Water Resources Inventory Report:

Physical, Chemical and Biological Characteristics of Wing, McDonald, Kemp and Bjerkness Creeks

2001

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Prepared for: **Kaslo Community Forest Society, Kaslo,BC.**

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Executive Summary

This is the fourth annual report relating to the Water Resources Program for Wing, McDonald, Kemp and Bjerkness Creeks. This monitoring program is administered by the Kaslo and District Community Forest (KCFS) and funded by Forest Renewal BC.

McDonald, Kemp and Bjerkness Creeks are designated as Community Watersheds and Wing Creek is a Domestic Watershed. These streams are low order streams located in the West Kootenays on the west side of Kootenay Lake. Three of these creeks (Wing, McDonald and Kemp) are within the Kaslo Community Forest. KCFS is a registered non-profit organization that was established in 1997 to increase the participation of the community in the management of local forests and to create local sustainable employment. It is also part of their mandate to ensure that forest management and harvesting techniques used will have the least impact on other resource values such as water quality. Harvesting activity levels vary from one watershed to the other. Wing Creek has had no harvesting to date. Most of the harvesting in McDonald Creek took place in the late 1980’s and further harvesting is planned. Two blocks downstream of the water intake were logged in the Kemp Creek watershed in 2000 and 2001, and no further developments are proposed for this watershed within the next five years. Logging in the Bjerkness Creek watershed was mainly completed during the 1970’s, with some private logging occurring in 2001.

This program was designed to provide a baseline of the water quality and quantity for at least five years, four of which have now been completed. However, some of the data collected in previous years may be somewhat unreliable due to problems with the automated continuous monitoring stations. To improve the quality of the data, modifications were made to the 2001 water quality and quantity monitoring program due to the persistent problems encountered with the continuous monitoring equipment. A more hands-on approach was adopted by discontinuing the use of this equipment and by increasing the frequency of manual gauge readings and water quality grab sampling. Gauge readings were done at various frequencies during the year, with up to four readings per week during freshet. Basic grab samples, which measured pH,

conductivity, total suspended solids and turbidity, were also collected at various frequencies with up to 3 or more samples per week during freshet. The sampling program was designed to focus most of the sampling during freshet, which is when most of the drastic changes occur, such as increases in water levels, suspended solids and turbidity. Field measurements of air temperature, water temperature, pH and conductivity were also collected at each site visit. In addition to this basic sampling regime, stratified samples were collected during freshet and the fall low flows. These samples were analysed for the following parameters: true colour, hardness, total alkalinity, total dissolved solids (filterable residue), low level nutrients (nitrate+nitrite, soluble reactive phosphorus, and total phosphorus), bacteriology (total and faecal coliforms, and *E. coli*) and low level metals (total metals and dissolved aluminum). All measured parameters were compared to provincial Water Quality Guidelines for drinking water and/or aquatic life. Benthic and periphyton samples were collected in Wing Creek and Bjerkness Creek.

The hydrometric data collected during 2001 indicate that water flows were generally lower than average due to the lower than average snow pack levels and that freshet ended a month earlier than in previous years. The flows in Wing Creek did not even register an increase during freshet. After decreasing during summer months, flows returned to average in the fall when precipitation levels returned to normal during the months of October and November.

Water temperatures in all creeks were within the Water Quality Guidelines for aquatic life with a maximum of 13 ^{o}C recorded in both McDonald Creek and Bjerkness Creek. The average pH was slightly basic in all creeks and varied slightly over the course of the year. The average conductivity for Wing, McDonald, Kemp and Bjerkness Creeks was 242 μS/cm, 178.9 μS/cm, 213.8 μS/cm and 169.8 μS/cm, respectively. No seasonal pattern for both pH and conductivity were noticeable for Wing Creek, however pH was significantly lower during freshet in the other three creeks. This is to be expected as spring runoff results in a dilution of the ions contributing to pH and conductivity.

A seasonal pattern is to be expected for both turbidity and total suspended solids, with these values increasing during spring freshet. The increased runoff during freshet entrains sediments and small particles that contribute to the suspended matter in the water. Turbidity and total suspended solid values showed little changes for the recorded period for Wing Creek due to the constant flows throughout the year. Increases during spring freshet were more noticeable in the other creeks but no significant differences were found between mean concentrations of these parameters in low and high flows. In general, turbidity and total suspended solids were relatively low in all creeks with a maximum turbidity of 2.5 NTU recorded in Kemp and Bjerkness Creeks and a maximum total suspended solids of 8.4 mg/L, 10.2 mg/L and 16.2 mg/L recorded in Wing, Kemp and Bjerkness Creeks, respectively. These values resulted in no exceedances of the B.C. Water Quality Guidelines.

All remaining water quality results were within the limits set by the Water Quality Guidelines (MELP, 1998). Faecal coliforms for Wing and Bjerkness Creeks, however, exceeded the Drinking Water Quality Guidelines for untreated water for one sampling event during spring freshet. This indicates that faecal contamination may be an issue during spring freshet. Careful monitoring of the drinking water is highly recommended especially during spring freshet.

The species diversity, presence of low tolerance species indicate a healthy ecosystem in Wing Creek, however, the moderate HBI number and decrease in specialised feeders suggest that the ecosystem may be slightly impacted. On the other hand, the abundance of chironomids collected, the moderate HBI number and the dominance of generalist feeders such collector gatherers and collector filterers all suggest that Bjerkness Creek is slightly impacted. The benthic data collected in 2001 differed from the previous years, as organisms were much more abundant and the diversity of taxa was also greater. The extremely low water levels and dry weather experienced in the former part of the year may have caused an increase in abundance and species diversity as well as causing a shift to a greater proportion of more tolerant species, due to increased water temperatures.

The current water quality and quantity monitoring program will require downsizing due to reduced funding. The program should, however, be maintained as it provides crucial information on the state of the health of the watersheds. Impacts due to anthropogenic activities, such as forest harvesting, can be monitored by comparing before and after water quality conditions within the creek. Water quality results can be compared to B.C. Water Quality Guidelines and ensure that the drinking water provided to local residents remains in its pristine condition. The following recommendations will ensure that program objectives will be achieved in Wing, McDonald, Kemp and Bjerkness Creeks:

- Collection of manual gauge readings should continue at the same frequency set out in the 2001 water quality and quantity program. Gauge readings are a critical component of this program and readings are completed up to four times per week during the freshet period. Additional readings should also be completed during and after major rain events.

- Metering of the stream should be completed 8 times during the year, to produce a stage-discharge curve. Metering of the stream is important as it provides a relationship between the water levels and the discharge. This should be repeated every year due to the inherently unstable nature of streams.

- Collection of basic grab samples should continue at the same frequency set out in the 2001 water quality and quantity program. These basic samples should measure pH, conductivity, turbidity and total suspended solids. The sampling frequency may be up to 3 to 4 times weekly during spring freshet. Additional sampling to the scheduled samples should also be collected during and after major rain events.

- Collection of stratified samples could be decreased, as four years of data have been collected. Most of the parameters were below water B.C. Water Quality Guidelines and/or below detection limits. However, continued sampling of micro-organisms including faecal coliforms and *E. coli* is recommended, due to potential faecal contamination concerns during freshet.

- “Snapshot” monitoring of stratified sampling could be completed at a reduced frequency. For example some parameters could be measured once during low and high flows.

- Four years of benthic data are now available for Wing Creek and Bjerkness Creek providing a relatively good baseline. Since the program must be downsized, biological sampling frequency could be reduced from annually to every 3 to 5 years, as the biota are good indicators of the health and functioning of the stream. Cumulative impacts and changes over time within the watershed would be displayed by a shift in the community composition.

- A cursory annual report could be produced summarising the data collected (including production of tables and graphs) with a more in depth report produced every 3 to 5 years.

With these recommendations in place, the monitoring program will continue to collect good quality data that can be used in characterizing the water quality and quantity of these streams.

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1 INTRODUCTION

This report constitutes the fourth annual report for the water quality monitoring program for Wing, McDonald, Kemp and Bjerkness Creeks. The previous two reports have been completed by Aquatic Resources Ltd. and to reduce duplication of work the general background information was obtained from the 2000 report (Sundberg 2001).

1.1 Background

The water quality monitoring program for Wing, McDonald, Kemp and Bjerkness Creeks was initiated in 1998 by the Ministry of Environment, Lands and Parks (MELP) and the Kaslo and District Community Forest Society (KCFS) as part of the Forest Renewal B.C. (FRBC) Water Resources Inventory Program in the Kootenay Region. The KCFS is a registered non-profit organization that was established in 1997 to increase participation of the community in the management of the local forests and to create local sustainable employment. The KCFS's mandate is to meet targets for allowable harvest (10,000 m^3 annual allowable cut) in the Kaslo Community Forest using forest management and harvesting techniques that will have the least impact on other resource values, such as water quality.

The Kootenay Region monitoring program was developed to create a network of water quality information for Community Watersheds and high value fisheries streams. Wing, McDonald, Kemp and Bjerkness Creeks were chosen as representative watersheds because of their status as Community Watersheds (McDonald, Kemp and Bjerkness Creeks) and as a Domestic Watershed (Wing Creek). In addition, all four watersheds have different levels of forestry developments and/or proposed harvesting. It is important to track the effects of anthropogenic influences on water bodies that provide drinking water to communities.

This program was designed to provide a baseline of the water quality and quantity for at least five years, four of which have been completed (Sundberg 2001; Quamme and Sundberg 2000). This report presents the results obtained from the water quality and quantity monitoring program for 2001.

Eventually, the baseline data obtained at these stations will be used to develop Water Quality Objectives consistent with the site specific characteristics and seasonal and temporal variation inherent to these drainages. Additionally, the baseline data will be utilised to detect any changes incurred by future developments within these drainages.

1.2 Rationale and Objectives

The purpose of this Water Resource Inventory is to enable short and long-term evaluation of the water resource. This specific project monitors water quality and quantity within Wing, McDonald, Kemp and Bjerkness Creeks and in addition monitors biological characteristics in Wing and Bjerkness. The 2001 monitoring program was modified to reduce the reliance on automated equipment that was not functioning properly to a more intensive manual gauge reading and grab sampling program. Grab samples capture water quality parameters, while gauge readings allow the development of an annual discharge curve, once a hydrograph has been developed for each creek.

Through the monitoring of watersheds like Wing, McDonald, Kemp and Bjerkness Creeks, the Water Resources Inventory Program hopes to achieve the following objectives:

- characterize baseline water quality, water quantity and ecological health of streams throughout BC,
- track trends in water quality and provide early warnings of abnormal changes or conditions that might be damaging to aquatic systems,
- evaluate impacts of land use activities and assess the efficacy of the Forest Practices Code (FPC) in protecting water quality,
- use information collected to set water quality objectives for community watersheds, a FPC requirement.

The specific objectives of the 2001 study were to:

- continue the water monitoring program initiated in 1998,
- provide information on the status, health, trends and uses of water resources within or adjacent to the Kaslo Community Forest’s operating area,

- establish a baseline water quality and quantity data set from which to compare data from subsequent years (e.g. post harvest), and
- assess the biological integrity of the benthic macroinvertebrate communities in Wing and Bjerkness Creeks.

2 Study Area

2.1 Characteristics of Study Streams

Wing, McDonald and Kemp Creeks are located within the Kaslo Community Forest near the Village of Kaslo and Bjerkness Creek is located at the Community of Mirror Lake (Figure 2.1). General characteristics of each watershed are presented in the following table.

Table 2.1. General characteristics of Wing, McDonald, Kemp and Bjerkness Creeks.

	Wing Cr.	McDonald Cr.	Kemp Cr.	Bjerkness Cr.
EMS Id	E232104	E233202	E233203	E232103
Aspect	E	SE	NE	N
Length (km)	3.02	7.68	10.32	6.46
Watershed area (ha)		217.9	1,179.5	2,499.3
Maximum elevation (m)	1,550	1,242	2,150	2,554
UTM at monitoring station	11.5512334.501059	11.5512293.501056	11.5512272.501019	11.5512237.501062
Elevation at monitoring station (m)	824	732	976	635
Gradient at monitoring station (%)	3.0	3.0	>25	3.0
Stream order*	3rd	2nd	4th	3rd

*Stream orders were derived from 1:20,000 scale TRIM maps.

2.1.1 Wing Creek

Wing Creek flows eastward into Kootenay Lake and is characterized by generally steep gradients. Its headwaters are a series of small first order tributaries that drain a steep (~70% gradient) catchment area covering 1-2 km^2. The middle reaches flow through a steep (~50% gradient), deeply incised channel, while the lower reaches have lower gradients (<20%) and are less confined (Wells 1995).

Typical of high-relief drainage basins in the area, the Wing Creek watershed contains extensive debris slide scars and gullies. Debris slide scars, roughly 100 years old, are located along the middle portions of the watershed and appear to be related to an extensive forest fire that occurred around that time (Wells 1995).

Wing Creek is a domestic watershed providing water to local residents for domestic and irrigation purposes. There are currently 9 registered water licenses (Appendix 3).

No fisheries information was available for this watershed. Based on channel gradients downstream, it is probable that fish are unable to migrate upstream from Kootenay Lake.

There has been no logging or development activities within this watershed. Any industrial developments should be undertaken with care due to the area's unstable slopes and erosion potential.

2.1.2 McDonald Creek

The headwaters of McDonald Creek originate from the southern end of the Blue Ridge on the eastern edge of the Selkirk Mountains and consist of a small wetland located at 1,242 m in elevation. The creek flows southwards until it reaches the Village of Kaslo, then turns east to discharge into Kootenay Lake. The upper parts of the watershed are relatively steep with several avalanche chutes originating from the southeast side of the mountain. Small gravely sediment flats and woody debris accumulations characterize the stream channel. The substrate appears to be highly mobile in parts of the channel, with unstable steps composed of small woody debris.

McDonald Creek is a community watershed providing water to local residents and the waterworks local authority of Kaslo for domestic and irrigation purposes. There are currently 4 registered water licenses (Appendix 3).

No fisheries information was available for this creek, however, the stream designation is similar to a fish-bearing stream due to the community watershed designation.

Forest harvesting took place in the watershed during the late 1980's, and further harvesting is planned within the next five years. Development within this watershed is currently limited, but the channel's instability and steep slopes make it likely that further developments would increase its sediment load (Wells and Wallace 1999). An IWAP was completed in 2000. The recommended ECA level for this watershed is 20 % for the entire watershed and 15 % for the eastern slopes (Green 2000). Road and trail construction should be avoided on the steep slopes on the east flank of Mt. Buchanan. Vehicular access within this watershed makes it a popular destination for local recreationalists.

2.1.3 Kemp Creek

Kemp Creek flows northeast into the Kaslo River and is fed by tributaries that cascade down its steep valley walls into two main sub-basins. The western sub-basin originates at an elevation of 2,150 m, while the east sub-basin begins at 2,010 m elevation.

The upper parts of the watershed are characterized by steep, glacier carved valley walls with avalanche scarred slopes. The creek flows through a steep, V-shaped valley just upstream of the village water intake, where sediment deposits from erosion and debris slides accumulate.

Kemp Creek is a community watershed providing water to waterworks local authority of Kaslo, which then distributes it to residents of Kalso for domestic purposes. There are currently 2 registered water licenses (Appendix 3).

No fisheries information was available for this watershed, however, the stream designation is similar to a fish-bearing stream due to the community watershed designation.

Two blocks were harvested downstream of the water intake in the Kemp Creek watershed in 2000 and 2001. No further developments are proposed within this watershed within the next five years.

2.1.4 Bjerkness Creek

The headwaters of Bjerkness Creek originate from a cluster of alpine lakes on Trafalgar Mountain at an elevation of 2,554 m. Lofstedt Creek, which is a tributary of Bjerkness Creek, enters the mainstem at 640 m elevation. The morphological characteristics of this tributary vary greatly between the upper and bottom elevations. The upper reaches are characterized by shallow flows, steep gradients and bedrock substrate. The lower reaches, downstream of the Lofstedt Farm intake, have gentler gradients and a predominantly marshy substrate (Wells and Wallace 1999).

Bjerkness Creek is a community watershed providing water to the community of Mirror Lake for domestic and irrigation purposes. There are currently 54 registered water licenses (Appendix 3).

Bjerkness Creek has been reported to support populations of kokanee and rainbow trout (FISS). These are part of adfluvial populations residing in Kootenay Lake and utilizing the lower reaches of Bjerkness Creek for spawning and juvenile rearing.

Most of the logging activities within this watershed took place during the 1970's and the latest harvesting was completed in 2001 on private land by Cooper Creek Cedar. This logging is located along the lower reaches of Bjerkness Creek in the vicinity of the community water intake. Some sections of the cutblock appear to be relatively close to the creek and are within the riparian zone.

2.2 Biogeoclimatic Zones

The study watersheds traverse four different biogeoclimatic subzones (Wells and Wallace 1999). The lower elevations (<1,200) are mostly found within the ICHdw sub-zone (dry warm Interior Cedar-Hemlock subzone) and the mid elevations (1,200 m to 1,550 m) are within the ICHmw2 subzone (Shuswap moist warm Interior Cedar - Hemlock subzone). The upper elevations (1,550 m to 1,950 m) are within the ESSFwc4 variant (Selkirk wet cold Enngelman Spruce – Subalpine Fir subzone). The highest ridges are in the Alpine Tundra or the ESSFwcp (Wet Cold Parkland Engelmann Spruce – Subalpine Fir subzone).

The mean annual precipitation of the ICH biogeoclimatic zone is 50 to 100 cm and the ESSF is 70 to 200 cm. The ICH subzones are characterized by very hot, moist summers and very mild winters with light snowfall. Soils generally dry out for moderate to long periods of time in late summer. Snowpacks are generally of moderate depth and duration, which, combined with the mild climate prevent soils from freezing to any significant depth (the exception being some bladed soils). Climate is not a major limitation to growth on zonal sites, with moisture becoming limiting on dry sites and frost becoming limiting on some depressional sites (Braumandl and Curran, 1992). The ESSFwc4 subzone is likely colder and wetter, with more snow than the ICH.

Very few climax or old-growth stands of ICHdw subzone exist due to logging and fires set by miners at the turn of the century. The ICHdw is the most diverse subzone in the province in terms of tree species. It contains 14 commercial species with the most common being Douglas fir *(Pseudotsuga menziesii)*, western larch *(Larix occidentalis)*, western cedar *(Thuja plicata)*, western hemlock *(Tsuga heterophylla)*, paper birch *(Betula papyrifera)* and white pine *(Pinus monticola)*. Common shrub species include falsebox *(Paxistima myrsinites)*, Douglas maple *(Acer glabrum)*, black huckleberry *(Vaccinium membranaceum)* and baldhip rose *(Rosa gymnocarpa)*. Common herbs are twinflower *(Linnaea borealis)*, prince's pine *(Chimaphilla umbellata)*, queen's cup *(Clintonia uniflora)* and wild sarsaparilla *(Aralia nudicaulis)* (Braumandl and Curran, 1992).

The ICHmw2 is characterized by stands of western hemlock and western red cedar in the climax forests. However, seral stands are more common and include primarily Interior Douglas fir, western larch, spruce (*Picea glauca x engelmannii*) and the two climax species above. Common shrubs throughout this zone include black huckleberry and falsebox. Common herbs consist of twinflower, princes's pine, queen's cup and one-leaved foam-flower *(Tiarella trifoliata* var. *unifoliata)*. Red–stemmed feathermoss *(Pleurozia schreberi)*, pipecleaner moss *(Rhytidiopsis robusta)* and step moss (*Hylocomium splendens*) are also prevalent (Braumandl and Curran, 1992).

The ESSFwc4 subzone is characterized by the predominance of stands of subapline fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmanni*). The dominant shrubs in this zone are white-flowered rhododendron (*Rhododendron albiflorum*), black huckleberry, and gooseberry (*Ribes sp.*). Herbs include oak fern (*Gymnocarpium dryopteris*), one-leaved foamflower, Sitka valerian (*Valeriana sitchensis*), and five-leaved bramble (*Rubus pedatus*).

2.3 Geology

The parent material within the study area consists predominantly of Paleozoic metamorphic bedrock with lesser amounts of Triassic argillites and Jurassic intrusives (Reesor 1996). A large

Quaternary glacial deposit form the Shutty Bench-Wing Creek area. Geology is of volcanic and sedimentary origin that was later metamorphosed. While most of the Kemp Creek area is underlain by the Triassic Slocan Group (TS – argillite, phyllite and limestone), the upper end of one of its tributaries is mapped as Jurassic Nelson Suite of Intrusives (biotite granodiorite) (Wells and Wallace 1999).

2.4 Wildlife

Wildlife occurrences within the study area are generally limited to ungulates (elk and deer), bear and a host of small mammals and winged species associated with the ICH and ESSF biogeoclimatic zones. There are no completed wildlife inventories within the area.

2.5 Locations of Monitoring Stations

The Wing Creek monitoring station can be accessed via Jacob's Subdivision Road, which is located approximately 6 km north of Kaslo along Highway 31 and is then accessed on foot via SubLot 13A. The makeshift weir at the sampling location is located approximately 500 m northwest of the road access point.

The McDonald Creek monitoring station is located near the community water intake weir and access is via Brennand Road. The site is located approximately 200 m from the road, on private land (L874).

The Kemp Creek monitoring station is located near the village water intake and dam. This site is accessible by road via the Kaslo municipal landfill and then along a steep road comprised mainly of loose material (e.g. boulders, cobbles, gravel and fines). This road has been reported as a significant sediment source to the creek (Wells 1995).

The Bjerkness Creek monitoring station is located at the Mirror Lake community reservoir. The community itself is located approximately 7 km south of Kaslo. Road access to the site is via Birch Hill Lane up to the gated watershed entrance. The dam is located ~1 km up the gravel road from the gate. Access can be obtained from the local resident residing next to the entrance.

2.6 Management Issues

McDonald, Kemp and Bjerkness Creek are designated as Community Watersheds and Wing Creek as a Domestic Watershed and therefore, must adhere to drinking water standards set out by the provincial and federal governments (CCME, 1996, MELP, 1998b, updated 1999). Because specific management guidelines in the Forest Practices Code exist for forestry activities that occur in Community Watersheds, the maintenance or enhancement of water quality should be a primary consideration to all users within the watershed. The management of wildlife species and their habitat, soils, biodiversity, visual impacts and archaeology are also some of the concerns for forestry operations.

3 METHODS

Modifications to the methodology were made to the 2001 water quality program. Due to persistent problems with the continuous monitoring stations, it was decided to remove the automated stations from the program and to proceed with a more intensive manual gauge reading and grab sample regime. Monthly reports were submitted to the Ministry Representative and are included in Appendix 2.

3.1 Data Collection

The purpose of this project is to determine the status of Wing, McDonald, Kemp and Bjerkness Creeks based on a thorough measurement of many of their physical, chemical and biological characteristics. Biological samples were only collected in Wing Creek and Bjerkness Creek. All data collection and reporting was carried out in accordance with Resource Inventory Committee (RIC) approved standards for inventories in B.C (MELP, 1998a and b).

3.1.1 Hydrometric Measurements

Manual water level measurements were collected from staff gauges at the water monitoring stations at Wing, McDonald and Bjerkness Creeks and at a gauge upstream of the Kemp Creek water intake. The number of gauge readings was increased in 2001 from weekly/biweekly in the 2000 sampling program to up to four times a week during freshet for a total of 90 readings for the entire year (Table 3.1). The new gauge reading frequency was incorporated on April 1 for the new fiscal year. Additional readings were also taken during major rain events.

A Price 622AA vertical shaft meter was used to measure stream velocity. Velocity measurement methodology followed RIC (1998) standard procedures, and involved metering the water at regular intervals across a cross section. For each reading the rod of the current meter was held in a vertical position with the probe completely submerged and pointing directly into the current. If water depth was sufficient, the readings were recorded at a depth of 0.6 m. Each velocity measurement was taken over at least 40 seconds. Readings were recorded across the entire wetted width of the creek, the stage level was recorded, and then the process was repeated.

The width-velocity data, coupled with manual stage readings, was used to create stage discharge curves for Wing, McDonald, Kemp and Bjerkness Creeks. Power regression calculations were performed on the stage level and flow data collected to determine regression constants for the formula $y=ax^b$. Results were analysed and erroneous data (outliers) were discarded based on the correlation coefficient *r*. The best fit line was graphed for each creek, and the formula was used to calculate flow values and produce hydrographs. All hydrometric forms are provided in Appendix 1.

Table 3.1 Schedule for gauge readings for the 2001 Kaslo water quality program.

Month	Readings / Week	Total / Month
January	Biweekly	2
February	Biweekly	2
March	2	8
April	3	12
May	4	16
June	4	16
July	3	12
August	2	8
September	1	4
October	1	4
November	1	4
December	Biweekly	2
Total		**90**

3.1.2 Grab Sampling

Two grab sampling methods were used to measure water quality. Measurements were taken in the field by the portable handheld meters (alcohol thermometer, Hanna pHep1 pH meter and Hanna DiST W conductivity meter), and grab samples were collected and shipped to a laboratory for analysis.

3.1.2.1 Laboratory Analysis

Basic water quality samples were collected throughout the year. The grab sampling frequency was also increased for the 2001 sampling program (Table 3.2). The basic grab samples were analysed for the following parameters: pH, specific conductivity, total suspended solids (non filterable residue) and turbidity.

Table 3.2 Schedule for water samples for the 2001 Kaslo water quality program.

Month	Water Samples / Week	Total / Month
January	Biweekly	2
February	Biweekly	2
March	1	4
April	2	8
May	3 or more	12
June	3 or more	12
July	1	4
August	Biweekly	2
September	Biweekly	2
October	Biweekly	2
November	Biweekly	2
December	Biweekly	2
Total		**54**

In addition to these basic samples, more intensive sampling, termed stratified sampling, occurred during the seasonal extremes of the year: the spring freshet season and the late fall season low flows. Stratified sampling during freshet was carried out between May 16 and May 31 and during low flow conditions between September 11 and October 2 (Table 3.3). Freshet is when water flows and quantities are highest, while the late fall season corresponded to base flow, when water flows and quantities are at their lowest. Water quality and quantity parameters are expected to be at their most extreme at these points throughout the year, and these times were sampled to determine the seasonal variation inherent to Wing, McDonald, Kemp and Bjerkness Creeks. Samples were to be taken weekly for 5 weeks, constituting a 5 in 30 sampling regime (5 samples within 30 days) which is required to characterize and perform statistical analyses on these data sets.

The stratified samples measured, in addition to the biweekly samples, true colour, hardness, total alkalinity, total dissolved solids (filterable residue), low level nutrients (nitrate+nitrite, soluble reactive phosphorus, and total phosphorus), bacteriology (total and faecal coliforms, and *E. coli*) and low level metals (total metals and dissolved aluminum).

Table 3.3 Water Quality Sampling Calendar, 2001

Date	Sample Set
May 16 to May 31, 2001	Stratified Set
September 11 to October 2, 2001	Stratified Set
Stratified Set: Basic Set PLUS total alkalinity, true colour, TDS,nutrients and bacteriology	

Standard techniques outlined in government RIC (Resources Inventory Committee) documents were followed (Cavanagh *et al*., 1998, Cavanagh *et al*., 1994a and b). Most of these variables could be analysed using the water collected in a standard 1L polyethylene bottle, however additional bottles were required for total metals and bacteria samples. Bacteria were collected in a sterilised bottle and total metals were collected in an acid-washed bottle and preserved with 2mL of concentrated nitric acid.

After sampling, all bottles were immediately placed in an ice-filled cooler and sent to the laboratory, where they were analysed within 48 hours. Passmore Laboratory performed the analysis on the basic samples, and Cantest Laboratories of Vancouver, B.C. performed the analysis on the stratified samples.

3.1.2.2 Field Measurements

Field measurements were taken in the field with portable handheld meters (alcohol thermometer, Hanna pHep1 pH meter and Hanna DiST W conductivity meter). The manual measurements for pH, air and water temperature, and conductivity were taken at each site visit. The field meter was calibrated regularly with standard solutions each time it was used in the field.

3.1.3 Biological Sampling

The sampling methodology for the biological sampling followed RIC standards (Cavanagh *et al*., 1994b), except where changes were deemed necessary, in which case, established scientific protocol was followed (Barbour *et al*., 1997; Plafkin *et al*., 1989). On September 26, 2001, Wing and Bjerkness Creeks were sampled in riffle areas for periphyton and benthic invertebrates.

3.1.3.1 Periphyton

A rectangular sampling frame made of flexible rubber was used to sample the periphyton. This material provided a known area of 41.25 cm^2 (7.5 cm x 5.5 cm). At each site, five replicate rocks were chosen from the stream to act as representative growing surfaces for the attached algae. If possible, relatively flat rocks at similar depth and light exposure were selected to minimise environmental variation and maximize ease of sampling. Only rocks completely covered by water were chosen. Aside from these requirements, the rocks were chosen randomly, without regard for apparent algal content.

The sampling frame was placed on a flat portion of the exposed surface and the entire surface within the frame was scraped with a scalpel. The scraped algae were then transferred onto a filter paper. The filter papers were wrapped in aluminum foil and put on ice to prevent additional growth of the algae and were then kept in the freezer until ready for processing in the lab. The samples were analysed for chlorophyll *a* and phaeophytin *a* biomass. These two pigments are the primary photosynthetic pigments in algae and are used to assess the amount of algae in the sample.

The periphyton samples were sent for analysis to ALS Environmental (formerly ASL Analytical Service Laboratories Ltd.) in Vancouver, BC.

3.1.3.2 Benthic Invertebrates

A Hess sampler (mesh size 210 μm with an area of 0.09 m^2) was used to quantitatively sample the streambed for benthic macroinvertebrates. At each stream location, five replicate sites were chosen and were approached in an upstream manner, in order to not disturb the substrate and potentially lose invertebrates. Riffles with adequate flow and a gravel/cobble substrate were chosen for sampling. Riffles, as opposed to pools or other habitats, were sampled for several reasons: they are easier to identify, are more uniform in microhabitat and therefore, more comparable and have high current velocities and shallow depths, facilitating the use of sampling equipment (Fore *et al*., 1996).

The Hess sampler was placed in the stream and positioned securely into the gravels to eliminate gaps between the bottom of the sampler and the streambed. Larger rocks were removed from within the sampler after being brushed thoroughly but gently and rinsed in the water inside the sampler. This process removed all attached organisms and washed them into the sampling net. The gravels were disturbed by hand to a depth of around 10 cm for about 1 minute. After rinsing the inside net of the sampler, the gravels were disturbed again and the net rinsed so that all organisms were collected into the bottom cup. The cup was detached and the entire contents (with a minimal amount of water) were transferred to a clean plastic 500 mL sample jar, after being rinsed through a 210 μm sieve. Large rocks and debris were discarded after being rinsed and inspected to remove all clinging organisms. A significant departure from the RIC protocol for Hess sampling was taken in this sampling method: the five samples were not composited into one, as dictated in the RIC protocol, but rather, left as individual replicates. Replication is necessary to determine the variation inherent in the benthic habitats and to statistically analyse data between and within sites over time.

Immediately after collection, all samples were preserved by adding between 200 to 300 mL of formalin (10% buffered formaldehyde). The samples were then taken back to the laboratory. After a week, the formalin was removed and the samples were preserved in 70% ethanol. The formalin preserves the invertebrates in a better state for taxonomic identification than ethanol alone. The samples were then picked for all organisms and subsampled if necessary. All organisms were then sent to Danusia Dolecki, at UBC, where they were counted and taxonomically identified to the level of genus, if possible. The level of identification largely rests on the detail of available taxonomic keys and on the condition and size of the specimens. While there is a vast collection of detailed taxonomic information for North American benthic macroinvertebrates, the possibility of finding unknown and therefore unnamed species in this B.C. stream exists, potentially losing detail and precluding a thorough species list. Very immature and small specimens are difficult to identify, having not developed some of the diagnostic features used in the taxonomic keys. In these situations, organisms were identified to the lowest possible level.

3.2 Data Analysis

3.2.1 Grab Sampling

The data collected from both the laboratory and field measurements were entered into spreadsheets and then displayed in various table and graphical form. Student's t-tests were completed to determine if there were significant differences between the high and low flow data (P=0.05) (Zar, 1984).

The data was also compared to current Water Quality Guidelines as outlined by MELP. These guidelines can be found in several publications (CCME, 1996; MELP, 1998b, updated, 1999). When water quality is found to exceed the stated guidelines, the implications are that further investigation is warranted. The first step is to determine if the data are real and not a result of contamination or incorrect sampling techniques. The level and frequency of the contamination is also investigated and compared to the stream hydrologic cycle at the time. Any potential contamination could be caused by seasonal extremes that are expected in any natural system, whether impacted by urbanisation, forestry, agriculture, or other anthropogenic activities. One of the goals of this monitoring program is to understand the water quality characteristics, which includes the inherent seasonal and temporal variability. In order to fully understand the water quality characteristics of this creek, it is important that the water quality data be strengthened over a period of years. In time, specific Water Quality Objectives can be developed for the Wing, McDonald, Kemp and Bjerkness Creeks drainage, which are realistic and site-specific. In the short term, resource managers must be aware of the potential variability in the data trends.

3.2.2 Biological sampling

3.2.2.1 Periphyton

For most ecological purposes, spectrophotometric determination is the most suitable for periphyton analysis, and was used in this study (Marker *et al*., 1980a and b). Chlorophyll *a* is recommended as an indirect measure of periphyton biomass because it is closely linked to photosynthesis. Phaeophytin *a* was also determined because the samples were taken in the fall, when senescence of algae may have begun. If dead and moribund cells and degradation products are present, then a phaeophytin correction is needed to estimate all periphyton (Wetzel and Westlake, 1974).

3.2.2.2 Benthic Invertebrates

Simple graphical and statistical analyses in the form of multimetric analysis, rather than multivariate statistics, were used to interpret the macroinvertebrate data, an approach favoured by other studies (Fore *et al*., 1996; Plafkin *et al*., 1989).

The metrics used to interpret the biological data are measurable attributes of the biota that change in some predictable way with increased human influence. Biometrics are increasingly being used because they are responsive to different types of anthropogenic impact, are robust to variations in sample size and have low variability both within a site and over time (Fore *et al*., 1996; Chessman and McEnvoy, 1998). By using metrics to assess the biological state of the streams, information regarding the elements and processes of aquatic communities is maximised. Biometric analyses included taxonomic richness, abundance, tolerance indices, feeding type and comparisons of dominant taxa to determine the health and state of the aquatic invertebrate community. The ratio of EPT (Ephemeroptera, Plecoptera and Trichoptera taxa) to chironomids is a common biometric used to indicate the health of aquatic communities. In general, the proportions of chironomids rise with increasing pollution, replacing the more sensitive EPT species.

Data from these metrics was ranked and judged on a scale ranging from unimpacted to severely impacted, and in this way, the state of the ecosystem was assessed. Reliable biometric indicators of disturbed streams were assigned a level of impact on water quality based on Table 3.4 (Plafkin *et al*., 1989):

In general, natural and undisturbed aquatic systems will have a greater diversity of species, including sensitive species with little tolerance for poor water quality (Lehmkuhl, 1979). In contrast, impacted streams will have comparatively fewer taxa (but often in large numbers) composed of tolerant species, while unimpacted streams contain comparatively more taxa dominated by intolerant species (Hilsenhoff, 1988). Therefore, in relatively unstressed streams, intolerant Ephemeroptera, Plecoptera and Trichoptera are dominant, while in stressed systems, they are replaced by the more tolerant Diptera and oligochaetes (Lenat and Crawford, 1994). In stressed streams, chironomids account for the majority of the increases in Diptera (Lenat and Crawford, 1994).

Table 3.4 Impact Levels of Common Biometric Analyses

Biometric	No Impact	Slight Impact	Moderate Impact	Severe Impact
Total Number of Taxa	>26	19 - 26	11 - 18	<11
Number of EPT Taxa	>10	6 - 10	2 - 5	<2
EPT/Total Taxa	>40%	30 - 39%	20 - 29%	<20%
EPT/EPT+Chironomid Ratio	>75%	50 - 75%	25 - 50%	<25%
% Dominant Taxon	<20%	20 - 29%	30 - 39%	>40%
Hilsenhoff Biotic Index	0 - 3.5	3.5 - 5.5	5.5 - 7.5	7.5 - 10

Tolerance values of the different taxa were used to determine Hilsenhoff's Biotic Index (HBI) with the following formula (Hilsenhoff, 1977):

Equation 1 Hilsenhoff's Biotic Index

$$HBI = (\Sigma n_i a_i) / N$$

n_i = the number of individuals in each taxonomic group

a_i = the pollution tolerance score for that taxonomic group

N = the total number of organisms in the sample

Tolerance values have been previously determined in the literature for each taxon based on their relative presence/absence in areas of known levels of disturbance. A higher rating means a higher tolerance to pollution. These values were originally developed for organic pollution (sediment loading and lowered oxygen values), however, studies have shown that these tolerance values are sensitive to a wide range of environmental degradation (Fore *et al*., 1996; Chessman and McEvoy, 1998). Tolerance values for each taxon were obtained from several documents (Plafkin *et al*., 1989; Barbour *et al*., 1997; Hilsenhoff, 1988a).

The taxa were also classified according to their functional feeding group (FFG), which categorises invertebrates based on their feeding mode (Cummins and Klug, 1979; Merritt and Cummins, 1996) (Table 3.5). As opposed to the previous biometrics, which measure the structure of the invertebrate community, FFG analysis measures its functioning relationships.

Table 3.5 Functional Feeding Group Classifications

Functional Feeding Group	**Dominant Food**	**Feeding Mechanism**
Predators	Living animal tissue	Attack prey, engulf or suck
Shredders	Living or dead CPOM*	Chewers (herbivores/detritivores)
Collector-Gatherers	Decomposing FPOM**	Detritivores or ingest sediments
Collector-Filterers	Decomposing FPOM	Suspension feeders
Scrapers	Periphyton	Graze surfaces
Parasites	Animal hosts	External/internal parasites
* CPOM = coarse particulate organic matter		
** FPOM = fine particulate organic matter		

For the purpose of this study, the taxa have been classified according to their primary feeding mode. When ambiguities about feeding ecology could not be resolved, taxa were identified as unknowns. Non-feeding stages such as pupae and non-aquatic adults were removed from the data set prior to the calculation of FFG analyses.

As with the pollution tolerance values, the functional feeding group classifications for each taxon were obtained from several documents (Plafkin *et al*., 1989; Barbour *et al*., 1997; Merritt and Cummins, 1996). Because of the lack of information specific to British Columbian streams, it was necessary to use these databases as surrogates for the multimetric analysis.

3.3 Quality Assurance and Quality Control

Quality assurance was maintained throughout the program and followed a systematic procedure. Firstly, only qualified, trained and experienced personnel who followed established protocol were used. As required by the contract, a quality assurance for the grab sampling component was conducted on September 26 by Ms. MJ. Jojic and Ms. Heidi McGregor, of Ministry of

Sustainable Resources Management, at which time duplicate samples were collected. Three types were used and included replicate samples at all sites, field blank samples at Wing and Kemp Creeks and trip blanks at Bjerkness and McDonald Creeks, which were all sent to Cantest. Each quality control method ensures that no contamination occurs at any step. Trip blanks are meant to detect any widespread contamination resulting from the container or preservative during transport and storage. Field blanks provide information on contamination resulting from handling techniques and from exposure to the atmosphere. Replicate samples ensures consistency in the sampling methods and technician. No duplicates were sent to Passmore, but the results of the basic samples at Cantest will be used to ensure consistency of the data.

Cantest and Passmore Laboratories conducted their own quality control procedures each time samples were analysed, but are not reproduced here, except to say that they passed all procedures within the allowable limits. Cantest is also a member of the CAEL (Canadian Association of Eligible Laboratories) and submits regularly to government testing and audits. All these methods ensured that the data was reliable and indicative of environmental conditions at that time.

To ensure the quality of the report and proper interpretation of the results, the report was submitted for review to Mr. Burke Phippen, R.P.Bio.

4 RESULTS AND DISCUSSION

All digital files of the report, tables and graphs are provided on compact disk in Appendix 4.

4.1 Hydrometric Measurements

The 2001 runoff was in most part much lower than average, due to the unusually low snow pack level, which was approximately 47% below normal. Typically, mountain streams experience extreme high flows at freshet, during snowmelt. This is often represented on the hydrograph by several peaks, which coincide with snow melt at different elevations. Other smaller peaks may also be present in the fall, at the onset of winter, when the amount of precipitation increases. The hydrographs for McDonald, Kemp and Bjerkness Creeks experienced below normal flows and the freshet period was represented by only one major peak which would coincide with snow melt at high elevation. No apparent peaks were displayed in the Wing Creek hydrograph. The precipitation was below normal during the summer, creating runoffs that were below average. Precipitation resumed to normal during the months of October and November, resulting in the November peak of 0.666 m3/s experienced in Bjerkness Creek.

4.1.1 Wing Creek

The Wing Creek stage-discharge curve was established using the regression formula $y=29{,}707.0296\ x^{7.8687}$ (r=0.97). The average daily discharge for the twelve-month period was 0.055 m^3/s. The maximum discharge reading for the period occurred on June 12 with a discharge of 0.077 m^3/s and the low for the period of record was 0.041 m^3/s and occurred throughout the period of record (Table 4.1).

The 2001 hydrograph for Wing Creek was not typical of high mountain streams as no significant peaks occurred throughout the year (Figure 4.1). This result differed from the 2000 hydrograph, which clearly showed an increase in discharge during freshet. Recorded flows varied between 0.01 m^3/s and 0.31 m^3/s in 2000 as the maximum reached in 2001 was 0.077 m3/s, a difference of 0.233 m^3/s. The unusual low snow pack during the winter of 2000-2001 created a relatively homogeneous hydrograph throughout the year. Because this watershed originates at fairly low elevations, it was not affected by high elevation snowmelt, which was well represented in Kemp and Bjerkness Creeks.

4.1.2 McDonald Creek

The McDonald Creek stage-discharge curve was established using the regression formula $y=342{,}213{,}259.8\ x^{36.2718}$. The average daily discharge for the twelve-month period was 0.013 m^3/s. Flows began to increase in early May with the maximum discharge reading for the period occurring on May 14 with a discharge of 0.480 m^3/s. A few smaller peaks were recorded during June after which the flows gradually decreased to reach a low of 0.0004 m3/s on August 29 (Table 4.2).

The 2001 hydrograph was characteristic of mountainous streams with a definite peak during spring freshet (Figure 4.2). Flows during freshet were slightly higher during 2001, with a high of 0.27 m3/sec attained in 2000. This years data also suggests that spring freshet would have occurred earlier in McDonald Creek than the other three creeks.

4.1.3 Kemp Creek

The Kemp Creek stage-discharge curve was established using the regression formula $y=12.2241x^{2.8862}$. The average daily discharge for the twelve-month period was 0.220 m^3/s. Flows began to increase in early May with the maximum discharge reading for the period occurring on May 28 with a discharge of 1.653 m^3/s. A few smaller peaks were recorded during June after which the flows gradually decreased to reach a low of 0.034 m3/s in November. The low for the period of record was 0.021 m^3/s and was recorded on February 9 (Table 4.3).

The 2001 hydrograph for Kemp Creek was characteristic of mountainous streams in that there was a significant peak during spring freshet, however there was only one major peak followed by a decrease in water flows (Figure 4.3). No major peak coincided with low elevation snow melt which usually occurs in April. The maximum flow was relatively similar to 2000 with a peak of 1.47 m^3/s on June 21, 2000. The unusual low snow pack during the winter of 2000-2001 and the paucity of snow at low elevations created a hydrograph displaying one major peak at freshet. This also resulted in a shift in the hydrograph with freshet ending a month earlier than in 2000.

4.1.4 Bjerkness Creek

The Bjerkness Creek stage-discharge curve was established using the regression formula $y=6.9096x^{2.9306}$. The average daily discharge for the twelve-month period was 0.622 m^3/s. Flows began to increase in early May with the maximum discharge reading for the period occurring on May 28 with a discharge of 5.412 m^3/s. A few smaller peaks were recorded during June after which the flows gradually decreased to reach a low of 0.184 m^3/s in November. The low for the period of record was 0.021 m^3/s and was recorded on February 22 (Table 4.4).

The 2001 hydrograph was characteristic of mountainous streams in that there was a significant peak at freshet, however there was only one major peak followed by a decrease in water flows (Figure 4.3). Flows were similar to 2000 with a peak of 3.03 m^3/s on June 21, 2000. The unusual low snow pack during the winter of 2000-2001 and the paucity of snow at low elevations created a hydrograph displaying one major peak at freshet. This also resulted in a shift in the hydrograph with freshet ending a month earlier than in 2000.

4.2 Grab Sampling

Basic samples collected throughout the year were sent to a laboratory and were analysed for pH, conductivity, turbidity and total suspended solids (TSS) (Tables 4.5 to 4.8). These parameters were graphically plotted for the entire year (Figures 4.5 to 4.20). The data for the stratified samples which were collected during spring freshet and fall low flows measured true colour, hardness, total dissolved solids, alkalinity, nitrate-nitrite, soluble reactive phosphorus, total phosphorus, total coliforms, faecal coliforms, *E. coli*, total metals and dissolved aluminum (Tables 4.9 to 4.16). Unfortunately, the detection limits for the stratified samples changed during the course of the program and were increased on the fifth sampling day. Due to this change half-way through the program comparisons between high and low flow averages for parameters with extremely low concentrations could not be made. In addition, some of the detection limits in the latter part of the program ended up being higher than some of the water quality guidelines. It is imperative that these detection limits remain the same throughout the program. In addition to grab samples, field measurements of air and water temperature, pH and conductivity were also collected.

4.2.1 General Water Quality Measurements

4.2.1.1 Air Temperature

Air temperature has a direct impact on the temperature of the water and can be affected by the amount of crown cover along the stream side. Direct sunlight for example will increase the air temperature, which will then increase the water temperature. In general air temperatures remained fairly constant during May to August with differences of ±5 ^{o}C which were affected by seasonal as well as diurnal changes (Figures 4.5 to 4.8). Temperatures were much lower during the winter months decreasing down to a minimum of –5 to -7 ^{o}C. The average air temperature during the recorded period was 7.6 ^{o}C with a maximum of 23 ^{o}C for Wing Creek, 8.6 ^{o}C with a maximum of 20 ^{o}C for McDonald Creek, 5.5 ^{o}C with a maximum of 18.5 ^{o}C for Kemp Creek and 10.2 ^{o}C with a maximum of 25 ^{o}C for Bjerkness Creek (Tables 4.5 to 4.8).

4.2.1.2 Water Temperature

Water temperature is extremely critical for the maintenance of a healthy functioning ecosystem due to its impact on other variables. For example, it affects the solubility of many chemical compounds and can influence the effect of pollutants on aquatic life. It also affects survival of salmonids, especially the egg and embryo stages which are more sensitive as they have adapted to a specific optimum range of temperatures. Stream-side vegetation removal can increase summer water temperatures by permitting sunlight to reach the water surface. Harvesting activities within Wing and McDonald Creeks has been minimal to inexistent and should have intact riparian habitats. Kemp Creek has had some harvesting downstream from the water quality monitoring station. Bjerkness Creek has had some logging completed in 2001 with harvesting within the riparian zone. The water temperature exhibited normal seasonal fluctuations for all creeks with a minimum of 0.3 ^{o}C and a maximum of 12.5 ^{o}C for Wing Creek, a minimum of –1 ^{o}C and a maximum of 13 ^{o}C for McDonald Creek, a miminum of –1 ^{o}C and a maximum of 11 ^{o}C for Kemp Creek, and a minimum of 1 ^{o}C and a maximum of 13 ^{o}C for Bjerkness Creek (Tables 4.5 to 4.8, Figures 4.5 to 4.8). The water temperatures were all within the Water Quality Guideline for aquatic life and fisheries, which allows a maximum between 13 and 15 ^{o}C for embryo development and 8 to 10 ^{o}C for spawning (CCME, 1996). However, fish presence has only been confirmed in Bjerkness Creek with rainbow trout and kokanee utilizing the lower reaches. Fish presence in the other drainages is not expected due to the high gradients found in the first few reaches.

4.2.1.3 pH

There were slight changes in pH levels throughout the data record for all creeks (Figures 4.9 to 4.12). The average pH was slightly basic at 8.16 for Wing Creek, 7.9 for McDonald Creek, 8.16 for Kemp Creek and 8.01 for Bjerkness Creek (Tables 4.5 to 4.8). pH varied approximately from 0.4 to 1 pH units over the recorded period. A high of 8.3 was recorded in July and August, and a low of 7.49 was recorded on January 16 for Wing Creek. A high of 8.18 was recorded on July 30 and August 23, and a low of 7.05 was recorded on August 29 for McDonald Creek. A high of 8.3 was recorded throughout the year, and a low of 7.8 was recorded on November 16 for Kemp Creek. A high of 8.22 was recorded on August 14 and November 14, and a low of 7.85 was recorded on June 27 for Bjerkness Creek.

No seasonal pattern for pH was noticeable for Wing Creek as the pH values collected during freshet were not significantly lower than those collected during the fall (P=0.987, $t_{0.05,(2),8} = 2.306$). This is to be expected as no significant changes in water levels were recorded. On the other hand, a seasonal pattern for pH was noticeable for McDonald, Kemp and Bjerkness Creeks as the pH values collected during freshet were significantly lower than those collected during the fall (P=0.002, $t_{0.05,(2),8} = 2.306$). A slight inverse relationship between discharge and pH should be expected, since during freshet, the ions that contribute to alkalinity are diluted.

4.2.1.4 Conductivity

There were also slight changes in conductivity throughout the year for Wing Creek (Figure 4.13) but seasonal ionic changes were clearly displayed in the other three creeks (Figures 4.14 to 4.16). Wing Creek had an average conductivity of 242 µS/cm with a high of 261 µS/cm recorded on April 19, and a low of 221 µS/cm recorded during the month of July. Conductivity averaged 178.9 µS/cm for McDonald Creek, 213.8 µS/cm for Kemp Creek and 169.8 µS/cm for Bjerkness Creek over the year and decreased substantially during freshet, to a low of 128 µS/cm on April 26 for McDonald Creek, 99 µS/cm on May 17 for Kemp Creek and 78 µS/cm on May

28 for Bjerkness Creek (Tables 4.5 to 4.8). Following freshet, conductivity increased steadily until water levels were at their lowest.

No seasonal pattern for conductivity was noticeable for Wing Creek as the conductivity values collected during freshet were not significantly lower than those collected during the fall (P=0.06, $t_{0.05,(2),8} = 2.306$). Since there was no noticeable increase in discharge during freshet in Wing Creek, it would be expected that conductivity would remain fairly constant throughout the year. On the other hand, the grab sampling data demonstrated that the conductivity at high flows were significantly lower than the low flows for McDonald, Kemp and Bjerkness Creeks (P=2.46E-11, 0.00098 and 0.0058, respectively, $t_{0.05(2),\ 8} = 2.306$). These seasonal patterns and relationship with discharge are as expected. Because conductivity corresponds to a measure of the ionic strength of the water, the more dilute the water, the lower the conductivity. Common ions like calcium, magnesium and potassium become diluted during the spring freshet, and increase when flows lessen. These changes in ionic concentration result in the seasonal differences seen in conductivity and are tied directly to water flows.

4.2.1.5 Turbidity

Turbidity readings also showed little changes throughout the recorded period for Wing Creek with a small peak on May 9, June 11, 12 and August 24 and a larger one on October 31 (Figure 4.17). The average turbidity was 0.53 NTU with a high of 1.8 NTU, which was recorded on October 31 and November 5, and a low of 0.15 NTU recorded on January 16 (Table 4.5). The high values recorded in the fall coincided with a low pressure system passing through the area. There were no significant differences between the low and high flow values (P=0.564, $t_{0.05(2),\ 8} = 2.306$).

Seasonal changes were not clear for McDonald Creek either (Figure 4.18). Turbidity averaged 0.397 NTU over the year and appeared to increase with the increasing flows during spring freshet to reach a maximum of 1.2 NTU on June 12 and then to decrease during low flows (Table 4.6). However, little turbidity changes were registered during the most significant flow peak. The low flow record of 0.13 NTU was registered on February 13. There was no strong correlation between turbidity levels and discharge levels (r=0.287) and there were no significant differences between high and low flows (P=0.38, $t_{0.05(2), 8} = 2.306$).

A seasonal pattern was more noticeable for Kemp and Bjerkness Creeks (Figures 4.19 and 4.20). Turbidity averaged over the year 0.39 NTU for Kemp Creek and 0.44 NTU for Bjerkness Creek, and increased with the increasing flows during spring freshet to reach a maximum of 2.5 NTU on May 28 for both creeks and then decreased during low flows (Tables 4.7 and 4.8). The low flow record of 0.12 NTU was registered on February 13 for Kemp Creek and 0.15 NTU was recorded in October for Bjerkness Creek. The grab sampling data demonstrated that turbidity levels were correlated with discharge levels (r=0.68, 0.71) for both Kemp and Bjerkness Creeks, however the differences between high flows and low flows were not significant (P=0.06, 0.182, respectively, $t_{0.05(2), 8} = 2.306$).

A seasonal pattern is to be expected as turbidity is caused by the amount of suspended matter in the water, including clay, silt, fine particles of organic and inorganic matter, and microscopic organisms. When spring freshet occurs, the runoff from the land carries soils, sediments and organic material, which is discharged, with the water, into the stream.

4.2.1.6 Total Suspended Solids

The total suspended solid measurements displayed a pattern similar to that of turbidity (Figure 4.17), since turbidity is caused by the amount of suspended matter in the water, including clay, silt, fine particles of organic and inorganic matter, and microscopic organisms. The average total suspended solid concentration for Wing Creek was 1.43 mg/L with a high of 8.4 mg/L, which was recorded on November 5. Minimum concentrations were below the detection limit, and occurred throughout the recorded period (Table 4.5). There were no significant differences between high and low flows (P=0.529, $t_{0.05(2), 8} = 2.306$).

Total suspended solids for McDonald Creek averaged 0.83 mg/L over the year and increased with the increasing flows during spring freshet to reach a maximum of 3.3 mg/L on June 11 and then decreased during low flows to reach below detection limits (Table 4.6, Figure 4.18). A second spike up to 4.5 mg/L was recorded on September 17. The differences between high flows and low flows were not significant (P=0.083, $t_{0.05(2), 8} = 2.306$).

Total suspended solids for Kemp Creek averaged 0.81 mg/L over the year and increased with the increasing flows during spring freshet to reach a maximum of 10.2 mg/L on May 28 and then decreased during low flows to reach below detection limits (Table 4.7, Figure 4.19). The differences between high flows and low flows were not significant (P=0.157, $t_{0.05(2), 8} = 2.306$).

Total suspended solids for Bjerkness Creek averaged 1.19 mg/L over the year and increased with the increasing flows during spring freshet to reach a maximum of 16.2 mg/L on May 28 and then decreased during low flows to reach below detection limits (Table 4.8, Figure 4.20). The differences between high flows and low flows were not significant (P=0.184, $t_{0.05(2), 8} = 2.306$).

The Passmore laboratory data indicated that suspended sediment levels were relatively low in all creeks, even during freshet, which resulted in no exceedances of the B.C. Water Quality Guidelines. Total suspended solid results from Cantest resulted in slightly higher values but also resulted in no exceedances of the B.C. Water Quality Guidelines. Increases of total suspended solids during freshet are usually of low consequence for aquatic life as organisms have developed high tolerance levels for short-term turbidity increases. Turbidity, however, interferes with the disinfection of drinking water and is aesthetically unpleasant. It is natural for turbidity and total suspended solids to increase during freshet and may be inherent to the watershed and unavoidable.

4.2.2 Stratified Sampling Measurements

Additional information was provided by the laboratory analyses of the stratified samples taken during freshet and low flows providing water quality characteristics during the most extreme conditions of the year. Results of the general parameters are presented in Tables 4.9 to 4.12 and results of the metal analysis are presented in Tables 4.13 to 4.16.

4.2.2.1 General Ions

Alkalinity usually indicates the presence of carbonate, bicarbonates or hydroxides and is a measurement of the water's ability to neutralize acids. Total alkalinity was relatively high throughout the sampling period, indicating water with good buffering capacity and presence of ions such as calcium and magnesium. Total alkalinity averaged 98 mg/L during freshet and 114 mg/L during low flows for Wing Creek, 67 mg/L during freshet and 91 mg/L during low flows for McDonald Creek, 24 mg/L during freshet and 75 mg/L during low flows for Kemp Creek, and 22 mg/L during freshet and 65 mg/L during low flows for Bjerkness Creek. Total hardness averaged 122 mg/L during freshet and 119 during low flows for Wing Creek, 73 mg/L during freshet and during low flows 100 mg/L for McDonald Creek, 26 mg/L during freshet and during low flows 73 mg/L for Kemp Creek, and 64 mg/L during freshet and 96 mg/L during low flows for Bjerkness Creek. These measurements are a result of the geology of the area. Total dissolved solids (TDS) averaged 147 mg/L during freshet and 125 mg/L during low flows for Wing Creek, 100 mg/L during freshet and 140 mg/L during low flows for McDonald Creek, 91 mg/L during freshet and 151 mg/L during low flows for Kemp Creek, and 80 mg/L during freshet and 161 mg/L during low flows for Bjerkness Creek. TDS is commonly used as a surrogate for conductivity, as they both essentially measure the concentration of dissolved ions in the water, although they use significantly different techniques and report the data in different units.

As expected, since there were little changes in discharge over the year in Wing Creek, no significant differences were found for high and low flow values. As found for conductivity, an inverse relationship between these water quality parameters and stream flow is likely in the other creeks. The low flow alkalinity, total hardness and TDS averages were significantly higher than the freshet averages (P=4E-07, P=1E-06 and P=9E-07, respectively (McDonald Creek) and P=0.001, P=0.0007 and P=0.0002, respectively (Kemp Creek) and P=0.002 and P=0.001, respectively (Bjerkness Creek) $t_{0.05(2),8} = 2.306$), however, averages for TDS were not found to be significant for Bjerkness Creek. As would be expected, the ionic concentration of the water increased with a concomitant decrease in water flows.

4.2.2.2 True Colour

The true colour of the water usually increases during spring freshet due to input of material from snowmelt and surface runoff. Most values obtained for all creeks were either at or below detection limits (<0.5 CU) during spring runoff and low flows.

4.2.2.3 Nutrients

Nitrogen levels in Wing, Kemp and Bjerkness Creeks suggest that nitrate+nitrite do not limit production. The average for the recorded period was 0.13 mg/L for Wing Creek, 0.25 mg/L for Kemp Creek, and 0.11 mg/L for Bjerkness Creek. Nitrate concentrations were found to be at or below detection limits in McDonald Creek suggesting that these levels may be limiting to production. Nitrate concentrations were found to be slightly higher at low flows than at high flows in Kemp Creek (P=0.046, $t_{0.05(2),8}$ =2.306). The difference however was not significant in Wing and Bjerkness Creeks (P=0.139 and 0.66, respectively, $t_{0.05(2),8}$ =2.306).

Total phosphorus and orthophosphate were relatively low and no significant differences were found between high and low flows in all four creeks (P=0.487, 0.503, 0.651 and 0.529, respectively, $t_{0.05(2),8}$ =2.306). No seasonal patterns were found for these nutrients.

Phosphorus is an essential plant nutrient and is often the most limiting nutrient to plant growth in fresh water. Orthophosphate is a measure of the inorganic oxidized form of soluble phosphorus and is the most readily available for uptake during photosynthesis. It is not surprising that nutrient levels were found to be extremely low and often below the detection limits. These parameters may not be the most appropriate to assess the productivity of an aquatic ecosystem as they are highly mobile and are rapidly taken up by the biological components of a stream and become organically bound. This is why true nutrient content is better represented by periphyton measurements. Nutrient concentrations of low order streams should not be measured directly in the water, but rather, indirectly, in the amount of algal growth they stimulate.

4.2.2.4 Bacteriology

As expected in a natural system, bacteria were found in all four creeks. The number of total coliform bacteria averaged 5.8 CFU/100 ml for Wing Creek, 7.8 CFU/100 ml for McDonald Creek, 6.6 CFU/100 ml for Kemp Creek and 10.8 CFU/100 ml for Bjerkness Creek during freshet and 22.7 CFU/100 ml for Wing Creek, 10.6 CFU/100 ml for McDonald Creek, 9.3 CFU/100 ml for Kemp Creek and 37.5 CFU/100 ml for Bjerkness Creek during low flows, however the differences between the two periods were not significant (P=0.261, 0.739, 0.65 and 0.051, respectively, $t_{0.05(2),8}$ =2.306). These results, however, do not indicate faecal contamination, as coliform bacteria are widespread in the environment and are more an indicator of the presence of large volumes of organic matter. Results for faecal and *E. coli* were in general at or below detection levels (< 1 CFU/100mL), however, on May 16, a maximum concentration of 6 CFU/100mL for faecal coliforms and 5 CFU/100mL for *E .coli* were obtained for Wing Creek and a maximum concentration of 17 CFU/100mL for faecal coliforms and 16 CFU/100mL for *E. coli* were obtained for Bjerkness Creek. This may indicate that faecal contamination may be an issue during freshet for Wing and Bjerkness Creeks as the surface runoff cleans the forest floor. Faecal coliforms normally do not live long in surface water, and are found only in areas that have had recent contamination. While coliform bacteria are generally harmless, the presence of faecal coliforms indicates faecal contamination of the water by warm-blooded animals, which suggests the potential for associated diseases. The source of the faecal coliforms is most likely mammalian or avian wildlife, and its contamination of the water is an unavoidable issue when dealing with watersheds used by both animals and humans. The water obtained from McDonald, Kemp and Bjerkness Creeks for domestic purposes is disinfected periodically throughout the year and thus acceptable levels of faecal coliforms cannot exceed 10 CFU/100mL (MELP, 1998, updated 1999). This value represents the 90^{th} percentile and therefore the guidelines were not exceeded in these watersheds. These calculations are based on 10 samples collected within a 30-day period. If all ten samples are used for this calculation, the 90^{th} percentile for faecal coliforms totalled 1 CFU/100ml for Wing, McDonald and Kemp Creeks and 3 CFU/100ml for Bjerkness Creek. Careful monitoring of the drinking water, however, is highly recommended especially during freshet.

4.2.2.5 Trace Metals

As expected, due to the relatively constant flows in Wing Creek throughout the year, most trace metal concentrations did not display any significant differences between high and low flows. As indicated by the relatively high alkalinity, conductivity and TDS data, total calcium averaged 34.61 mg/L and total magnesium averaged 8.31 mg/L with no significant differences between high and low flows.

Significant differences were found in McDonald, Kemp and Bjerkness Creeks for several metals between high and low flows: barium, calcium, lithium, magnesium, manganese, molybdenum, potassium, silicon, sodium, strontium and uranium for McDonald Creek; barium, calcium, magnesium, molybdenum, potassium, silicon, sodium strontium and uranium for Kemp Creek; and, barium, calcium, magnesium, molybdenum, potassium, strontium and uranium for Bjerkness Creek. These were all found to be at higher concentrations at low flows, as the increased discharge during freshet dilutes many ions, including most metals. However, at other sites this may not be the case, as some metals are associated with sediment particles, which are found to increase at freshet due to overland flow and snowmelt.

As predicted by the changes in hardness, alkalinity, conductivity and TDS, both calcium and magnesium were diluted in the spring freshet while their concentrations increased during low flows. Total calcium concentrations increased significantly from an average of 24.02 mg/L in the spring to 33.15 mg/L in the fall (P=4E-07, $t_{0.05(2),8}$ =2.306) for McDonald Creek, from 22 mg/L in the spring to 34.5 mg/L in the fall (P=0.0003, $t_{0.05(2),8}$ =2.306) for Kemp Creek, and from 18.8 mg/L in the spring to 27.1 mg/L in the fall (P=0.0035, $t_{0.05(2),8}$ =2.306) for Bjerkness Creek. Similarly, total magnesium concentrations were found to significantly increase from an average of 3.1 mg/L during freshet to an average of 4.11 mg/L during low flows (P=0.0003, $t_{0.05(2),8}$ =2.306) for McDonald Creek, from 4.4 mg/L during freshet to an average of 7.2 mg/L during low flows (P=0.0059, $t_{0.05(2),8}$ =2.306) for Kemp Creek and from 4.2 mg/L during freshet to an average of 7.0 mg/L during low flows (P=0.0001, $t_{0.05(2),8}$ =2.306) for Bjerkness Creek. All metals were either below the approved provincial Water Quality Guidelines or below current detection limits.

4.2.3 Quality Control

Quality control was maintained throughout the program by ensuring that all staffs involved in water sampling were fully trained and competent. Replicates of stratified samples were collected at all monitoring sites, and trip blanks and field blanks were collected at select sites.

Analysis of the replicate samples was conducted at Cantest and in general yielded similar results (Tables 4.9 to 4.16). Relative differences between duplicates must not exceed 25% relative difference. Relative differences for total coliforms were found to exceed this limit, which could suggest that total coliforms are not distributed uniformly in the environment. Some metal values were also found to vary between the two replicates. This may be indicative of environmental variability, poor field technique or poor laboratory technique. Unfortunately, field blanks were not collected for metals and therefore the source of the variability cannot be confirmed. The field and trip blank indicate that there was no environmental contamination during field sampling and during transportation (Table 4.17A).

Table 4.17A. Laboratory results of the field and trip blanks collected on September 26, 2001.

	PH (pH units)	Conductivity (us/cm)	Turbidity (NTU)	Total Suspended Solids (mg/L)
Wing Field Blank	5.89	<1	<0.1	<1
Kemp Field Blank	7.51	<1	<0.1	<1
Bjerkness Trip Blank	7.08	<1	<0.1	<1
McDonald Trip Blank	6.83	<1	<0.1	<1

An additional quality assurance measure was completed by comparing the results of the two laboratories and field measurements (Tables 4.17 to 4.20). In general, results for pH, conductivity and turbidity were higher at the Passmore Laboratory with differences of up to 1.3 pH units for pH, 27 µS/cm for conductivity and 0.25 NTU for turbidity. Total suspended solid results varied between the two laboratories with differences of up to 4.8 mg/L. Comparison with field data (Figures 4.21 to 4.28) suggest that the results obtained from the field meters are much more erratic and less reliable than laboratory results. This may suggest that calibration was completed incorrectly, since the probes are calibrated before each site visit, or that these models are fairly unreliable and should be upgraded to better models.

4.3 Biological Data

4.3.1 Periphyton

Direct periphyton measurements are difficult to determine, such that the Water Quality Guidelines give the standards in terms of chlorophyll *a* biomass. Pigment quantities give only rough estimates of biomass because the pigment per weight is influenced by many environmental and internal variables (life cycle, age, irradiance, temperature, salinity, nitrogen, phosphorus, magnesium, iron, antimetabolites etc.) (Wetzel and Westlake, 1974).

Chlorophyll *a* concentrations were relatively low at all sites (Table 4.21) averaging 0.147 mg/m^2 for Wing Creek and 0.012 mg/m^2 for Bjerkness Creek. Surprising enough, the highest results were found in Wing Creek where the channel is not exposed to direct sunlight with a forest canopy closure of 41 to 70%. Phaeophytin *a* concentrations were lower than chlorophyll *a*, averaging 0.069 mg/m^2 for Wing Creek and 0.001 mg/m^2 for Bjerkness Creek.

The majority of the periphyton found in these creeks can be estimated from the chlorophyll *a* biomass, which was found to be relatively low. This supports the observations made at the sites, in that periphyton was patchy. Primary productivity in most of these streams is likely limited by low nutrient concentrations, particularly phosphorus. Cold temperatures and scouring from the fast flowing water likely also inhibits the growth of algae on the rocks, particularly in Bjerkness Creek. The channel shows evidence of periodic substrate movement due to the multiple channels present.

4.3.2 Benthic Invertebrates

4.3.2.1 Wing Creek

An average of 884 invertebrates was found in each replicate sample, resulting in an average density of 9,829 organisms/m^2 (Table 4.22). The numbers varied from one replicate to another with a minimum of 463 organisms and a maximum of 1,557 organisms. This variability is indicative of the inherent patchiness of invertebrate communities. The average density was much higher than previous years with 2,779 organisms/m^2 in 2000 (Sundberg 2001), 754 organisms/m^2 in 1999 (Quamme and Sundberg 2000) and 2,456 organisms/m^2 in 1998 (Westcott 1999). The number of taxa was also much higher this year with an average of 38 taxa per replicate, of which half (19 in total) were from the more sensitive Ephemeroptera, Plecoptera and Trichoptera orders rather than Dipteran, which indicates, at first glance, a healthy and unimpacted stream community.

The composition of the invertebrate community was mostly dominated by Trichoptera with 23.9 % (Figure 4.29). The second largest group consisted of Ephemeroptera with 16.0 % followed by Plecoptera with 14.8 %. These results differ from the 2000 results in that Trichoptera were the least abundant of the EPT group with only 6.6 %. Diptera were the least abundant with 10.0 %. The other groups made up the remaining invertebrates totalling 35.4 %. This group consisted mainly of ostracods (seed shrimps), and annelida (worms). The species composition suggests a healthy ecosystem as the dominant EPT taxa such as *Anagapetus sp*. (Trichoptera), *Perlomyia sp*. (Plecoptera), *Ephemerella sp*. (Ephemeroptera) and *Zapada sp*. (Plecoptera) are all relatively intolerant to pollution with tolerance levels of 0, 0, 1 and 2 respectively. *Baetis sp*. were also abundant but their tolerance level is much higher (6). The presence of a dominant taxon that has a high tolerance value such as members of the family Enchytraeidae (Annelids), with a tolerance value of 10, indicates that the ecosystem may be impacted.

Chironomids were the dominant taxa of the Diptera but were not found in sufficient numbers to significantly influence the EPT/EPT+Chironomid ratio. The result of this ratio (88.3 %) indicates a healthy ecosystem. The predominance of annelids with a tolerance level of 10 contributed to an average HBI index of 4.6, which is higher than the 2000 result of 3.4, suggesting that the stream may be slightly impacted.

The functional feeding group analysis also suggests that Wing Creek is slightly impacted (Figure 4.30) as collector gatherers were the most abundant group representing 45.7 %. This group consists of generalist feeders, which are more adaptable to changing environments. Specialist feeders such as scrapers and shredders totalled 24.6 % and 12.8 %, respectively, which also indicates a relatively healthy ecosystem with sufficient inputs of organic material. The riparian zone along Wing Creek is relatively unimpacted by development and is the source of the abundant organic debris. It is surprising to note that scrapers were the second most abundant group, since most of the stream bed is shaded by a closed canopy (41-70 % canopy closure) which should result in lower periphyton growth, which is the main food source for scrapers. This result corroborates with the 2000 results (Sundberg 2001). Periphyton levels were also higher in Wing Creek than in Bjerkness Creek which is further corroborated by the greater percentage of scrapers in Wing Creek. The moderate amount of predators (7.3 %) is also a sign of a healthy habitat.

The species diversity, presence of low tolerance species indicate a healthy ecosystem, however the moderate HBI number and decrease in specialised feeders all suggest that Wing Creek may be slightly impacted. The extremely low water levels and dry weather experienced in the former part of the year may have impacted on the species composition of the community due to increased water temperatures.

4.3.2.2 Bjerkness Creek

An average of 1,890 invertebrates was found in each replicate sample, resulting in an average density of 20,996 organisms/m^2 (Table 4.23). As in Wing Creek, the numbers also varied from one replicate to another with a minimum of 1,277 organisms and a maximum of 2,679 organisms, once again demonstrating the inherent patchiness of invertebrate communities. This average is much higher than previous years with an average density of 8,654 organisms/m^2 for 2000 (Sundberg 2001), 4,302 organisms/m^2 for 1999 (Quamme and Sundberg 2000) and 8,287 organisms/m^2 (Westcott 1999). The number of taxa was also much higher this year with an average of 44 taxa per replicate, of which almost half (18) were from the more sensitive Ephemeroptera, Plecoptera and Trichoptera orders rather than Diptera.

The composition of the invertebrate community differed from the 2000 results in that Diptera increased from 13.1 % to 35.4 % becoming the dominant group (Figure 4.31). The second largest group consisted of Ephemeroptera with 31.9% followed by Plecoptera with 12.8 %. Trichoptera were the least abundant with 2.5%. The other groups totalled the remainder of the organisms with 17.4 %. This group consisted mainly of ostracods (seed shrimps), and annelids (worms). The species composition suggests a slightly impacted ecosystem as the dominant taxa such as Tanytarsini (Diptera), *Baetis sp*. (Ephemeroptera), *Candona sp*. (Ostracod) and *Eukiefferiella sp.* (Diptera) are all fairly tolerant species with tolerance levels of 6, 6, 8 and 8, respectively. Several species with lower tolerance levels were also present but in much less significant numbers such as *Ephemerella sp*. (Ephemeroptera), *Rhithrogena sp*. (Ephemeroptera), *Perlomyia sp.* (Plecoptera). The presence of a dominant taxon that is relatively tolerant such as Tanytarsini may also suggest an impacted ecosystem.

Chironomids were found in greater numbers than any previous years which influenced the EPT/EPT+Chironomid ratio resulting in a slightly impacted rating. The presence of relatively tolerant species contributed to an average HBI index of 4.8 also suggesting that the stream is slightly impacted.

The functional feeding group analysis also suggests that Bjerkness Creek is slightly impacted (Figure 4.32). Generalist feeders such as collector gatherers and collector filterers were the most abundant groups totalling 48.9 % and 22.0 % each. These two groups are more adaptable to changing environments as they can feed on several food sources. The presence of specialized feeders such as scrapers and shredder was much lower totalling 10.4 % each. The lower percentage of scrapers present may indicate that periphyton is limited as a food source. This is further corroborated by the relatively low concentrations of chlorophyll *a* obtained for Bjerkness Creek. The site is relatively open, permitting direct sunlight to reach the substrate and, thus, stimulate some growth, however, the cold temperatures and scouring from the fast flowing water likely also inhibits the growth of algae on the rocks. The low amount of predators (5.1 %) is also a sign of an impacted ecosystem.

The abundance of chironomids collected, the moderate HBI number and the dominance of generalist feeders such collector gatherers and collector filterers all suggest that Bjerkness Creek may be slightly impacted. The extremely low water levels and dry weather experienced in the former part of the year may have impacted on the species composition of the community due to increased water temperatures.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Site Analysis

Four years of data are now available for Wing, McDonald, Kemp and Bjerkness Creeks. The data obtained in previous years, however, was found to often be unreliable and contained numerous gaps. This years data, although not as frequent, provides a greater reliability as the hydrometric data is based on manual gauge readings.

5.1.1 Wing Creek

The hydrometric data collected during 2001 in Wing Creek indicated that water flows were lower than average and displayed no obvious peak during spring freshet. Due to the relatively constant water flows throughout the year, fluctuations for water quality parameters were also insignificant. It was found that results for pH, conductivity, hardness, total dissolved and suspended solids, and alkalinity were not significantly lower during freshet. Normally as water flows increase during freshet major ions become diluted. Water temperature exhibited normal seasonal fluctuations with a minimum of 0.3 ^{o}C and a maximum of 12.5 ^{o}C.

Both turbidity and total suspended solids remained fairly constant throughout the year. These values are expected to increase during freshet, due to the concomitant increase in surface runoff and entrainment of sediments and small particles that contribute to the suspended matter in the water. Since stream flows remained constant, so did these values.

The alkalinity in Wing Creek was relatively high throughout the sampling period, indicating water with good buffering capacity and the presence of relatively high concentration of ions such as calcium and magnesium. Average calcium concentrations of 35 mg/L were well above the range that suggests a high sensitivity to acid inputs (< 4 mg/L). The relatively high values obtained for total dissolved solids, conductivity and alkalinity indicate the presence of soluble ions and minerals. These characteristics are likely a reflection of the geology of the area and are within normal ranges.

Nitrate-nitrite levels in Wing Creek suggest that nitrogen may not limit productivity, however, phosphorus levels in the form of total phosphorus and ortho-phosphate were much lower. These low levels do not necessarily indicate a nutrient poor stream, but more likely that the majority of nutrients are bound up within the plant biomass.

Bacteria levels indicate that there may be microbiological concerns for Wing Creek during spring freshet. One sample collected on May 16, contained faecal coliform concentrations of 6 CFU/100mL and *E. coli* concentrations of 5 CFU/100mL. Disinfection of drinking water prior to consumption is highly recommended especially during freshet.

The species diversity, presence of low tolerance species indicate a healthy ecosystem in Wing Creek, however the moderate HBI number and decrease in specialised feeders may also suggest that a slightly impacted ecosystem. The benthic data collected in 2001 differed from the previous years, as organisms were much more abuandant and the diversity of taxa was also greater. The extremely low water levels and dry weather experienced in the former part of the year may have caused an increase in abundance and species diversity as well as causing a shift to a greater proportion of more tolerant species, due to increased water temperatures.

We are able to conclude that the water quality for Wing Creek was generally good, with no exceedances of the B.C. Water Quality Guidelines throughout the sampling period. The only exception would be the presence of faecal coliforms and *E. coli* during freshet. Further sampling would be required to ascertain if there is a contamination issue in Wing Creek, but without restricting access of all warm-blooded wildlife to the watershed, there will always be ambient levels of faecal bacteria.

5.1.2 McDonald Creek

The hydrometric data collected during 2001 in McDonald Creek indicated that water flows were lower than average. It was found that results for pH, conductivity, hardness, total dissolved and suspended solids, and alkalinity were significantly lower during freshet. This is to be expected as water flows increase major ions become diluted. Water temperature exhibited normal seasonal fluctuations with a minimum of -1 ^{o}C and a maximum of 13 ^{o}C.

Both turbidity and total suspended solids experienced some increase during freshet and fall rain events, however the differences between high and low flows were not significant. These values are expected to increase during freshet, due to the concomitant increase in surface runoff and entrainment of sediments and small particles that contribute to the suspended matter in the water.

The water alkalinity in McDonald Creek was relatively high throughout the sampling period, indicating the water had good buffering capacity and the presence of relatively high concentrations of ions such as calcium and magnesium. Average calcium concentrations of 29 mg/L were well above the <4 mg/L threshold that indicates a high sensitivity to acid inputs. The relatively high values obtained for total dissolved solids, conductivity and alkalinity indicate the presence of soluble ions and minerals. These characteristics are likely a reflection of the geology of the area and are within normal ranges.

Nutrient levels were very low in McDonald Creek. These low levels do not necessarily indicate a nutrient poor system, but that the majority of nutrients are bound up within the plant biomass.

Bacteria levels indicate that there were no microbiological issues for McDonald Creek, with all values below the detection limits (< 1 CFU/100 mL).

We are able to conclude that the water quality for McDonald Creek was generally good, with no exceedances of the B.C. Water Quality Guidelines throughout the sampling period.

5.1.3 Kemp Creek

The hydrometric data collected during 2001 in Kemp Creek indicated that water flows were lower than average. A shift in the hydrograph was also apparent with freshet ending a month earlier than in 2000. It was found that results for pH, conductivity, hardness, total dissolved and suspended solids, and alkalinity were significantly lower during freshet. This is to be expected as water flows increase major ions become diluted. Water temperature exhibited normal seasonal fluctuations with a minimum of -1 ^{o}C and a maximum of 11 ^{o}C.

Both turbidity and total suspended solids experienced some increase during freshet and fall rain events, however the differences between high and low flows were not significant. These values are expected to increase during freshet, due to the concomitant increase in surface runoff and entrainment of sediments and small particles that contribute to the suspended matter in the water.

The water alkalinity in Kemp Creek was relatively high throughout the sampling period, indicating the water had good buffering capacity and the presence of relatively high concentrations of ions such as calcium and magnesium. Average calcium concentrations of 29 mg/L were well above the <4 mg/L threshold that indicates a high sensitivity to acid inputs. The relatively high values obtained for total dissolved solids, conductivity and alkalinity indicate the presence of soluble ions and minerals. These characteristics are likely a reflection of the geology of the area and are within normal ranges.

Nitrate-nitrite levels in Kemp Creek suggest that nitrogen may not limit productivity, however, phosphorus levels in the form of total phosphorus and ortho-phosphate were much lower. These low levels do not necessarily indicate a nutrient poor stream, but that the majority of nutrients are bound up within the plant biomass.

Bacteria levels indicate that there were no microbiological issues for Kemp Creek, with all values at or below the detection limits (1 CFU/100 mL).

We are able to conclude that the water quality for Kemp Creek was generally good, with no exceedances of the B.C. Water Quality Guidelines throughout the sampling period.

5.1.4 Bjerkness Creek

The hydrometric data collected during 2001 in Bjerkness Creek indicated that water flows were lower than average. A shift in the hydrograph was also apparent with freshet ending a month earlier than in 2000. It was found that results for pH, conductivity, hardness, total dissolved and suspended solids, and alkalinity were significantly lower during freshet. This is to be expected as water flows increase major ions become diluted. Water temperature exhibited normal seasonal fluctuations with a minimum of 1 ^{o}C and a maximum of 13 ^{o}C.

Both turbidity and total suspended solids experienced some increase during freshet and fall rain events, however the differences between high and low flows were not significant. These values are expected to increase during freshet, due to the concomitant increase in surface runoff and entrainment of sediments and small particles that contribute to the suspended matter in the water.

The water alkalinity in Bjerkness Creek was relatively high throughout the sampling period, indicating the water had good buffering capacity and the presence of relatively high concentrations of ions such as calcium and magnesium. Average calcium concentrations 23 mg/L were well above the <4 mg/L threshold that indicates a high sensitivity to acid inputs. The relatively high values obtained for total dissolved solids, conductivity and alkalinity indicate the presence of soluble ions and minerals. These characteristics are likely a reflection of the geology of the area and are within normal ranges.

Nitrate-nitrite levels in Bjerkness Creek suggest that nitrogen may not limit productivity, however, phosphorus levels in the form of total phosphorus and ortho-phosphate were much lower. These low levels do not necessarily indicate a nutrient poor stream, but that the majority of nutrients are bound up within the plant biomass.

Bacteria levels indicate that there may be microbiological concerns for Bjerkness Creek during spring freshet. One sample collected on May 16, showed faecal coliform concentrations of 17 CFU/100mL and *E. coli* levels of 16 CFU/100mL. Disinfection of drinking water prior to consumption is highly recommended especially during freshet.

The abundance of chironomids collected, the moderate HBI number and the dominance of generalist feeders such collector gatherers and collector filterers all suggest that Bjerkness Creek may be slightly impacted. The benthic data collected in 2001 differed from the previous years, as organisms were much more abuandant and the diversity of taxa was also greater. The extremely low water levels and dry weather experienced in the former part of the year may have caused an increase in abundance and species diversity as well as causing a shift to a greater proportion of more tolerant species, due to increased water temperatures.

We are able to conclude that the water quality for Bjerkness Creek was generally good, with no exceedances of the B.C. Water Quality Guidelines throughout the sampling period. The only exception would be the presence of faecal coliforms and *E. coli* during freshet. Further sampling would be required to ascertain if there is a contamination issue in Bjerkness Creek, but as this is a natural watershed, there will always be ambient levels of faecal bacteria.

5.2 Recommendations for Future Work

5.2.1 Sampling Design and Techniques

It is recommended that water quality and quantity sampling continue at these sites for at least four more years due to some of the unreliable data collected in the initial years of monitoring. Sampling should continue throughout all seasons in order to determine the natural variation on a temporal scale, with the greater emphasis during spring freshet and major rain events. These periods are critical in understanding the hydrology of each watershed and their response to such events, and this is the period when water quality is the most likely to deteriorate due to increased turbidity and total suspended solids. The sampling regime should remain consistent with the manual program initiated in 2001.

5.2.2 Hydrological Data

- Collection of manual gauge readings should continue at the same frequency set out in the 2001 water quality and quantity program. Gauge readings are a critical component of this program and readings are completed up to four times per week during the freshet period. Additional readings should also be completed during and after major rain events.

- Metering of the stream should be completed 8 times during the year, to produce a stage-discharge curve for each creek.

5.2.3 Grab Sampling

- Collection of basic grab samples should continue at the same frequency set out in the 2001 water quality and quantity program. These basic samples should measure pH, conductivity, turbidity and total suspended solids. The sampling frequency may be up to 3 to 4 times weekly during spring freshet. Additional sampling to the scheduled samples should also be collected during and after major rain events.

- Collection of stratified samples could be decreased drastically, as four years of data have been collected. Most of the parameters were below water B.C. Water Quality Guidelines and/or below detection limits. However, continued sampling of micro-organisms including faecal coliforms and *E. coli* is recommended, due to potential faecal contamination concerns during freshet. It is important for Community Watersheds serving the drinking water needs of its residents that coliform levels, particularly faecal coliforms, be low. Local communities and license holders should routinely measure coliforms within their distribution systems to determine the appropriate treatment of the drinking water. Measuring bacterial levels in the creek may not the best indication for the pathogen potential at the tap. Cracked and dirty distribution systems often contribute more bacteria at the tap than those present in the water at the intake.

- "Snapshot" monitoring of stratified sampling could be completed at a reduced frequency. For example some parameters could be measured once during low and high flows.

5.2.4 Benthic Invertebrates and Periphyton

- Four years of data are now available for Wing Creek and Bjerkness Creek providing a relatively good baseline. Since the program must be drastically decreased, biological sampling frequency could be reduced from annually to every 3 to 5 years, as they are good indicators of the health and functioning of the stream. Cumulative impacts and changes over time within the watershed would be displayed by a shift in the community composition.

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7 GLOSSARY OF TERMS

alkalinity - is the measure of the ability of water to maintain its pH and neutralize acidic inputs. It is determined primarily by the amount of carbonate, bicarbonate and hydroxide ions in the water.

bank, right or left - The margin of a channel as viewed facing downstream. The expression "right" or "left" applies similarly to right or left abutments, cableway towers, etc.

bench mark - A permanent, fixed reference point for which the elevation is known. It may when practicable, be related to GSC datum.

benthic invertebrates – the animals lacking a backbone found in the gravels and sediments at the bottom of a stream. Common benthic invertebrates include worms, snails, water mites, leeches, small crustaceans, and insect larvae. Benthic invertebrates are a very important food source for fish. They also play a major role in the decomposition of organic material, and therefore, affect nutrient availability in the water.

collectors – benthic invertebrates that feed on fine pieces of organic material such as leaf fragments, bacteria, stream bed deposits and waste products from other organisms. Collectors are often further divided into more specific feeding mechanisms such as filtering collectors like clams or blackfly larvae and gathering collectors like many mayfly and caddisfly and midges.

control -The condition downstream from a gauging station that determines the stage/discharge relation. It may be a stretch of rapids, a weir or other artificial structure. In the absence of such features, the control may be a less obvious condition such as a convergence of the channel or even simply the resistance to flow through the downstream reach. A shifting control exists where the stage/discharge relation tends to change because of impermanent beds or banks.

conductivity - is termed specific conductance if standardized to 25°C. It is as measure of the ionic content of the water, and specifically, its ability to conduct an electrical current. Dissolved ions such as sodium, potassium, calcium, magnesium, sulfate and nitrate contribute to the conductivity of the water as do dissolved organic substances.

cross section of a stream - A specified vertical plane through a stream bounded by the wetted perimeter and the free surface.

discharge, Q - The volume of liquid flowing through a cross section per unit of time. It is not synonymous with "flow".

discharge measurement - The determination of the rate of discharge at a gauging station on a stream, including an observation of "no flow", which is classed as a discharge measurement.

dissolved oxygen - is oxygen dissolved in the water. Oxygen is essential for most aquatic life forms and chemical reactions within streams such that minimum concentrations are necessary for a functioning system. Excessive amounts of oxygen and other supersaturated gasses (caused by high pressures of dam spillways for example) can negatively affect aquatic life through the production of “gas bubble trauma” or the over inflation of swim bladders in fish. Dissolved oxygen concentration is a function of the temperature of the water. With increasing temperature, the solubility of oxygen decreases. At the same time, the respiratory requirements of aquatic organisms increase with increasing temperature, however, there is less oxygen in the water to meet these increased needs, and death can result.

flow - The movement of water in a channel without reference to rate, depth, etc.

functional feeding groups – a classification system based on the feeding mode of invertebrates.

gauge correction - Any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

gauge height - The height of the water surface above the gauge datum; it is used interchangeably with the terms "stage" and "water level".

gauge observation/reading - An actual notation of the height of the water surface as indicated by a gauge, it is the same as a "gauge height" on when the 0.000 metre mark of the gauge is set at the "gauge datum".

gauging station - The complete installation at a measuring site where systematic records of water level and/or discharge are obtained.

hardness - is a measure of the concentration of ions such as calcium and magnesium. The geology of the area will greatly influence both the hardness and the types of ions comprising it. The hardness of the water partly determines the toxicity of metals such as cadmium, copper and zinc, with a decrease in hardness resulting in an increase in toxicity. Hardness itself is not a health concern, but can cause scaling and calcium deposits.

instar – one of the many immature stages of an insect which lives and feeds in water. A larval form will go through several stages called instars to reach the adult. For example, the larvae grows from instar 3 to instar 4 y shedding its exoskeleton and growing to the next stage.

larvae – the immature stage of an insect which lives and feeds in water. The insect undergoes what is termed complete metamorphosis and changes from egg to larvae to pupae to adult.

level check - The procedure followed to determine the movement of a gauge with respect to the gauge datum.

metric – a measurable attribute of the biological assemblage (such as taxa richness or percentage of dominant species) that changes in some predictable way with increased human influence.

nutrients - nitrogen and phosphorus are the two most important nutrients required for plant growth. Various chemical forms of these nutrients exist in the water and some are more important than others in determining how much primary production or plant growth will occur. Nitrate and phosphate are the more readily available forms and are most commonly measured. These nutrient levels need to be high enough to support a healthy plant community, which provides the basis of the food chain. Excessive amounts of nutrients, however, can also cause problems. A high amount of plant growth eventually leads to a high amount of dead plant material. Oxygen, required to decompose the organic material, can be significantly depleted to a point where aquatic organisms die. Nitrite is another form of nitrogen commonly measured because of potential health problems for both aquatic organisms and humans. In high concentrations, nitrite can bind to the haemoglobin of blood and prevent its uptake of oxygen.

Babies under 3 months of age are especially at risk for developing “blue baby” syndrome, and can die as a result of drinking contaminated water.

nymph – the immature stage of an insect which lives and feeds in water. The insect undergoes what is termed incomplete metamorphosis and changes from an egg to a nymph to an adult (lacks a pupal stage). The nymph stage may last from a few months to several years. Although technically different, the word larvae is often used in place of nymph for the sake of simplicity.

parasites – benthic invertebrates that feed directly on the body fluids of other aquatic animals, but do not initially kill their animal prey. Rather, parasites feed off their hosts for a significant period of time, allowing their hosts to live and therefore provide a constant source of food.

pH - the concentration of hydrogen ions in the water. The pH of water indicates how basic or neutral it is. A pH of 7 is neutral, above 7 is basic and below 7 is acidic. The pH also influences the toxicity of metals, especially aluminium and iron. At more acidic pH levels, these metals are significantly more toxic.

predators – benthic invertebrates that feed directly on other aquatic animals such as fish and invertebrates. Predatory organisms include dobsonfly larvae, fishfly larvae, dragonflies and watersnipe fly larvae.

primary production – the amount of plant growth, used as a food source for herbivorous animals such as benthic invertebrates and fish.

pupae – the final immature stage of an insect which lives and feeds in water. The insect undergoes what is termed complete metamorphosis and changes from egg to larvae to pupae to adult.

reference point - A point of known elevation from which measurements may be made to a water surface. It is also known as a measuring point.

riparian – the vegetation that grows on the banks of streams. Riparian plants are terrestrial, not aquatic, however, their leaf litter does contribute to the organic matter content of the stream and is often a major source of food for aquatic organisms.

scrapers – benthic invertebrates that graze on algae attached to stones and other surfaces. Many of these organisms are flattened to hold onto surfaces while feeding. Scrapers include water pennies, limpets and snails, netwinged midge larvae, certain mayfly larvae and others.

shift - A change in the stream control, which alters the stage/discharge relationship. The change can be either temporary or permanent.

shredders – benthic invertebrates that feed on coarse organic material such as leaves, algae and rooted aquatic plants. These organisms play an important role in breaking down leaves or large pieces of organic material to a size that can be used by other macroinvertebrates. Shredders include certain stonefly and caddisfly larvae, sowbugs, scuds and others.

stage; gauge height; water level - The elevation of the free surface of a stream, lake or reservoir relative to a gauge datum.

stage/discharge relation - A curve, equation or table which expresses the relation between the stage and the discharge in an open channel at a given stream cross-section.

stilling well - A well (tube) connected with the stream in such a way as to permit the measurement of the stage in a relatively still condition (natural surge dampened).

stream - The generic term for water flowing in an open channel.

stream gauging - All of the operations necessary for measuring discharge.

taxon – a level of identification or classification such as family, order, genera or species. Taxa is the plural form.

TDS (total dissolved solids; filterable residue) - the total amount of dissolved solids in the water, or those small enough to pass through a 0.45 μm filter. TDS can be used as a surrogate for specific conductance, as both methods are a measure of the ionic content of the water.

temperature - the temperature of the water directly affects the productivity of the system through influencing the chemical reactions occurring within the water as well as the growth of plants and animals. Extremes of either temperature will negatively affect growth, but in our temperate environment, it is more important that temperature is not allowed to rise too high.

TSS (total suspended solids; non-filterable residue) - the total amount of solids suspended in the water, or those large enough to be caught by a 0.45 μm filter. A close relationship may be established between TSS and turbidity, since they both measure clay, silt and colloidal material suspended in the water.

turbidity - is an optical characteristic of water, in that it is a measure of how much light passes through it. Turbidity is caused by the amount of suspended matter in the water, including clay, silt, fine particles of organic and inorganic matter, and microscopic organisms. High turbidity levels can obscure light availability and reduce plant production as well as negatively affect some animal behaviors such as predator avoidance. Particles can also settle out on the stream bottom and smother aquatic invertebrates as well as developing fish embryos. Turbidity is of a health concern for humans drinking chlorinated water due to the possible reaction of chlorine with organic materials to produce carcinogenic substances.

wading rod - A light hand held, graduated, rigid rod, for sounding the depth and positioning the current meter in order to measure the velocity in shallow streams suitable for wading. It may also be used from boats or ice cover in shallow streams.

APPENDIX 1: Hydrometric forms.

APPENDIX 2: Monthly reports.

APPENDIX 3: List of water licenses.

APPENDIX 4: Digital copies of the report, tables, graphs and raw data.