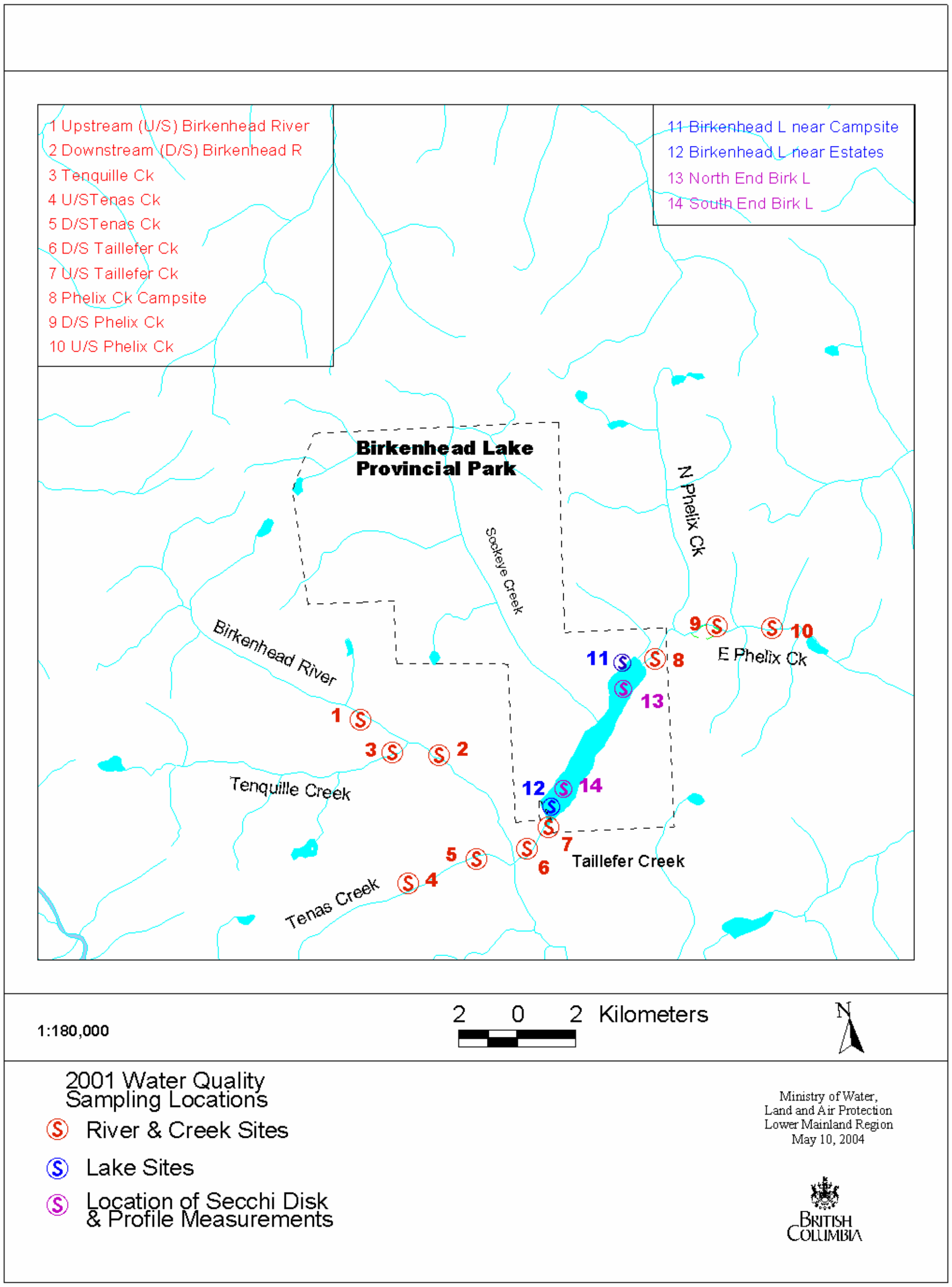

Figure 12: Sampling site locations.

a railroad, highway and hydroelectric transmission corridor in the valley, as well as the Mount Currie Band Reserve and some urban development in the lower reaches and valley.

Figure 13: Monitoring site on the Birkenhead River downstream.

Two sampling locations were chosen above the falls in the Birkenhead River (Figure 12). One of these sites was located downstream of logging activities while the other site was located upstream of the logging. The downstream sampling site was located near the forestry bridge at kilometre 11 of the Birkenhead Forestry Road (Figure 13). Above this area, harvesting activities have occurred on the north side of the valley. The cutblocks upstream of this location are of various ages. The area has been replanted and there has also been natural regeneration. The area where the sampling site was located is very steep-sided and the substrate consists of large boulders and cobble. The wetted width of the river at this location was 15 metres (measured on the bridge) and the maximum depth was one metre.

Figure 14: Upstream monitoring site on the Birkenhead River.

The upstream sample was collected upstream of the harvesting activities near the bridge at the end of the Birkenhead Forestry Road (Figure 14). The wetted width of the river at this location was 12.4 metres (measured on the bridge) and the substrate consisted of gravel and sand. The water appeared clear and the flow was fast and smooth at the time of sampling.

As this upper portion of the Birkenhead River watershed has forestry activities bordering it, sediment inputs into the river were identified as the greatest potential concern. Sampling was thus planned for rain events as this should correspond with the greatest potential for surface water runoff over the harvested areas to result in elevated suspended sediment levels.

4.2 Tenquille Creek

Tenquille Creek is 11.2 km long with steep-sides and consists mostly of cascades and pools with a boulder cobble substrate. Where the creek drains out of Tenquille Lake in the alpine there is a cascade and falls which prevents fish from accessing the lake (FISS 2002). Rainbow trout are found in the creek, although a previous survey of the creek attributes a lack of spawning habitat and limited rearing habitat as a constraint to increasing the fisheries production in this creek (FISS 2002).

Figure 15: Tenquille Creek monitoring site.

The valley surrounding Tenquille Creek has been harvested to the stream banks. After harvesting, a large forest fire severely burned much of the Tenquille Creek watershed in 1991. The burnt area has since been replanted. Besides the potential sedimentation into the system due to logging, the UBWSG had concerns about the breakdown products from the fire retardant used and whether they may still be detectable in the creek. Nitrogen compounds were consequently sampled to examine this.

Samples were collected in Tenquille Creek at the forestry road bridge crossing the creek (Figure 15). This location is downstream of the area which was harvested and subsequently burnt in the forest fire. The wetted width at the sampling location was six metres and the water depth was 1-2 metres. The substrate was comprised of bedrock, with boulders and large woody debris also present in the creek. The water was clear flowing at the time of sampling. Again, rain events were targeted for the Tenquille Creek sampling. An upstream sampling location was not accessible.

4.3 Tenas Creek

Figure 16: Downstream Tenas Creek monitoring site.

Tenas Creek is 9.43 km in length and is located in a steep-sided valley (FISS 2002). The substrate of the steep creek is mostly boulder and cobble, and the creek consists primarily of cascades. Fish migrations are obstructed by a log jam 450 metres upstream of the mouth of the creek and 25 metre high waterfalls, approximately 1 km upstream from the mouth of the creek (FISS 2002). Dolly Varden char were caught in the creek near the log jam in a previous fish survey of Tenas Creek (FISS 2002). Tailed frogs (Ascaphus truei) were also observed in this watershed in 2001 and 2002.

There is a newly constructed unnamed logging road in the Tenas Creek watershed. The logging road was built in 2000 and follows Tenas Creek almost to the alpine area. As of 2002, no harvesting activities had yet occurred beyond kilometre 2 in this newly accessible area. In the lower reaches of Tenas Creek, the Tenas Creek logging road is located near the creek's confluence with the Birkenhead River. Forest harvesting activities have occurred in this area in the recent past and the area has since been replanted. Samples were collected in Tenas Creek downstream of an area which was harvested in approximately the early 1990's (Figure 16). The wetted width at the sampling location was ten metres and there were many large boulders in the creek. There were large step pools ten metres in length and one metre in depth in the area. The water was clear and fast flowing.

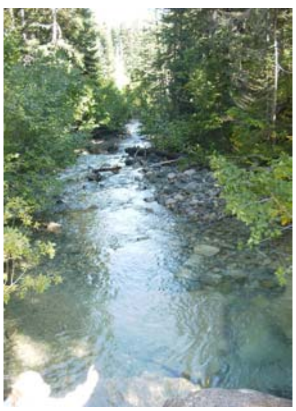

Figure 17: Upstream Tenas Creek monitoring

At the upstream sampling location, the wetted width was six metres and maximum depth was one metre (Figure 17). This site was upstream of the harvested area. The substrate in the creek was mainly boulders and cobbles and there was large woody debris in the channel. During the sampling of a summer rain event the water was rushing and was a silty, milky colour. Rain events were targeted for the collection of water samples from Tenas Creek, as this would be the time when there was the greatest potential sedimentation into the creek.

4.4 Birkenhead Lake

The Birkenhead Lake watershed drains a 395.1 hectare area (FISS 2002). The lake is 6.4 km long and averages 0.4 km in width. It has a mean depth of 21.6 meters, with a maximum depth of 38.4 meters in the southwest portion. The estimated surface area of the lake is 408.8 hectares, while the water volume of the lake is estimated at 88,511,730 meters3. High water can usually cause a rise of 1.3 meters and occurs in either late June or early July due to snowmelt.

Figure 18: Birkenhead Lake near the Estates.

The impacts of the recreational use of Birkenhead Lake and the surrounding lands were identified as a concern by the UBWSG. Recent algal blooms and the potential for depleted oxygen levels in the lake were identified as the primary concerns. Due to the location of the provincial park at the north end of the lake and the Birkenhead Estates at the south end, sampling locations were selected at each end of the lake. At the south end of the lake, sampling sites were located offshore of the Birkenhead Estates community dock (offshore of lot 17) (Figure 18) and in the centre of the basin at this end of the lake. At the north end of the lake, a sampling site was located in the centre of the basin at this end of the lake close, to the beach at the campsite.

On July 25, 2001 and August 27, 2001, dissolved oxygen and temperature measurements were made at the sites at each end of the lake. At the other sampling sites in the lake closer to the shore, water samples were collected to test for bacterial and nutrient concentrations. These samples were collected in the summer during a long weekend when it was anticipated to be the highest recreational use (the most people were expected at the lake).

4.5 Taillefer Creek

Taillefer Creek is 2.2 km long and gently sloped with a gradient of 1.3% (FISS 2002). The substrate is composed of gravel, cobbles and fines with primarily riffle and pool habitat (FISS 2002). Channel discharge measurements ranged from 3.0 - 3.9 m3/s while water velocity measurements ranged from 0.05 - 0.1m/s. The creek flows into the Birkenhead River and is the only outlet from Birkenhead Lake.

Figure 19: Upstream monitoring site in Taillefer Creek.

Taillefer Creek provides spawning habitat for chinook salmon, and spawning and rearing habitat for rainbow trout and kokanee salmon (Bell-Irving 2001, pers.comm.). The creek is the main source of recruitment for the lake rainbow trout population (FISS 2002). Rainbow trout spawn in the first 100m of the creek at the head of outlet (FISS 2002). It is thought that bull trout cannot use this spawning habitat since the rainbow trout now dominate this habitat (Bell-Irving, 2002 pers.comm.). Coho salmon, Dolly Varden char and steelhead salmon have also been observed in the creek (FISS 2002).

It was previously believed that salmonids could not gain access into Taillefer Creek due to the falls in Birkenhead Canyon. Local residents, however, have seen and captured the occasional chinook salmon in the creek in 1999 and 2001 (Wetzel 1998, pers.comm.; Schollen 1999, pers.comm.). The Department of Fisheries and Oceans transplanted 10,000 - 15,0000 chinook fry into the creek in June 2001, 2002 and 2003. The chinook fry released into the creek showed good growth and appeared in good condition during a subsequent survey (Bell-Irving 2001, pers.comm.).

Figure 20: Downstream sampling site in Taillefer Creek.

Birkenhead Estate properties border the west side of Taillefer Creek and, therefore, there is the potential for water quality to be negatively impacted by improperly maintained septic systems. Samples were collected in Taillefer Creek upstream of the Estate properties at the lake outlet (Figure 19). Samples were also collected downstream of the cabins (Figure 20). Samples were collected when the cabins were expected to be busiest, during statutory holidays in August.

4.6 Phelix Creek

Phelix Creek is 12.78 km in length (FISS 2002). It flows from an upstream fast moving, bouldery bottom creek, with steep gradients ranging between 9 - 22%, to a relatively low gradient meandering stream with a gradient between 1 - 5% and substrate consisting of predominantly fines and gravel (FISS 2002). The channel discharge for Phelix Creek ranges from 0.7 - 2.1m3/s and water velocity measurements ranged between 0.4 - 0.7 m/s (Bussanich 1999). Two branches of the creek merge approximately 2 kilometers upstream of Birkenhead Lake. The 'east branch' of Phelix Creek has many names according to the local landowners. For the purposes of this report, it will be referred to as East Phelix Creek. The other branch is often referred to as North Phelix Creek. The lower reaches below the confluence of the east and north branches form a large floodplain adjacent to Birkenhead Park. This low gradient area (1%) is dominated by riffles and pools with fines and gravel as substrate. Waterfalls located approximately 3 kilometres upstream of the mouth of Phelix Creek as well as abundant log jams in the creek act as barriers to fish migration within the creek (FISS 2002).

Both North and East Phelix Creeks provide important spawning and rearing habitat for bull trout. The lower reaches of Phelix Creek also provide spawning and rearing habitat for kokanee and rainbow trout (FISS 2002; Scott Resource Services Inc. 2000). A current estimate of the total amount of suitable habitat for kokanee spawning is 250m² (FISS 2002). This is significantly below historical reports and either the methodologies used in different years to estimate the populations were different, or there has been a significant loss of kokanee spawning habitat in Phelix Creek (Sebastian 1982). Mountain whitefish have also been observed spawning in the creek in low densities (FISS 2002).

The forested area surrounding North Phelix Creek was previously harvested. Currently there is no harvesting activities occurring in the area and the forestry road is now impassable. East Phelix Creek rushes from the forested mountains into a large flat valley. A new forestry road was constructed in 2000 and proceeds into the valley where East Phelix Creek originates. No harvesting has yet occurred in this area. However, the aquatic habitat of the portion of East Phelix Creek located in the valley has been detrimentally altered by agricultural activities. The once swampy area with several undefined channels flowing through it has been largely channelized for agricultural purposes. In 2001, charges were laid and fines were imposed on a farmer in the area who dug out a tributary to East Phelix Creek and stripped the vegetation along the stream while preparing the land for agricultural use. In other reaches, siltation from stream banks and water velocity barriers may be affecting bull trout and rainbow trout spawners.

Figure 21: Downstream Phelix Creek sampling site.

Figure 22: Upstream sampling site on East Phelix Creek.

Phelix Creek threatens campsites in the provincial park with destruction due to channel migration and flooding during freshet (BC Parks 1999). The lower reaches of the creek have serious erosion problems resulting in many riparian trees falling into the creek. This is likely a result of poor road design and water management upstream (FISS 2002). Consequently, water samples were collected downstream of the campground near the provincial park entrance (where a foot path crosses the creek) (Figure 21). Water samples were also collected in East Phelix Creek, both upstream and downstream of the agricultural activities. The upstream sampling location was next to the logging road on the south side of Blackwater Creek Road, approximately three quarters of the distance up a private driveway (Figure 22).

5.0 RESULTS

5.1 Forestry Impacts

5.1.1 Birkenhead River

Table 1 shows the results from samples collected in the Birkenhead River and analyzed for total suspended solids (NFR). Samples were collected three times during a summer rain event on August 2 and 3, 2001. The results indicate that during this summer storm the suspended sediments in this portion of the upper Birkenhead River were low. All samples collected at both the upstream and downstream sampling sites were reported to have less than 5 mg/L of suspended solids and were thus below the laboratory detection limit. The British Columbia guideline for total suspended solids in a clear flowing system (when background conditions are < 25 mg/L) is that the induced sediment load should not exceed 25 mg/L for a duration of 24 hours (Cadmus Group Inc. and MacDonald Environmental Sciences Ltd. 1999). Consequently, these guidelines were not exceeded during this sampling period.

5.1.2 Tenquille Creek

The results from analyses conducted on samples collected in Tenquille Creek in an area downstream of logging activities and a previous forest fire are shown in Table 1. The results show that suspended sediments in this portion of Tenquille Creek, a tributary of the Birkenhead River, were low during this summer storm. All three samples collected had suspended solids levels less than 5 mg/L, and were thus below the detection limit of the laboratory methodology and below the established guidelines. These results suggest that sedimentation from surface runoff in the Tenquille Valley were not elevated during this summer storm.

Samples to be analyzed for nitrite and nitrate were also collected at the Tenquille Creek site. Nitrogen is a common breakdown product from fire retardants which were used to fight the large forest fire near Tenquille Creek in 1991. The measured levels of nitrite (<0.002 mg/L and 0.002 mg/L) are far below the BC guideline to prevent acute impacts on aquatic life (0.06 mg/L), and to protect recreation and aesthetics (1 mg/L) (Nordin and Pommen 1986). The measured nitrate and nitrite concentrations of 0.002 - 0.01 mg/L (assumed to be mostly nitrate) were also far below the British Columbia water quality guideline set to protect aquatic life (200 mg/L), and to protect recreation and aesthetics (10 mg/L). These nitrate concentrations are also well below 5 – 10 mg/L, levels at which toxic impacts to amphibians have been seen. These results are not unexpected since the forest fire and fire retardant use occurred approximately a decade earlier.

5.1.3 Tenas Creek

Table 1 shows the results from samples collected in Tenas Creek and analyzed for total suspended solids (NFR). The total suspended solid concentrations (TSS) in Tenas Creek ranged from <5 mg/L to 56 mg/L. At all times, the downstream Tenas Creek site had lower total suspended solid concentrations (<5 – 9 mg/L) than the upstream site (10 – 56 mg/L). Even though the one value was elevated (56 mg/L), the other two values measured in the 24 hours at this site were lower and thus the guideline was not exceeded. As well, since the elevated values occurred at the upstream sampling site, it cannot be directly attributed to the forest harvesting at this time (although other activities such as the roads could be a factor).

The results indicate that suspended solids were higher in Tenas Creek than they were in Tenquille Creek and the Birkenhead River during the same summer storm. The Tenas Creek results also show the variability in suspended sediment concentrations both within a localized area (as the upstream site had higher TSS levels than the downstream site at all times), and over the course of the storm (as both the upstream and downstream sites showed variability in the three samples collected). This variability with time of sampling illustrates how random grab sampling may not capture peaks in TSS and is thus not the most effective means of examining sedimentation inputs.

5.1.4 Summary

The results from the sampling in the Birkenhead River, Tenquille Creek and Tenas Creek showed that total suspended solids levels were:

- low during this summer storm, and
- variable with location and time, even during the course of this one storm.

The sampling for this was only conducted during one summer storm event by grab sampling. Consequently, due to the small sample size, it would be difficult to conclude that these conditions persist in the watershed at other times, and at other locations. Automated sampling which collects or records water quality data on a frequent basis (i.e. every 15 minutes) provides better information for assessing TSS or turbidity conditions. Information collected about the concentrations of TSS over time and the duration of these events would assist in determining the impacts on aquatic life as more recent criteria developed for the MWLAP suggests that both duration and concentration are important in determining the severity of impacts to aquatic life from sediment pulses.

Sampling was only conducted during a summer storm event and thus the total suspended solids concentrations could have been underestimated. If land or vegetation disturbance is influencing suspended sediment levels, then conditions would be expected to be worse when the more regular, large rainfalls occur. Sampling for suspended solids is thus often conducted during the wet season when the ground is already saturated. Rainfall will then result in greater surface runoff, and thus higher levels of suspended sediments entering local waterbodies. The conditions around the time of this summer storm, when the ground was not saturated, are thus likely not representative of the worst-case conditions following long periods of rain.

5.2 Recreation and Development Impacts

5.2.1 Taillefer Creek

Water samples from Taillefer Creek were analyzed for fecal coliforms, pH and non-filterable residue (NFR). Sampling was conducted on August 6, 2001 and August 28, 2001 when the lake was predicted to be busiest with summer users. Table 2 shows the results from the laboratory analyses conducted on the samples. Both upstream and downstream water samples had no detectable fecal coliforms, pH's close to neutral (between 7.16 and 7.37), and total suspended solids concentrations less than the laboratory detection levels (NFR < 5 mg/L). All of these values are lower than their respective criteria for the protection of human health and aquatic life.

The two sets of samples collected in Taillefer Creek suggest that at these times, the recreational properties of the Birkenhead Lake Estates were not negatively impacting on the microbiological, pH and sediment levels in the creek. As only one sample was collected at each site on each date, the sample size was very small. Due to the limited sampling, it is not possible to conclude that there is no impact from these developments. The results do indicate, however, that there is likely no widespread deleterious impact on the creek. This is supported by visual observations of the area, however, more sampling would be necessary to determine this conclusively.

5.2.2 Phelix Creek

Water samples from Phelix Creek were collected for fecal coliform bacteria, pH and NFR on August 6, 2001 and August 28, 2001. The water samples collected downstream of the provincial park campsite had results similar to those from Taillefer Creek (Table 2). Fecal coliforms were undetectable, pH was close to neutral (6.72 to 7.25) and NFR was below laboratory detection levels (<5 mg/L). All of these values are lower than their respective criteria for the protection of human health and aquatic life. These results suggest that there are no widespread bacteriological or suspended sediment problems in this portion of Phelix Creek. It therefore does not appear that the recreational activities bordering the lower reaches of Phelix Creek are negatively impacting on the measured water quality parameters at this time. This is supported by visual observations of the area, however, more sampling would be necessary to determine this conclusively.

5.2.3 Birkenhead Lake

In order to examine the possible impacts of recreation activities on Birkenhead Lake water quality, water samples were collected to test for fecal coliform bacteria and pH. In August 2001 samples were collected at three locations in the lake when it was expected to be busiest with recreational users. The results from sampling on these two dates (August 6 and 28, 2001) are shown in Table 3. There were no fecal coliforms detected in any of the samples and the pH's were near neutral (6.7 - 7.38).

Lake productivity was monitored in Birkenhead Lake during the course of the summer by measuring secchi disc extinction depths. The results indicate that water clarity in the lake appears to be good (Figure 23). The figure shows that in June, the depth at which the secchi disk was visible was similar at both the north and south ends of the lake (approximately 6m). The depth measurements at both sites then increased (could be seen deeper) and decreased (could not be as seen deep) over the summer months in relatively similar patterns (although the north end had lower water clarity). The north end of the lake had the shallowest secchi disk reading of 4.5 m on August 6, 2001. This date was around the time of a large storm event, therefore the decrease in water clarity may be attributable to surface runoff elevating water turbidity. By September 9, 2001, the secchi measurements at both the north and south sites were deeper than they were at the beginning of June when the sampling began. The results obtained from the 2001 secchi disc measurements are similar to the results from a lake survey which was conducted in August of 1969. The secchi disc reading noted in this survey was six metres at the south end of the lake which is similar to what it was in 2001 (Harding and Offin 1969).

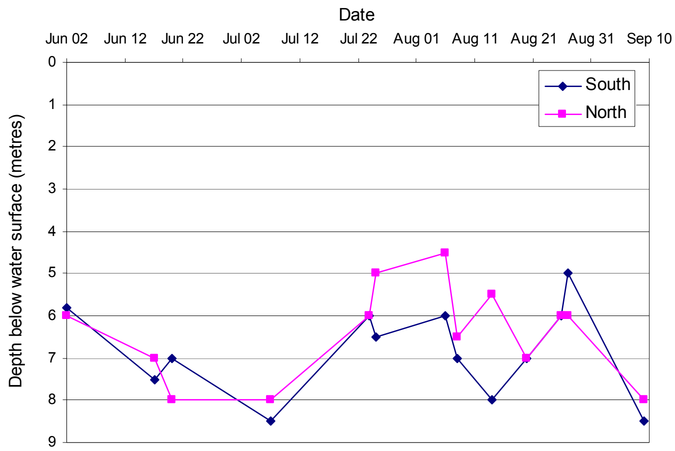

Figure 23: Secchi disc measurements taken in Birkenhead Lake.

The shallower secchi disc measurements in the north end of the lake later in the summer may have been a result of the visible algal bloom in the north end of the lake. This is the second year that this has been noticed. Prior to this, blooms were not observed on the lake.

Birkenhead Lake water temperature and dissolved oxygen concentrations were measured on July 25, 2001 and August 27, 2001. The July 25th results are shown in the graphs in Figure 24. These figures show that, at both ends of the lake, water temperature dropped with depth, as expected. Water temperature was approximately 16 - 17°C at the water surface and dropped to approximately 7 - 8°C between 15 and 20m. The DO on the other hand increased with depth at the north end of the lake and fluctuated at the south end of the lake, where the DO dropped between 2 and 10 metres, then increased. Neither temperature nor dissolved oxygen exceeded their maximum or minimum requirements. Consequently, both temperature and dissolved oxygen were at levels suitable to support aquatic life in Birkenhead Lake.

The results from the temperature and dissolved oxygen profile measured on August 27, 2001 are also displayed in Figure 24. The patterns are similar to those seen in July, except temperature readings at depth were warmer in August than in July at both ends of the lake. Inversely, DO readings were somewhat lower at depth in August, although not to a level where aquatic life would be harmed.

As Birkenhead Lake is naturally oligotrophic, meaning that it has little nutrients or plant growth and an abundance of oxygen, the algal bloom that has been visible in the lake in recent years may indicate an anthropogenic nutrient input (such as manure or fertilizer runoff), or a change in conditions such as an increase in water temperature which may occur with climate change. The die-off of this algae at the end of the summer may result in lower dissolved oxygen concentrations in the lake due to the decomposition of the algae. The large size and cold water of the lake would help reduce the severity of these potential problems. In order to continue to assess this over time, weekly secchi disc monitoring should continue over summer months. Monthly temperature and dissolved oxygen profiles over the summer would also assist in examining warming trends in the lake and the potential dissolved oxygen problems due to the decomposition of recurring algal blooms.

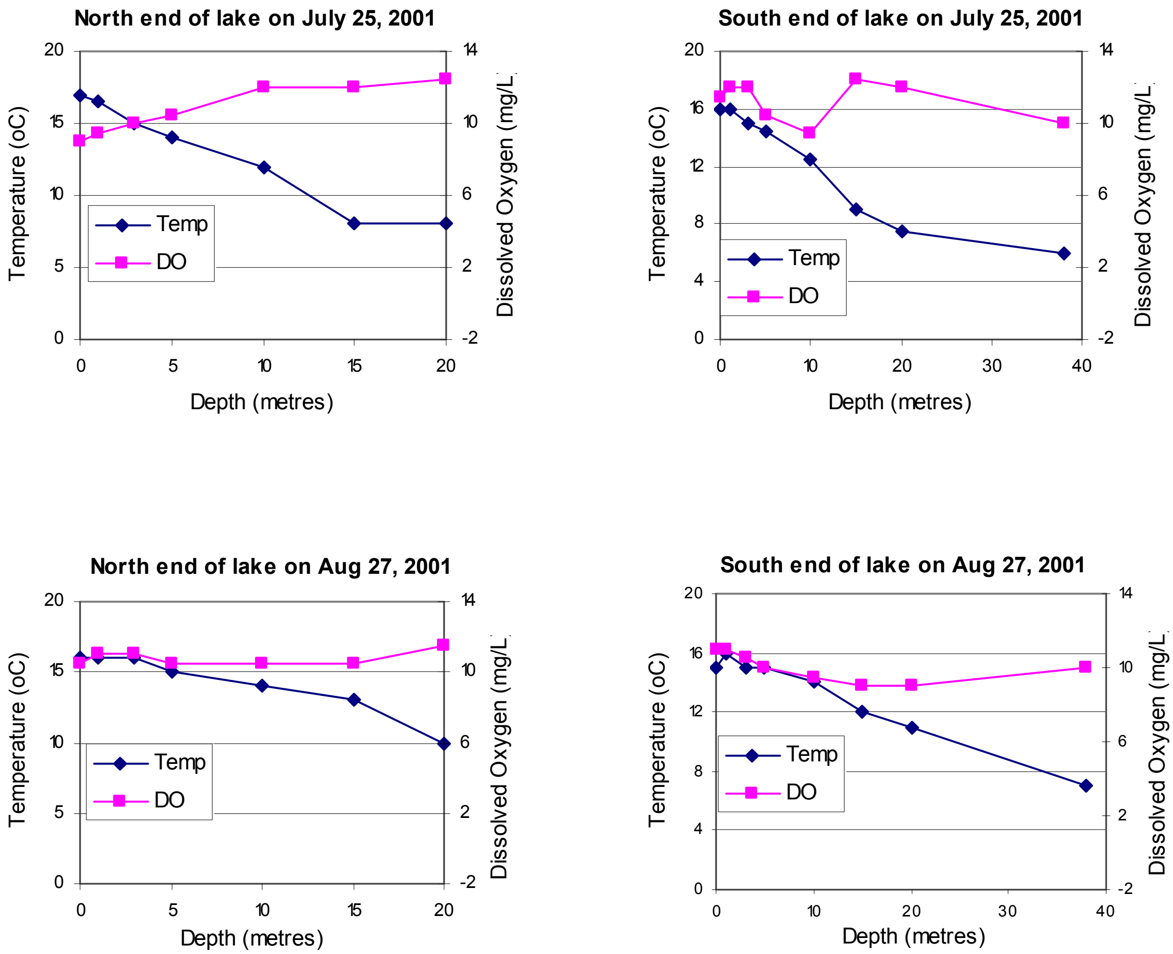

Figure 24: Temperature and dissolved oxygen measurements taken at depth at the north and south ends of Birkenhead Lake.

5.3 Agricultural activities

5.3.1 Phelix Creek

Water samples were also collected in Phelix Creek upstream of the campsite, closer to the areas of agricultural activities. The results from the November 11, 2001 storm event sampling are shown in Table 3. Very low or undetectable numbers of fecal coliforms were measured in all of the samples (< 1, 1 and 2 colonies / 100 mL). The pH reported for each site was close to neutral (7.36 - 7.63), while total suspended solids concentrations were below laboratory detection limits at all stations (< 5 mg/L).

The results from the nutrient analyses conducted on these samples are also shown in Table 3. The ammonia concentrations in these samples ranged between 0.006 – 0.008 mg/L. These levels are well below the criteria set to protect aquatic life from acute toxicity (criteria ranges between 11.7 – 15.2 mg/L depending upon pH and temperature) (Nordin and Pommen 1986). Nitrite was below the laboratory detection level (0.002 mg/L) at all sites, and was thus well below the British Columbia water quality criteria set to protect aquatic life from acute toxicity (0.06 mg/L to 0.60 mg/L depending upon chloride content) (Nordin and Pommen 1986). The nitrate and nitrite concentration (assumed to be mostly nitrate due to the low nitrite levels) ranged between 0.057 – 0.089 mg/L. These concentrations are below the levels at which chronic effects have been observed on amphibians (5-10 mg/L), and levels which will protect recreation and aesthetics. Ortho-phosphate levels in the samples were also very low (< 0.001 mg/L).

This data is from grab sampling during only one storm event on one date. Consequently, this small sample size with no information about conditions at other times is not enough to draw firm conclusions from. Since surface water runoff from agricultural areas is largely influenced by the current activities occurring on the land and by the amount of runoff, these results may not be representative of the conditions at other times. If fertilizers are used or manure spread shortly before a rain event it can be expected that the runoff would be higher in bacteria and nutrients than if they had not be applied to the land before the precipitation. Consequently, more sampling dates to capture a wider variety of the activities which occur on the land, and the variability in the water quality associated with these activities and with seasonal weather patterns would be necessary to further evaluate the impacts of the agricultural activities.

6.0 CONCLUSIONS

Based on the limited sampling conducted, the following observations were made:

- Total suspended sediment concentrations measured in Birkenhead River, Tenquille Creek, Tenas Creek and Phelix Creek were low.
- Fecal coliform concentrations in Taillefer Creek, Phelix Creek and Birkenhead Lake were very low or undetectable.
- pH was close to neutral in Taillefer Creek, Phelix Creek, and Birkenhead Lake.
- Nutrient concentrations in Phelix Creek were low.
- Dissolved oxygen concentrations in Birkenhead Lake were high, and consequently, the lake provides conditions suitable for aquatic life. Dissolved oxygen levels should continue to be monitored during summer months to ensure that any future algal blooms do not lower the dissolved oxygen concentration to levels detrimental to aquatic life.
- Water temperature in Birkenhead Lake was neither high enough, nor low enough to cause harm to aquatic life. Temperature should continue to be monitored with dissolved oxygen concentrations during the summer months. This would provide information about changing conditions, factors potentially affecting algal blooms and the potential impacts of climate change.
- Water clarity in the lake was good, however, a longer collection period would allow for the assessment of trends over time. Monitoring secchi disc measurements over the summer months would also provide information about possible nutrient additions in the watershed. This is important as the cause of the bloom visible in the lake in recent years is unknown.

Due to the small sample sizes, it was not possible to draw conclusions about the effects of forestry, agriculture and recreational activities on waterbodies in the upper Birkenhead watershed. It was apparent, however, that at the times of sampling, these activities were not resulting in visible detrimental impacts in the sampled waterbodies. In order to conclude whether these samples collected are reflective of the conditions in the watershed at other times and whether they persist, replicated sampling would be necessary at multiple sites on multiple dates. More frequent sampling would be necessary to sample different weather and seasonal conditions in order to be able to decipher natural variability in the parameters to variability due to human activities in the watershed.

Table 2: Results from samples collected in Birkenhead River, Tenquille Creek and Tenas Creek on August 2 – 3, 2001.

Site	Date	Time (PST)	Non-Filterable Residue (mg/L)	Nitrite (mg/L)	Nitrate + Nitrite (mg/L)
Birkenhead River Upstream	August 2, 2001	11:50:00	< 5[a]		
Birkenhead River Upstream	August 2, 2001	18:45:00	< 5		
Birkenhead River Upstream	August 3, 2001	13:00:00	< 5		
Birkenhead River Downstream	August 2, 2001	10:00:00	< 5		
Birkenhead River Downstream	August 2, 2001	17:20:00	< 5		
Birkenhead River Downstream	August 3, 2001	10:50:00	< 5		
Tenquille Creek Downstream	August 2, 2001	11:10:00	< 5	< 0.002	0.01
Tenquille Creek Downstream	August 2, 2001	18:20:00	< 5	< 0.002	0.005
Tenquille Creek Downstream	August 3, 2001	11:40:00	5	< 0.002	0.002
Tenas Creek Upstream	August 2, 2001	10:30:00	56		
Tenas Creek Upstream	August 2, 2001	17:45:00	10		
Tenas Creek Upstream	August 3, 2001	11:10:00	24		
Tenas Creek Downstream	August 2, 2001	09:30:00	8		
Tenas Creek Downstream	August 2, 2001	17:00:00	< 5		
Tenas Creek Downstream	August 3, 2001	10:40:00	9		

[a] *Results that are shown as '<' indicate that the parameter measured was less than the detection level available based on laboratory methodology used.*

Table 3: Results from samples collected for fecal coliform, pH and non-filterable residue analyses in Taillifer Creek, Phelix Creek and Birkenhead Lake on August 6 and August 28, 2001.

Site	Date	Fecal coliform (colonies/ 100 mL)	pH	Non-Filterable Residue (mg/L) @105°
Taillifer Creek upstream	Aug 6, 2001	< 1	7.37	< 5
Taillifer Creek upstream	Aug 28, 2001	< 1	7.16	< 5
Taillifer Creek downstream	Aug 6, 2001	< 1	7.34	< 5
Taillifer Creek downstream	Aug 28, 2001	< 1	7.16	< 5
Phelix Creek downstream campsite	Aug 6, 2001	< 1	7.25	< 5
Phelix Creek downstream campsite	Aug 28, 2001	< 1	6.72	< 5
Birkenhead Lake Cabin Community Dock	Aug 6, 2001	< 1	7.35	*
Birkenhead Lake Cabin Community Dock	Aug 28, 2001	< 1	6.7	
Birkenhead Lake Cabin Lot 17	Aug 6, 2001	< 1	7.38	
Birkenhead Lake Cabin Lot 17	Aug 28, 2001	< 1	6.97	
Birkenhead Lake Campsite	Aug 6, 2001	< 1	7.38	
Birkenhead Lake Campsite	Aug 28, 2001	< 1	7.1	

Results that are shown as '<' indicate that the parameter measured was less than the detection level available based on laboratory methodology used.

** Secchi disk measurements taken in lake as a surrogate of productivity.*

Table 4: Results from water quality analyses conducted on samples collected in Phelix Creek on November 11, 2001.

Sampling Location	Fecal coliform (colonies/ 100 mL)	pH	Non-Filterable Residue (mg/L) @ 105°C	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate + Nitrite (mg/L)	Ortho-Phosphate (mg/L)
East Phelix Upstream	1	7.36	< 5	0.007	< 0.002	0.082	0.001
East Phelix Downstream	2	7.63	< 5	0.008	< 0.002	0.057	0.001
Phelix Creek Downstream	< 1	7.63	< 5	0.006	< 0.002	0.089	< 0.001

Results that are shown as '<' indicate that the parameter measured was less than the detection level available based on laboratory methodology used.

Appendix B: RAW WATER QUALITY DATA FROM THE LOWER BIRKENHEAD RIVER IN THE 1970's

PARAMETER	Aug 31/72	Nov 21/72	Mar 15/73	Aug 15/73	Mar 13/74	Aug 15/74	May 6/75	Aug 19/75	Apr 7/76	Nov 22/76	Mar 10/77	Aug 17/77
True Colour (rel. units)	5	<5										
pH (rel. units)	7.5	7.5	7.9	7.4	7.7	6.9	7.6	7.2	7.6	7.6	7.2	7.5
RES 105C (mg/L)	30	54			50							
RESF105 (mg/L)	28	42	50	28		26	54	30	54	38	48	24
RESNF105 (mg/L)					<1	4	3	13	1	1	1	9
Specific Conductance (umho/cm)	40	65	100	43	82	25	70	41	76	58	68	36
Temperature (°C)	13	3	4.5	15	3	14.5	10	16	8	6.5	5.5	15
Dissolved Oxygen (mg/L)	10.4	11.6	12.4	10.1	13.1	10.8	11	10.2	10.9	11	12.6	9.8
Turbidity (J.T. Unit)	1.4	0.2	0.2	1.6								
AKALI P (mg/L)							25.7	14.5		<0.5		
AKALI T (mg/L)	15.5	23	29	14.6	25.5	13	25.7	14.5	27.5	21.2	27.8	14.5
Chloride (mg/L)	<0.5	0.6	0.6	<0.5	<0.5	<0.5	0.5	<0.5	0.5	0.5	<0.5	<0.5
Hardness (mg/L)	18	28	33.9	14.6	31.5	13.7	30.1	16.8	32.1	22.2	28.2	14.1
Ammonia (mg/L)			<0.01	<0.01	0.01	<0.005	0.008	0.009	<0.005	0.006	<0.005	<0.005
Nitrate + Nitrite (mg/L)										0.06	0.06	0.03
Nitrate (mg/L)	0.03	0.06					0.07	<0.02	0.05	0.06	0.06	0.03
Nitrite (mg/L)	<0.005	<0.005					<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Organic Nitrogen (mg/L)			0.06	0.03	0.01				0.13	<0.01	0.04	0.01
NIT KJEL (mg/L)	0.03	0.05				0.11	0.08	0.06	0.13	0.01	0.04	0.01
Total Nitrogen (mg/L)	0.06	0.11										
Ortho Phosphate (mg/L)					<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Total Phosphorus (mg/L)	0.003	<0.003		0.006	0.003	0.006	0.005	0.011	0.003	0.004	0.003	0.008
Silica (mg/L)	5	7.3										
Sulphate (mg/L)	<5	11.6										
Total Arsenic (mg/L)								<0.005				
Dissolved Boron (mg/L)	<0.1	<0.1										
Dissolved Calcium (mg/L)	6	9.6	12	5.1	11	4.7	10.6	5.7	11.3	7.7	9.8	4.8

PARAMETER	Aug 31/72	Nov 21/72	Mar 15/73	Aug 15/73	Mar 13/74	Aug 15/74	May 6/75	Aug 19/75	Apr 7/76	Nov 22/76	Mar 10/77	Aug 17/77
Total Chromium (mg/L)	0.016	<0.005					<0.005	<0.005	<0.005			
Total Copper (mg/L)	0.004	<0.001					<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Dissolved Iron (mg/L)	0.37	<0.04					<0.1	0.3	<0.1	<0.1	<0.1	0.3
Total Lead (mg/L)	<0.003	<0.003					<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dissolved Magnesium (mg/L)		0.88	0.95	0.44	0.99	0.48	0.89	0.62	0.95	0.72	0.91	0.51
Total Magnesium (mg/L)	0.54	0.88										
Total Manganese (mg/L)	0.02	<0.01						0.02	<0.02	<0.02	<0.02	<0.02
Total Nickel (mg/L)	0.05	<0.01					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dissolved Potassium (mg/L)	0.3	0.6										
Dissolved Sodium (mg/L)		1.2										
Dissolved Zinc (mg/L)								E				
Total Zinc (mg/L)	<0.005	<0.005					<0.005	0.005	<0.005	<0.005	<0.005	<0.005
Fecal Coliform (MPN)					<2		<20	<20	<20	<2		
Total Coliform (MPN)	7		<2		5		<20	<20	20		<2	