Water quality and accumulation of periphyton (attached algae) in the Bulkley River and tributaries, 1997: relationship with land use activities in rural watersheds

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Table of Contents

List of Figures

List of Tables

List of Appendixes

1. INTRODUCTION

In recent years, studies in the upper Bulkley River upstream of Houston have noted elevated levels of bacteria, nutrients and attached algae (periphyton). A 1992 fisheries study in the upper Bulkley at Houston found fish species composition was dominated by longnose dace and to a lesser extent longnose suckers, together accounting for about 90% of all fish in the study area. This pattern occurred upstream and downstream of the sewage treatment plant discharge and is believed to reflect a combination of low stream flows, warm temperatures, and perhaps eutrophication in this section of the river, providing longnose dace with a competitive feeding advantage over steelhead and salmon juveniles.

Land use activities in a watershed, such as timber harvesting, road building, and livestock grazing can result in changed hydrological properties, rates of sediment and nutrient delivery, and altered levels of temperature and dissolved oxygen in streams. Poorly maintained residential septic tanks and runoff of manure and fertilizers from agricultural areas can result in addition of nutrients and bacteria which may result in high organic production rates (eutrophication) and lead to several undesirable effects, including a proliferation of attached algal in streams and algae blooms in lakes. Cumulative effects, in the lower basin, of altered flows, increased water temperature, nutrients and sediment from assorted disturbances in a watershed may result in negative changes in stream habitat and fish food communities, thereby reducing survival opportunities for salmonids.

In 1996 the Habitat and Enhancement Branch of Fisheries and Oceans initiated a two year study of water quality and periphyton standing-crop in the upper Bulkley River and other tributaries draining rural settlement areas of the Bulkley Valley. Thirteen sites in the Bulkley River and selected tributaries were sampled in July and September 1996 (Remington 1997). Unusually high stream flows occurred during the 1996 growing season, including two major rainfall events prior to sampling, which is believed to have resulted in scouring (removal) of periphyton, thus introducing a bias to the 1996 study. The study found periphyton biomass at all sites in the upper Bulkley River to exceed the criterion for the protection of aesthetics and recreation, and one site to exceed the criterion for the protection of aquatic life.

1.1 Objectives

The objectives of the study are to:

- Monitor water quality and accumulated periphyton standing crop (algae biomass at the end of the growing season) at 15 sites located in the upper Bulkley River watershed and selected tributaries to the lower Bulkley River.

- Report and assess the water quality and periphyton standing crop data relative to the Ministry of Environment, Lands and Parks (MELP) *Bulkley River basin water quality assessment and objectives* (Nijman 1986), and the *Approved and working criteria for water quality* (Nagpal 1996).

- Review general land use activities in the contributing areas of the monitoring sites and identify possible relationships between these activities and water quality and aquatic productivity.

2. STUDY AREA

2.1 Monitoring Sites

Fifteen monitoring sites were chosen in consultation with Pierre Lemieux, HEB, based on knowledge of fish habitat values and land use activities in the watersheds (Figures 1 & 2). Detailed monitoring site descriptions are found in Appendix 1. Photographs of each sampling site are found in Appendix 2.

Site 1 is on Maxan Creek, the major tributary to Bulkley Lake, in the headwaters of the upper Bulkley River. Sites 2 through 7 are located along the length of the upper Bulkley River from just downstream of Bulkley Lake to within the District of Houston. All are upstream of the only known nutrient point source, the Houston sewage treatment plant.

Site 8 is located on Buck Creek 11.7 km upstream of the rural settlement area surrounding Houston. Site 9 is located on Buck Creek about 300 m upstream of its' confluence with the upper Bulkley within the District of Houston. Buck Creek, the major tributary to the upper Bulkley, supplies about 19% of flows, on average, to the upper Bulkley at Houston.

About 5 km downstream of the District of Houston, the upper Bulkley is joined by the larger Morice River to form the lower Bulkley River. The Morice contributes more than 90% of flows to the lower Bulkley River at their confluence. Sites 10 through 15 are located on tributary streams of the lower Bulkley River: Thompson Creek, Canyon Creek, Toboggan Creek and Reiseter Creek. Two sites are located on Toboggan Creek; Site 13 downstream of Toboggan Lake and Site 14 downstream of the confluence of Owens Creek. Site 15, Reiseter Creek, was chosen as a control site because there is believed to be little or no human activity in proximity of the creek (although forestry is an activity in the watershed).

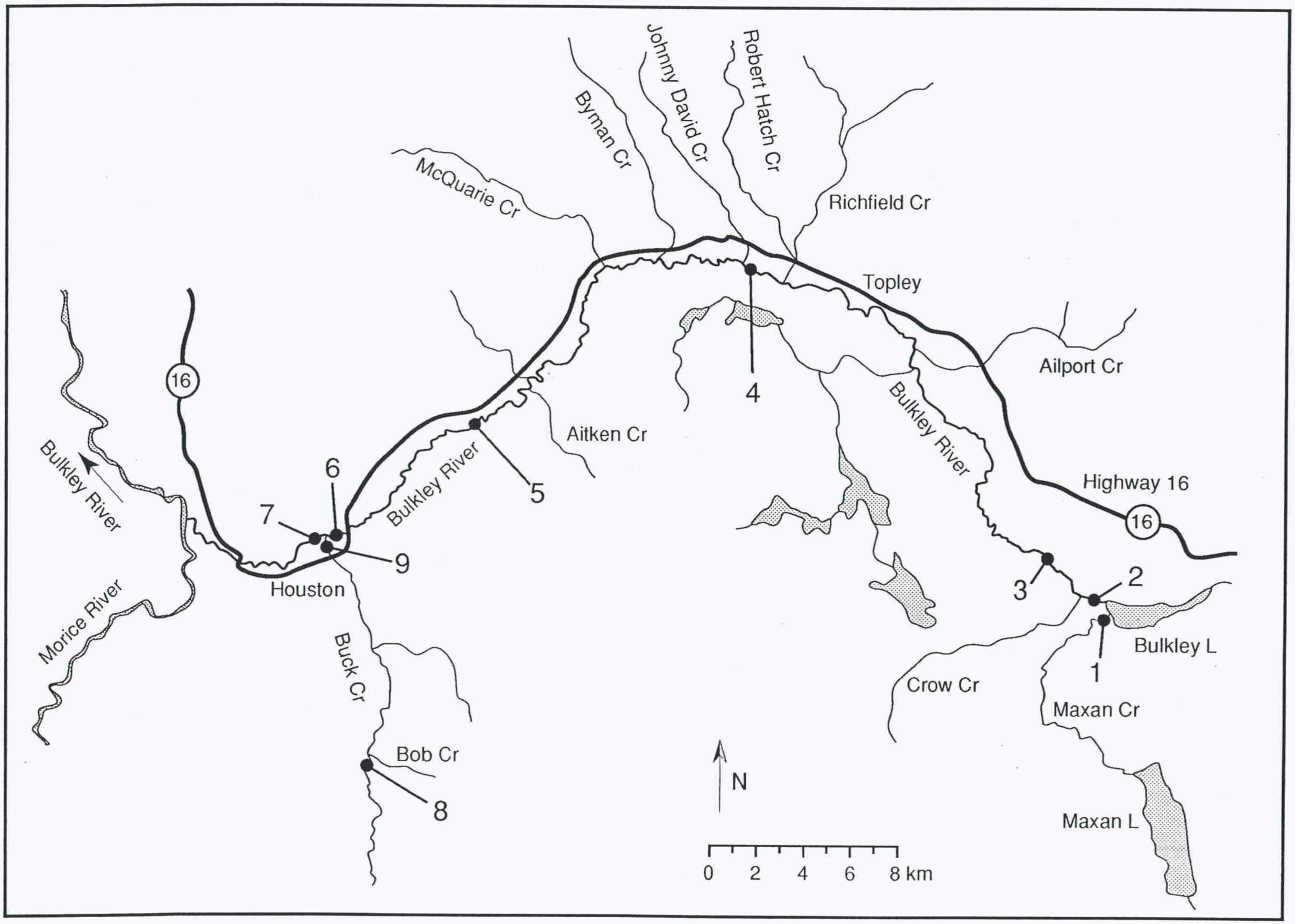


Figure 1 Upper Bulkley River water quality and periphyton monitoring sites 1997

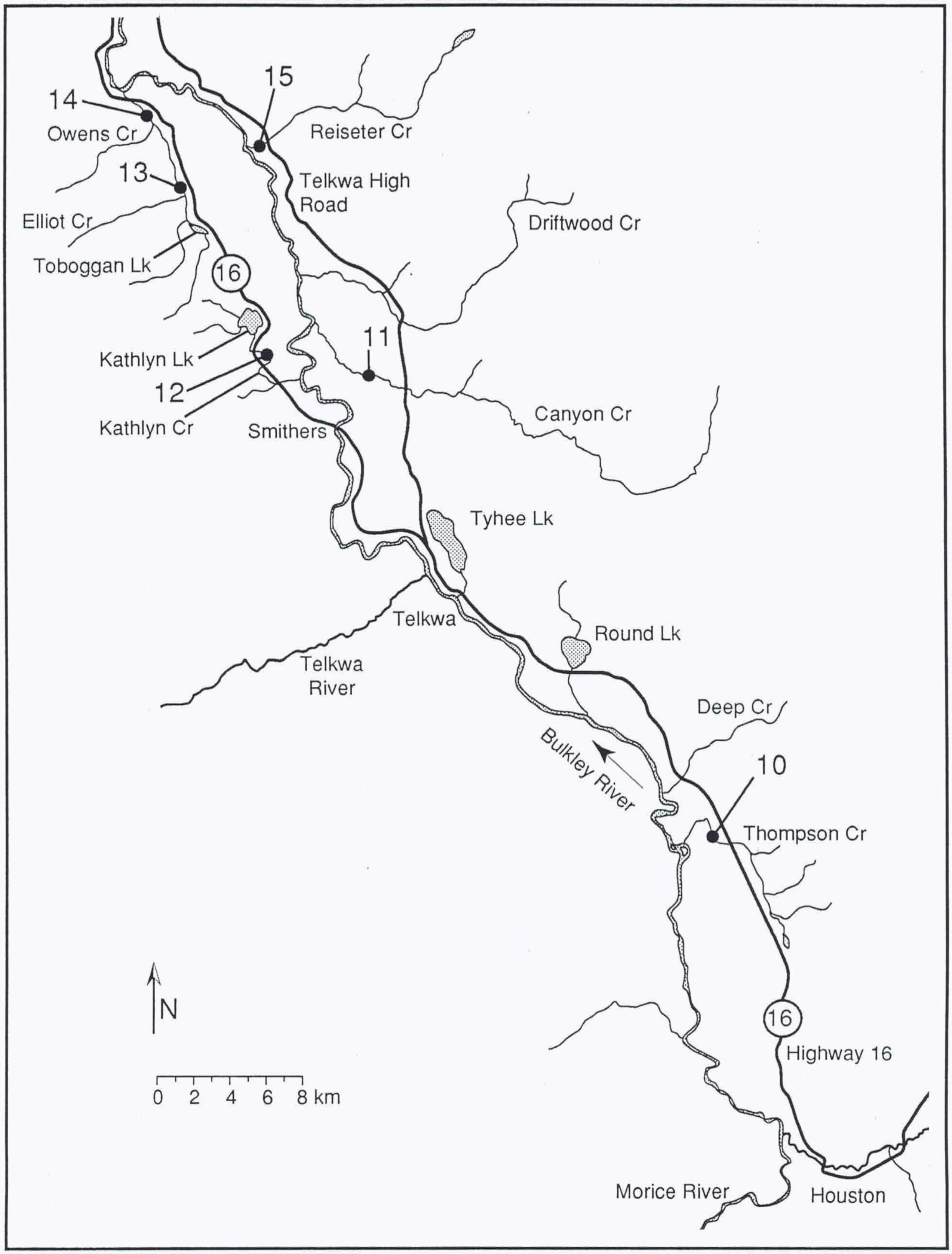


Figure 2 Bulkley River tributaries water quality and periphyton monitoring sites 1997

3. METHODS

3.1 Sampling Methods

Water quality and periphyton monitoring was conducted September 17 to October 2, 1997. There are no longer hydrometric gauge stations on any of these watersheds, but streamflows appeared to be normal for the summertime low flow period; in contrast to 1996, when unusually high flows persisted for entire growing season.

3.1.1 Water sampling

Water sampling was carried out as per MELP *Ambient freshwater and effluent sampling manual* (Cavanagh and others, 1994) and *Sampling for water quality* (Environment Canada 1983). Field parameters monitored included water temperature and dissolved oxygen. Field pH was monitored for the first half of the study prior to pH meter breakdown. Dissolved oxygen measurement was conducted with a YSI dissolved oxygen meter which was calibrated daily using the Winkler chemical method (Hach OX-DT test kit with digital titrator).

Water samples were immediately iced and shipped same day by air to Burnaby for analysis by Philip Services Corporation (PSC) Analytical Laboratory. All shipments were received by the laboratory the day following sampling.

A second phosphorus sample was taken at Site 15 Reiseter Creek on 02-Oct-97 when the first sample was suspected to have been contaminated at the laboratory. A second bacteriological sample was obtained at the same time. Streamflows and turbidity were higher in Reiseter at the time the second sampling due to heavy rains.

3.1.2 Periphyton sampling for chlorophyll a analysis

Every attempt was made to chose similar periphyton monitoring sites with reference to factors which may influence algae growth rates, such as current velocity, water depth, substrate particle size, and percent shading. In order to standardize for water depth and current velocity, I attempted to sample at 15-20 cm water depth and 30-40 cm/s current velocity, which was close to the shoreline of the larger streams. Within the 'standardized' periphyton sampling locality, individual rocks were chosen randomly for sampling.

Periphyton sampling was based upon methods found in the MELP *Biological Sampling Manual* (Cavanagh and others 1994). Six replicate periphyton samples were collected at each site. Periphyton was scraped and washed from the randomly selected rock into a glass container, which was immediately placed on ice in a darkened cooler. A tracing of the sampled area was then made of each rock.

Each day, the individual samples were filtered onto a 0.45 µm filter, and 2-3 drops of $MgCO_3$ suspension added as pH buffer. The sample filters were immediately placed in a darkened thermos containing activated desiccant and were frozen immediately. Frozen samples were shipped by air in a cooler containing dry ice to PSC laboratory. The frozen samples arrived at the laboratory the following day and were kept frozen prior to chlorophyll *a* analysis. The rock areas scraped were determined by measuring the field tracings with a compensating planimeter.

One periphyton sample for community composition and was collected at each site and preserved with Lugol's solution. Scrapings were included from at least four rocks at each site. Periphyton qualitative community composition analysis was conducted by Mary Bolin, algae taxonomist, Victoria, BC.

Exceptions—Periphyton monitoring was omitted at Sites 1,2 and 12 because I was unable to locate suitable gravel or cobble substrate due to: very fine gravel and sand at Site 1, and incised stream channels with silt substrate at Sites 2 and 12.

Two sets of replicate periphyton samples were taken at Site 6, upper Bulkley River downstream of Avalon Creek. The first set were taken at the time of water sampling 24-Sep-97. These were taken from near the mid-stream gravel bar in the 'standardized' periphyton sampling location. The second set was taken 02-Oct-97 of the conspicuous green filamentous mat which covered the higher velocity riffle area (and covered approximately 70% of the river at this locality). The long green filamentous algae mat was too thick to sample by standard methods. Instead the scrapings from one small rock were divided onto 6 filters, the rock area was divided by 6 for biomass/m^2 calculation.

3.2 Analytical Methods

Low level analysis for othophosphorus (MDC 1 μg/L) was requisitioned in the 1997 study, as a result of high variability in orthophosphorus revealed in replicate sampling in 1996. Nordin (1985) recommends low level determination for phosphorus, noting this is particularly important when considering impacts on streams with low ambient levels of nutrients, where otherwise innocuous inputs (for example <3 μg/L of orthophosphorus) could cause a very large increase in algae.

Methods used by PSC analytical laboratory for water quality and chlorophyll *a* analysis are based upon those found in *Standard Methods for the Examination of Water and Wastewater*, 18th Edition (American Public Health Association 1992).

Methods used by Mary Bolin for periphyton qualitative community composition are as follows. The sample was placed in a counting chamber and allowed to settle for 24 hours. A 5 or 10 mL subsample of sample was settled, dependent on the density of cells in the sample. The sample was examined using an inverted microscope at 500X phase contrast magnification. Overall scans at 200X phase contrast magnification were made of the entire chamber to ensure an even distribution of cells and that no large cells, filaments or colonies are missed. At least 20 microscope fields were examined at 500X and four transects of the settling chamber were examined at 200X. For each sample, the percent composition by volume of the algal phyla, including diatoms, was estimated visually. The relative abundance of the various species found was also visually estimated. A list of references used for identification is found in Appendix 4 Table 3.

4. SUMMARY OF EXISTING WATER QUALITY INFORMATION

4.1 Upper Bulkley River

Review and assessment of water quality in the Skeena River watershed British Columbia, 1995 (Remington 1996) noted that orthophosphorus concentrations in the upper Bulkley River upstream of Houston were elevated compared to other streams in the Skeena watershed (Morice, lower Bulkley, Telkwa, Kispiox, Skeena and Lakelse rivers). Orthophosphorus, also called soluble reactive phosphorus (SRP) is a measure of the bioavailable form of phosphorous which is understood to be the usual limiting factor to the growth of algae in streams. Orthophosphorus concentrations of approximately 16 µg/L were reported in the upper Bulkley upstream of the only known nutrient point source, the sewage treatment plant at Houston. This was the highest orthophosphorus concentration of any of the seven Skeena River watershed sites monitored monthly from 1983 to 1987 (Wilkes and Lloyd 1990). In comparison, orthophosphorus concentrations in the nearby Morice River averaged ≤3 µg/L (the minimum detectable concentration).

Algal standing crop in the upper Bulkley, upstream of the sewage treatment plant, has previously been reported at or near the Bulkley River objective level for protection of aesthetics and recreation of <50 mg/m^2 chlorophyll *a* (Remington and others 1991, 1993, 1994). The District of Houston and MELP Pollution Prevention (Portman 1995) suggested that further studies were needed to determine the sources of nutrients to the upper Bulkley River.

Fecal coliform bacteria concentrations upstream of the sewage treatment plant at Houston have also often exceeded the water quality objective for this section of Bulkley of ≤10 colonies/100 mL 90th percentile. The *British Columbia Water Quality Status Report* (MELP 1996) noted that upper Bulkley water quality is generally good, but that fecal coliforms at times do not meet acceptable levels for drinking water.

MELP Water Management Branch lists 59 domestic and stock watering licenses and 11 irrigation licenses on the upper Bulkley. The maximum amount of water licensed for withdrawal from the upper Bulkley represents about 46% of the summertime 7 day average low flow (10 year return) which leads to concerns regarding downstream impacts of reduced flows on the fisheries resource. The largest quantity of licensed water withdrawals are the irrigation licenses, all of which are on tributary streams. There are no data on actual water utilization. Given the relatively moist central interior climate, actual water usage for irrigation is believed to be lower than permitted volumes. Water use for irrigation would increase during hot dry summers, when streamflows are at seasonal lows, and could possibly contribute to warmer water temperatures, increased eutrophication and reduced in-stream flows for fish. The two Water Survey Canada (WSC) hydrometric stations in the watershed, a year-round station on Buck Creek and a seasonal station on the upper Bulkley have been decommissioned in recent years,

Juvenile fish enumeration conducted in 1990 and 1992 found fish species composition in the upper Bulkley at Houston to be dominated by longnose dace and to a lesser extent longnose suckers (Bustard *In* Remington and others 1993). This pattern occurred upstream and downstream of the sewage treatment plant discharge, and was thought to reflect a combination of low stream velocities, warm temperatures and possibly eutrophication, providing longnose dace with a competitive feeding advantage over steelhead and salmon juveniles.

4.2 Bulkley River Tributaries

There are little or no data on nutrient, bacterial and periphyton biomass levels in other Bulkley River tributaries. Concerns have been received by the Ministries of Environment, Agriculture and Forestry regarding water quality deterioration or physical disturbance of streams which were attributed to cattle operations, including Toboggan, Canyon, and Driftwood creeks and Round and Tyhee lakes (Gaherty and others 1996). The overwintering of cattle near Toboggan Lake and Toboggan Creek has particularly been of concern to DFO managers. Incidents of fish disease have been reported downstream of Toboggan Creek Hatchery, believed to be caused in part by animal wastes in the creek.

Canyon Creek, a tributary stream in the agricultural portion of the lower Bulkley valley, supports 29 domestic and stock watering licenses, a community waterworks license and 6 irrigation licenses. The total licensed water use approximately equals the 7 day average 10 year low flow for this creek. There are no data on actual water utilization by licensees and, given the relatively moist central interior climate, actual water usage for irrigation is believed to be lower than permitted volumes. Water use for irrigation would increase during hot dry summers, when streamflows are at seasonal lows, and could possibly contribute to warmer water temperatures, increased eutrophication and reduced in-stream flows for fish. The WSC hydrometric station on Canyon Creek has also been decommissioned,

5. RESULTS

5.1 QA/QC

Quality control was assessed by the collection of triplicate sequential water samples at Site 8, Buck Creek upstream of the settlement area surrounding Houston. These data are found in Appendix 3 Table 1. The coefficient of variation (standard deviation divided by the mean) expressed as percentage is a method of assessing the precision of both field and laboratory quality control. An accepted rule of thumb is to set the maximum variation between triplicate results at a level of 10% (Gaskin 1993). However the arbitrary acceptable limit depends to some extent on the complexity of any or all of the stages within the monitoring program for any given parameter. In the 1997 study, the coefficient of variation was found to be less than 2% for all parameters except fecal coliforms.

In general, a higher degree of variation was determined in replicate sampling in 1996. This was believed to be due to historically high streamflows and heavy rain events which occurred prior to the 1996 monitoring. The high coefficient of variation in replicate orthophosphorus samples noted in 1996 may have been corrected by the change to low level orthophosphorus determination (MDC 1 μg/L) in 1997.

A high coefficient of variation (52%) was determined for fecal coliforms. Microbiological data is intrinsically very variable due to the clumped nature of the distribution of the organisms

(Warrington 1988). Bacteria tend to be concentrated on particles of organic material rather than evenly dispersed throughout the water column. Numerous samples over time are required to obtain a more accurate estimation of microbiological quality. For this reason the water quality objectives for the Bulkley basin require the analysis of at least one sample per week for 5 weeks in a period no longer than 30 days.

5.2 Comparison of water quality and periphyton data with MELP Bulkley River objectives and water quality criteria

5.2.1 Microbiological indicators

Bulkley River and tributaries water quality data September-October 1997 are found in Appendix 3 Table 2. As in 1996, two microbiological indicator organisms were sampled, fecal coliforms and fecal streptococci (also known as enterococci). Both are indicative of contamination from human and animal feces. The Bulkley River objective and provincial criteria for fecal coliforms for the protection of drinking water is ≤10 colonies/100 mL (90th percentile). The criteria for fecal streptococci is ≤3 colonies/100 mL (90th percentile). Because of the high degree of variability encountered in the use of microbiological indicators, the 90th percentile is calculated from at least 5 samples in a 30 day period.

In the 1997 study, water samples from 10 of the 15 sites, including the control, contained one or more microbiological indicator in exceedance of its' criterion. Since only one microbiological sample was collected per site, the data are considered inconclusive, but highly suggestive of the need for further monitoring.

5.2.2 Discussion: nutrients, algae and eutrophication

5.2.2.1 MELP Water Quality Criteria

The MELP Water Quality Criteria for Nutrients and Algae (Nordin 1985) are proposed to protect water resources from degradation by excessive amounts of algae. Eutrophication is the process by which lakes and streams become biologically more productive due to increased supply of nutrients (phosphorus and/or nitrogen). If sufficiently large amounts of nutrients enter lakes and streams, man's use of waters can be impaired by the algal biomass present. Eutrophication at low levels and in some habitats may benefit sport fisheries. However as the eutrophication process accelerates, negative consequences, such as changes in fish food benthic organism communities and habitat conditions, can result in a shift in fish species away from salmonids and toward more tolerant species.

In the majority of cases, phosphorus is the limiting nutrient for algal growth. In streams algae can only make use of phosphorus that is dissolved and directly available for uptake. The best analytical measurement which approximates this is orthophosphorus. In streams there are several necessary conditions which must be satisfied before phosphorus becomes a factor causing nuisance levels of algal growth. These conditions are suitable water velocity, substrate, light, temperature and grazing pressure. Since phosphorus concentration in the stream is such a relatively poor indicator of algal biomass, and biomass itself is likely to be the focus of concern, algal biomass was chosen as the measure of the criterion. The mean of 6 replicate biomass samples during the late summer low flow period are used in the calculation of periphyton standing crop.

Protection of aesthetics and recreation criterion—The Bulkley River objective value of less than 50 mg/m^2 chlorophyll *a* was established for protection of uses related to recreation and aesthetics (Nijman 1986). Nordin (1985) discusses the difficulty in assessing a level of algal biomass which is acceptable from the perspective of aesthetics. He cites examples in other British Columbia rivers in which algal biomass in the range of 35-100 mg/m^2 caused complaints about the appearance of the river, and reduced enjoyment of use of the river by fishermen. The growth, predominantly filamentous diatoms, was brown or brownish green, slimy and often occurred as long trailing strands. The growth coated the rocks, making footing hazardous, and fouled fishing lures, making angling difficult.

Under certain conditions of light and temperature, enrichment with either organic or inorganic nutrients promotes the dominance of certain prolific periphyton species, often a blue green or green filamentous algae. This is often considered a 'nuisance' condition for the following reasons (Welch 1980):

- An undesirable change in the appearance of the river, and reduced enjoyment of use of the river by fishermen.
- The clogging of water intakes with floating clumps of filaments occurs.
- Undesirable taste and odors can be created if the affected stream is used for a water supply.

Protection of aquatic life criterion—A value of less than 100 mg/m^2 chlorophyll *a* is the MELP criterion to protect against undesirable changes in aquatic life (Nordin 1985, Nagpal 1996). To define what levels of algal biomass in a stream represent an n impairment of use for aquatic life, the scientific literature and the experience of environmental biologist working in British Columbia were surveyed. Excessive amounts of algal biomass accumulation can be detrimental to fish in streams by causing the following problems:

- A secondary BOD is created that can deplete oxygen downstream as the filaments break off, or are dislodged, float away and decompose in shallow backwater areas.
- Change in oxygen concentration in streambed gravels. With heavy algal biomass, algal respiration or the decomposition of algal tissue in the gravel can damage or destroy incubating eggs. The oxygen concentration can also be affected by restriction of water flows through the gravel.
- Change in the invertebrate community to less desirable groups.
- Fry rearing and overwintering may be impaired by algal growth as well. Excellent habitat for fry (such as cobble) where fry rear and overwinter in the spaces between the cobbles provides high survival. Reduction in oxygen could reduce survival particularly for some species.

- Change in the survival of invertebrates or the forage success of fish. Heavy algal biomass may provide additional shelter for stream invertebrates from fish, and consequently affect fish growth and survival rates.

5.2.2.2 Bioavailable nutrients

The MELP Water Quality Criteria for Nutrients and Algae (Nordin 1985) identified dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (PO_4) as the forms of nitrogen and phosphorus most important to algae growth in streams. Although phosphorus limits algal growth in the majority of cases, nitrogen can be the limiting form in some circumstances.

DIN is the sum of nitrate and ammonia. Phosphorus in water is normally categorized as being either dissolved or particulate, depending on whether it passes a 0.45 µm filter. 'Dissolved' phosphorus, therefore, may include a substantial colloidal component. Within the dissolved fraction, inorganic P occurs as orthophosphate (PO_4) which is usually estimated by variations of the molybdenum blue method. Measurements based on the molybdenum blue method are often referred to as 'othophosphorus' or 'soluble reactive phosphorus' (SRP). This method may substantially overestimate orthophosphate concentrations by hydrolyzing organic and colloidally bound forms.

Summary data for the biologically available nutrients for each site 1997 are found in Table 1. It should be stressed that a dataset of only one sample per site is very limited. Periphyton accumulate on the substrate throughout the growing season, whereas this dataset represents nutrient levels only during low flows at the end of the growing season. Nutrient levels, both natural (erosional) and anthropogenic would be much higher during spring and early summer runoff period.

Table 1 Bulkley R and tributaries biologically available nutrients Sep-Oct 1997

µg/L	Site 1 Maxan	Site 2 Bulkley D/S lake	Site 3 Bulkley D/S Crow	Site 4 Bulkley D/S Richfield	Site 5 Bulkley at Knockholt	Site 6 Bulkley D/S Avalon	Site 7 Bulkley D/S Buck	Site 8 Buck U/S settlement
Ammonia	< 5	< 5	< 5	< 5	< 5	9	< 5	< 5
Nitrate	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
DIN	< 25	< 25	< 25	< 25	< 25	< 29	< 25	< 25
Ortho-P	37	24	28	12	8	8	15	33

µg/L	Site 9 Buck at Houston	Site 10 Thompson	Site 11 Canyon	Site 12 Kathlyn	Site 13 Toboggan D/S Lake	Site 14 Toboggan D/S Owens	Site 15 Reiseter
Ammonia	9	< 5	< 5	< 5	< 5	9	7
Nitrate	< 20	< 20	< 20	50	< 20	< 20	30
DIN	< 29	< 25	< 25	55	< 25	< 29	37
Ortho-P	24	16	4	12	5	6	10

DIN (ammonia and nitrate) levels were generally less than or near detection limits. A somewhat elevated nitrate level (55 µg/L) was measured in Kathlyn Creek. The highest orthophosphorus levels were found in Maxan Creek (37 µg/L) and Buck Creek upstream of the settlement area at Houston (33 µg/L). Orthophosphorus levels at other upper Bulkley sites ranged from 8-28 µg/L, with levels tending to decrease downstream. Thompson and Kathlyn creeks had an orthophosphorus levels of 16 and 12 µg/L respectively. The other lower Bulkley tributary streams had orthophosphorus levels of less than 10 µg/L.

In unpolluted rivers, SRP averages about 10 µg/L on a worldwide basis (Webb and Walling 1992). Agricultural activities may increase dissolved phosphorus to the range of 50-100 µg/L, and to >500 µg/L during snowmelt.

Ratio of nitrogen to phosphorus (N:P ratio)—The combined nutrient data from the 1996-1997 monitoring are found in Appendix 3 Table 3, as well as the ratio of nitrogen to phosphorus calculated for each of the sites. The N:P ratio in water provides an indication of the relative availability of these two important nutrients (Nordin 1985). Ratios of N:P (in available forms) of less than 5:1 are indicative of nitrogen limitation, ratios of 5-15:1 indicate no limitation or co-limitation and ratios of greater than 15:1 indicate phosphorous limitation. The N:P ratios indicate nitrogen limitation to algae growth in Maxan Creek, Buck Creek, the upper Bulkley River, Thompson Creek and Kathlyn Creek, while the others have co-limitation or no limitation to algae growth.

5.2.3 Periphyton biomass and community composition

5.2.3.1 Periphyton Biomass

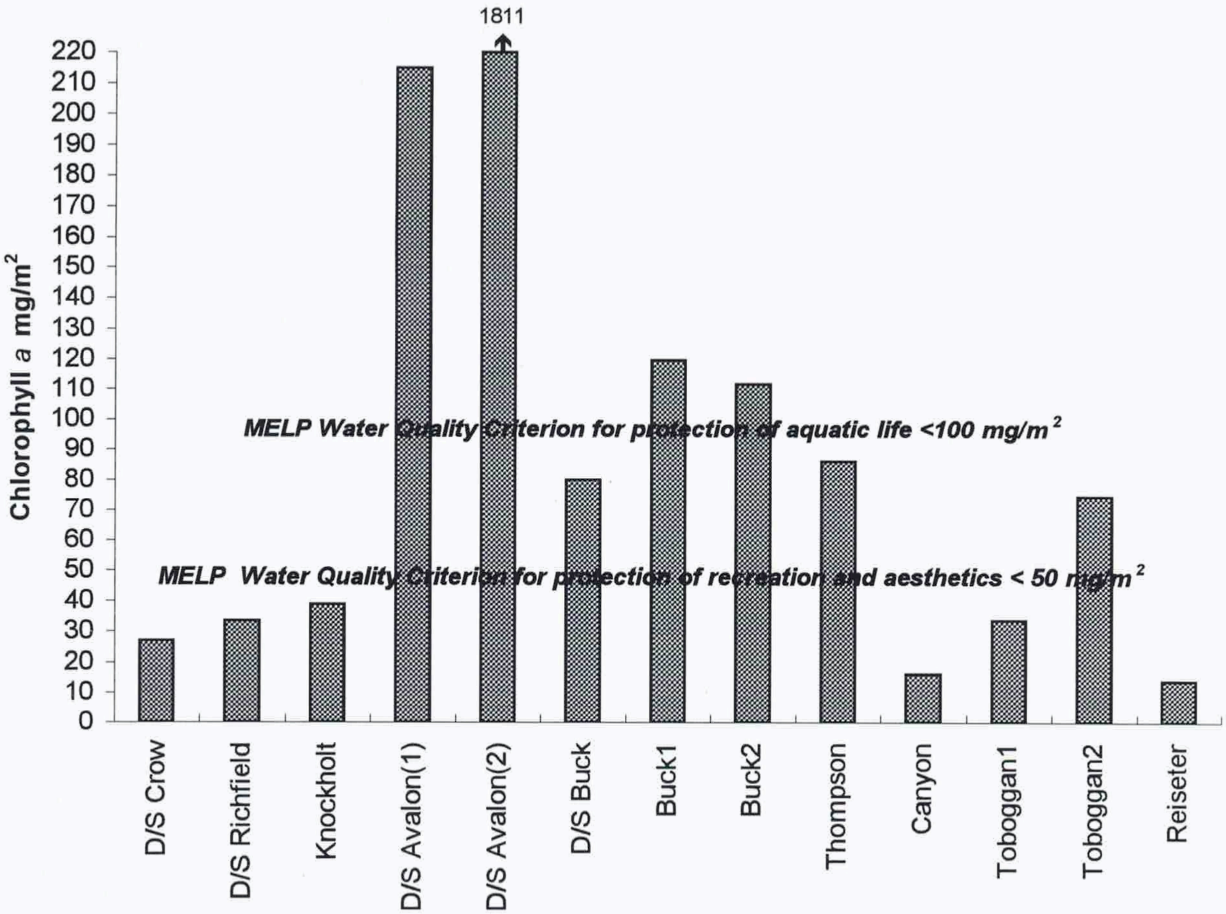
The 1997 periphyton biomass data are found in Appendix 4 Table 1. A comparison between mean periphyton biomass and provincial water quality objectives and criteria are shown in Figure 3.

The criterion for protection of recreation and aesthetics and the criterion for protection of aquatic life were exceeded in Buck Creek both upstream and downstream of the settlement area surrounding Houston. Recreation and aquatic life criteria were exceeded in the upper Bulkley downstream of Avalon Creek within the District of Houston, The recreation criterion was exceeded in the upper Bulkley downstream of the Buck Creek confluence, also in the District of Houston.

Periphyton sampling sites were 'standardized' for other factors influencing algal growth rates, particularly current velocity and depth (section 3.1.2) resulting in sampling occurring in shallow nearshore areas in the larger streams. At Site 6, the upper Bulkley downstream Avalon Creek, periphyton samples were taken 24-Sep-97 from nearshore of a mid-stream gravel bar shown in the Appendix 2 page 4 photograph. The periphyton in the sampling area appeared to be a mat of diatoms and green filamentous algae which covered the surface and filled the interstices between rocks. The mean biomass of the 24-Sep-97 samples was 215 mg/m^2.

A conspicuous blanket of green filamentous algae covered the entire riffle area surrounding the gravel bar, shown in Appendix 2 page 5 photo which was shot with a polarizing lens. On a return visit to the site 02-Oct-97, a second set of samples were taken of the green filamentous mat in the riffle area. Because it was impossible to detach and separate only a portion of the thick stringy algal mat, only one small rock was scraped, and the algae divided onto 6 filters. The measured rock area was then divided by 6 for a mean biomass per square meter calculation. By this non-standard method a biomass of over 1800 mg/m^2(!) was determined.

Figure 3 Periphyton standing crop (chlorophyll *a)* Bulkley River & tributaries September-October 1997



5.2.3.2 Periphyton community composition

Periphyton community composition at each monitoring site is found in Appendix 4 Table 2. Many habitat factors regulate the spatial distribution of riverine algae which are not well understood. It should be noted that only one sample was taken at each site, therefore these data should be viewed as a general qualitative representation of the periphyton community. Many of these sites were also sampled in 1996 and, in general, the community composition was very similar to the 1997 data. Comparisons between the 1996 and 1997 data are found in the discussions below were appropriate.

Under otherwise favorable conditions, enrichment with nutrients or organic material can result in a proliferation of certain characteristic algae, usually filamentous blue green and green genera. Much of the following discussion on algae associations is taken from Palmer (1977), who reviews algae in natural, enriched and polluted waters, with particular reference to ecological associations, indicator species and nuisance species.

Upper Bulkley River—Diatoms (Bacillariophyceae) predominated the periphytic algae community at all sites, representing between 60% and 92% of the community. The number of taxa per site, or richness, of the periphyton community was high, with 10-12 taxa/site.

Low levels (<2%) of blue green algae (Cyanophyta) were found at several sites. The filamentous *Oscillatoria* is considered to be an indicator species of eutrophication which has the potential to become a nuisance. *Anabaena* is considered an indicator of eutrophication and is a taste and odour producing algae.

Green algae (Chlorophyta) are found at all upper Bulkley sites, and represent 40% and 30% of the community composition at Site 4 (D/S Richfield) and Site 6(2) (the second periphyton sample D/S Avalon). Both these sites had quite visible green filamentous beds predominated by *Mougeotia*, a genus considered to be associated with eutrophication. These two sites had similar cobble substrate with high current velocity (70 cm/sec.), which may favor this genus. Other green algae present, all of which are associated with eutrophication, are *Closterium* (an Indicator), *Ulothrix* (which forms dense tufts of filaments), and *Cosmarium*.

Buck Creek—Richness was slightly lower in Buck Creek, with 6 and 7 taxa/site at the upstream and downstream sites. The green algae *Closterium,* considered to be an indicator of eutrophication comprised 12% of the algae community at Site 8, the upstream site, the remainder being diatoms.

Diatoms comprised 100% of the community at Site 9, the downstream site in Houston. The green algae *Ulothrix,* also associated with eutrophication, was noted in algal clumps mixed with *Gomphonema herculeanum*, a diatom which forms on gelatinous stalks. Although it was not apparent at the time of sampling, there is a possibility that the substrate could have been disturbed earlier in the growing season, since this particular site is next to a walking path in Houston and dog and human footprints have been observed going in and out the water here in the past.

Thompson Creek—The filamentous blue green algae *Oscillatoria*, which is associated with eutrophication, comprised 4% of the community at Thompson Creek Site 10, with diatoms comprising 96%. Richness, 7 taxa/site, was similar to that of Buck Creek. The appearance of the algal community was quite normal in 1997, as opposed to that of 1996.

The 1996 data for Thompson Creek, both biomass and community composition are strikingly different. Prior to sampling in 1996, the hay field immediately upstream had reportedly been treated with Round-up® (a herbicide) and the field appeared completely brown and dead. Heavy rains had fallen subsequently, and downstream water users had expressed concern that drinking water supplies may been affected. At the time of sampling, the rocks in Thompson Creek appeared to be devoid of the normal thin gray diatom layer, and biomass in 1996 was a low 5.7 mg/m^2. Clumps of green filamentous algae were observed and sampled, but they were barely submerged and may not have been submerged prior to the preceding rainfall event. The 1996 periphyton community composition was composed of 95% the green algae *Microspora*, and 5% diatoms, represented by only 2 taxa. I am highly suspicious that heavy rains following herbicide application may have washed enough of the herbicide into the creek to seriously affect the normal flora. Conditions appeared to have returned to normal in 1997.

Canyon Creek—Richness was high at Canyon Creek Site 11 with 13 taxa/site. Green algae comprised 39% of the community, dominated by *Ulothrix*, *Cosmarium*, and *Closterium*, all of which are associated with eutrophication. The 1996 periphyton community was composed of 100% diatoms, with a similar richness of 7 taxa/site, with a trace amount of *Oscillatoria*.

Toboggan Creek Site 13—Diatoms comprised 100% of the community at Toboggan Creek downstream of the lake, and richness was low, 4 taxa/site. In 1996 diatoms comprised 99.5% of the community, with a richness of 7 taxa/site. *Cladophora* comprised the remaining 0.5%.

Toboggan Creek Site 14—Richness was 7 taxa/site at Toboggan Creek downstream of Owens Creek, consisting of 95% diatoms and 5% the filamentous blue green *Oscillatoria*, which is associated with eutrophication. Also present were mats of *Oscillatoria*, *Ulothrix*, *Spirogyra* and the diatom *Gomphonema geminatum* on stalks.

In 1996, green algae comprised 25% of the community at this site, mostly *Spirogyra*, as well as algal mats composed of *Spirogyra* and *Gomphonema geminatum* on stalks.

Reiseter Creek—Richness was 7 taxa/site at Reiseter Creek Site 15, composed 100% of diatoms, which was very similar to the 1996 findings.

5.3 Predominant land use activities

The predominant land use activities in the contributing areas of the 15 monitoring sites are summarized in Table 2. Detailed livestock density and animal unit calculations are found in Appendix 5 Table 1. Cattle ranching and forestry are to predominant land use activities in the contributing areas of most of the monitoring sites. Kathlyn Creek is an exception, small hobby farms, a golf course and septic tanks associated with lake-side residences are the primary activities in this watershed. The Reiseter Creek watershed is an active timber harvesting area, but has little or no ranching or other human activity close to the creek, which is in a steep walled canyon in its lower reaches.

Table 2 Major land use activities observed in contributing areas of monitoring sites

Site	Location	Land Use Activities	Total Animal Units[1]
1	Maxan Cr U/S Bulkley L	Forestry, cattle range, closed mine	
2	Bulkley R D/S Bulkley L	Cattle ranching, forestry	
3	Bulkley D/S Crow Cr	Cattle ranching, forestry	158
4	Bulkley D/S Richfield Cr	Cattle ranching, forestry	533
5	Bulkley at Knockholt	Cattle ranching, forestry	657
6	Bulkley D/S Avalon Cr	Cattle ranching, septic tanks, forestry	975
8	Buck Cr U/S settlement	Forestry, hobby farms, closed mine	few
9	Buck Cr at Houston	Cattle ranching, septic tanks, forestry	338
7	Bulkley D/S Buck Cr	Cattle ranching, septic tanks, forestry	1313
10	Thompson Cr	Cattle ranching, forestry	339
11	Canyon Cr	Cattle/sheep ranching, forestry	406
12	Kathlyn Cr	Septic tanks, hobby farms, golf course	50
13	Toboggan Cr D/S lake	Cattle ranching, forestry	223
13	Toboggan D/S Owens Cr	Cattle ranching, forestry, fish hatchery	580
11	Reiseter Cr	Forestry	0

[1] Total animal units in contributing area of monitoring site. Source: Appendix 5 Table 1.

5.3.1 Forestry

The principal water quality variables that may be influenced by timber harvesting are temperature, dissolved oxygen, suspended sediment and nutrients (Chamberlin and others 1991). When streamside vegetation is removed, summer water temperatures usually increase in direct proportion to the increase in sunlight that reaches the water surface. While fish productivity might be enhanced in cold headwater streams, the increased water temperature may have negative effects in the lower watershed.

Concentrations of dissolved oxygen in intergravel spaces may be reduced if fine organic debris accumulates on and in the streambed. The high chemical and biological oxygen demands of such debris and the bacteria on it may persist for long periods until the bottom material is removed by high flows. Logging and skidding near or across small streams obscured by snow are particularly likely to contribute fine organic debris to watercourses during spring runoffs.

Clogging of surface gravels by fine inorganic sediments can restrict intergravel flow enough to lower dissolved oxygen concentrations. This problem usually occurs only when large or persistent volumes of sediment emanate from active road systems, mass soil movements, bank slumps or destabilized upstream channels (Scrivener and Brownlee 1989).

Although the harvesting of timber interrupts the cycling of nutrients between vegetation and soils, most studies reveal no significant impact on nutrient levels in forest streams. Concentrations of inorganic nutrients (e.g. N, P, K, Ca) in streams may increase after logging, but usually by moderate amounts and for short periods. Limited nutrient losses may be related to slashpile burning near streams, erosion of abandoned and active logging roads, and to the modification of the flood hydrology of small streams.

Streams in which algal production is limited by a particular nutrient (e.g., phosphorus) may have major algal blooms in response to minor increases in that nutrient, if temperature and flow conditions permit. These blooms can harm salmonid production if their remnants settle into interstitial gravel space. For this reason, forest fertilizers, like pesticides, should not be applied within buffer strips along streams.

5.3.2 Cattle ranching

Livestock wintering areas—In agricultural areas nutrient losses from livestock wintering areas or feedlots generally exceed those from other agricultural sources by several orders of magnitude (Loehr 1974). Snowmelt runoff produced on the frozen surfaces of wintering areas entrains nutrients in manure in both particulate and dissolved forms. Where contaminated runoff reaches nearby streams high nutrient loads may result. Phosphorous movement by subsurface flow from wintering areas and feedlots to watercourses is generally not significant; on well drained sites all but the coarsest soils demonstrate adequate capacity to tie up phosphorus from these sources (Hart and Mayall 1991)

Grazing—Well drained slopes with a herbaceous vegetation cover have a low susceptibility to surface runoff and erosion, and where manure is exposed to snowmelt runoff it is widely distributed rather than concentrated as in livestock wintering areas. Wetlands that are intensively grazed may be significant sources of nutrients since they are source areas of snowmelt and storm runoff and are subject to flooding.

Fertilization—Fertilizer application has been recognized in other agricultural basins as a potential cause of stream enrichment (Cooper 1993). In the study area most fertilizer is applied to perennial forage crops on well drained uplands which would be subject to minimal surface runoff. Excessive surface irrigation would have the potential to transport fertilizer broadcast on the field surface but it is expected that such cases would be rare, ranchers generally being conservative of both their chemical fertilizer and water supply.

The most significant potential for phosphate fertilizer loss to streams is at sites that are poorly drained or subject to flooding. Poorly drained riparian areas and wetlands have the potential to deliver nutrients to streams by flooding, storm runoff and subsurface flow.

Accelerated erosion—A final mechanism of phosphorus loss to surface waters in agricultural areas is by surface erosion or channel bank erosion. In many agricultural areas surface erosion of exposed mineral soils is a significant problem. Sediment (bearing phosphorus) may be transported from road surfaces, ranch yards or fields under cultivation however, in the study area erosion is expected to be minimized by the maintenance of perennial forage crops and the recent introduction of 'no-till' replanting systems.

Channel bank erosion may be accelerated by human manipulation of channels and by use of streamside areas by livestock. A detailed channel inspection would be required to assess the significance of intensive use of riparian areas by grazing livestock, of livestock watering sites or the impact of channel modification on sediment and nutrient transport.

5.3.3 Septic systems

Certain residential areas within the District of Houston are not presently hooked up to the municipal sewage collection system and rely on septic systems; in particular, a small subdivision along Avalon Creek and the residential area north of the railway line and on the upper Bulkley River floodplain. Probably the most significant residential development impact in the watershed is thought to be from lakeside septic systems (Boyd and others 1984). Septic system effluent has high phosphorus content derived from human wastes and detergents. Many studies have shown that, where systems are located on well drained mineral soils set back an approved distance from receiving waters, there is little likelihood of contamination.

6. DISCUSSION

6.1 Microbiological indicators

Direct comparison with federal and provincial criteria for the protection of drinking water quality is not possible for this study, because 5 or more samples in 30 days are a requirement for assessing microbiological indicators. Nonetheless, fecal coliforms and/or fecal streptococci were found in exceedence of drinking water criteria at every site in 1996 and 10 of the 15 sites in 1997, indicating the need for further monitoring on a watershed-wide basis. *Review of cattle-community watershed conflicts in the Skeena region* (Gaherty and others 1996) suggested a number of potential water quality monitoring locations for identified 'community watersheds' and for those in which a substantial number of water licensees rely on the watercourse for domestic water use.

6.2 Upper Bulkley River

6.2.1 Eutrophication

There are signs of eutrophication of the upper Bulkley River, particularly in the lower reaches in the vicinity of Houston. Periphyton standing crop in the upper Bulkley River exceeded the MELP objective for the protection of aesthetics and recreation at all sites in 1996. The criterion for the protection of aquatic life was exceeded at Site 6 D/S Avalon Creek in both years. The very conspicuous , and some would call 'nuisance', proliferation of filamentous green algae at Site 6 is probably the result of the combination of favorable growing conditions at that site and an adequate supply of nutrients during the growing season.

The relatively high orthophosphorus levels in Maxan Creek (Site 1), the upper Bulkley immediately downstream of Bulkley Lake (Site 2) and Buck Creek upstream of the main settlement and agricultural area around Houston (Site 8) is somewhat puzzling. The upper Bulkley drainage is part of the Nechako-Plateau physiographic region, characterized by a bedrock geology of basalt and other volcanic rocks which have been heavily influenced by glaciation (Runka 1972). The major soil forming deposits are gently undulating glacial till, glacial outwash, and glacial lacustrine deposits. Generally igneous rock is not high in phosphorus, although phosphate bearing minerals are often found in association with metamorphic ore bearing deposits.

Further study of the phosphorus loading potential of upper Bulkley River watershed soils is required.

It would not be unlikely that late September-early October sampling would coincide with Fall turn-over in Maxan Lake, Bulkley Lake and Goosly Lake, resulting in phosphorous loading from lake sediments. As mentioned in section 5..2.2.2, actual concentrations of bioavailable dissolved inorganic phosphorus (PO_4) may be substantially overestimated by SRP because of the amount of phosphorus which may be colloidally bound. This may be particularly true for lakes, where SRP may over-estimate PO_4 by more than an order of magnitude (Newbold 1992). Maxan and particularly Goosly Lakes are noticeably coloured by natural tannins and lignins, which are generally known to have a high organic complexing capacity. A further evaluation of the actual bioavailability of phosphorous loading from these lake-headed sources is required.

Regular nutrient sampling throughout the growing season would be necessary in order to understand the correlation between growing season nutrient levels and downstream periphyton standing crop at the end of the growing season. Carbon, phosphorus and nitrogen, or particular chemical forms of these elements, may be in relatively short supply and undergo considerable utilization as they pass downstream. Biota remove nutrients from river water, but they also regenerate nutrients to the water at some later point in time. As a nutrient atom undergoes a series of transformation, completing a 'cycle' by returning to a previous state, it also transverses some distance downstream. This open, or longitudinally displaced, cycling has been termed 'spiraling'. A given nutrient atom, as it passes downstream, may be used again and again.

The relatively low orthophosphorus levels found at the downstream upper Bulkley River sites compared to higher in the watershed may be the result of nutrient uptake and cycling by the biota. Phosphorous is also removed from the water column by adsorption onto the surfaces of particles, particularly clays, and, during periods of steady flow, accumulation in the sediment. These sediments may be resuspended during storms or freshet and at least some of the adsorbed phosphorous may become available again.

6.2.2 Land use activities

Mining and forestry—Land use activities in the upper Bulkley River watershed are a closed open-pit silver mine, forestry and beef cattle ranching. While some nutrient loading due to explosives use would be expected during active mining, nutrient run-off from the closed minesite seems unlikely. Studies show that nutrient increases (mostly nitrate) are fairly limited after logging and usually persist for only a few years. The predominant effect of these land use activities may be in the runoff of sediments primarily from roads. This would be particularly the case if the soils of the upper watershed are shown to be phosphorous bearing.

Cattle ranching—Cattle ranching is a predominant land use in the upper Bulkley watershed. Approximately 1300 breeding cattle are over-wintered in the upper Bulkley watershed, and nearly that number of calves are additionally present during the growing season. A relationship between phosphorous concentrations in streams draining watersheds and the various types of land uses in the watershed have been well documented in the past (Cooke and others 1986). As the land use changes from predominantly forest to predominantly agriculture, phosphorus concentrations in streams increase.

Gaherty and others (1996) identified seasonal feeding areas (including over-wintering sites, cow-calf operations and feedlots) as an environmental risk to water bodies in the Skeena Region through manure run-off. In regions like Skeena, with high snow melt runoff or high rainfall, these operations are thought to pose a medium to high pollution risk to both surface and ground water. Other operations on cattle farms which may affect water quality include feed storage (particularly silage) and sawdust storage. Silage runoff, because of its high biochemical oxygen demand (BOD) and nutrient content is a more potent contaminant than manure, and so is especially important. Further study is required to identify problems which may be associated with the siting of specific over-wintering and feedlot operations.

Gaherty and others assessed the contribution of grazing lands to water quality concerns to not be significant. Cattle densities on range lands are very low and with very limited winter use. The concerns identified related to the use of natural waters for watering. Cattle in the region generally have unlimited access to streams or lakes for watering, which may cause extreme bank erosion and direct deposition of manure, a microbiological as well as nutrient hazard.

Septic systems—Septic systems servicing the residential area which is built on the upper Bulkley floodplain north of the railway tracks in Houston may not be sufficiently elevated above groundwater during periods of high flows. Although this area is protected by dikes, flooding of basements occurred in the spring of 1997. Typically groundwater within a floodplain rises and falls with river levels and likely reaches the zone of the septic drain fields for this residential area during extreme events, increasing the chance of nutrient and microbiological contaminants reaching the main river.

6.3 Thompson Creek

The very low periphyton standing crop observed in Thompson Creek in 1996 (5.7 mg/m^2 and comprised of only two diatom genera) seemed surprising given the presence of 339 breeding beef cattle in a relatively small watershed. The herbicide Round-up® had been applied to the hay field immediately upstream during the weeks prior to sampling and may have entered the stream in sufficient quantities to have had a toxic effect on the periphytic algae. Great concern was expressed by downstream water users in 1996 that their drinking water supplies had been contaminated, forcing them to import drinking water. This incident suggests that both education and monitoring/enforcement may be appropriate regarding management practices for the use of herbicides in community watersheds. In the upstream agricultural area, Thompson Creek is protected by a very narrow deciduous riparian zone. A wider riparian zone may have provided more protection for the creek by keeping agricultural chemicals at a distance and by filtering surface runoff.

In 1997 the periphyton standing crop was 86.1 $mg/m^{2,}$ which exceeds the criterion for recreation and aesthetics and the community was 96% diatoms represented by 7 genera. A small amount of a filamentous blue green algae associated with eutrophication was also present. Cattle ranching is the primary land use activity in this watershed and is the likely source of nutrients to Thompson Creek.

6.4 Toboggan Creek

There are also signs of eutrophication of the lower Toboggan Creek drainage. In addition to very elevated microbiological indicators (2420 fecal coliforms QT MPN), periphyton standing crop exceeded the criterion for protection of aesthetics and recreation at Site 13 downstream of Owens Creek in 1997. Filamentous blue green and green algae genera often associated with eutrophication were present both in 1996 and 1997 at this site.

Orthophosphorus levels were not elevated during the sampling period in either year and N:P ratios indicate that primary productivity in Toboggan Creek is co-limited by nitrogen and phosphorous.

Although present, forestry is thought to be a relatively minor activity in the Toboggan watershed. Agriculture has historically been an important activity in the Evelyn Station area of the watershed. One hay, three dairy and eight beef cattle operations are present in the relatively small Toboggan Creek watershed; with 353 breeding cattle and 20 sheep over-wintering near the lake and creek. Runoff of nutrients and bacteria from dairy barns and confined cattle winter feeding areas have been documented elsewhere to contribute to bacterial loading and eutrophication. Further monitoring of eutrophication and fish health problems in this watershed is needed.

6.5 Other tributary streams

Periphyton standing-crop in Canyon, Kathlyn and Reiseter Creeks did not exceed criteria levels in either year.

Fecal coliforms and/or fecal streptococci were found in exceedence of drinking water criteria for every sample in these three creeks. Direct comparison with federal and provincial criteria for the protection of drinking water quality is not possible for this study, because 5 or more samples in 30 days are a requirement for assessing microbiological indicators. Nonetheless, these findings are high suggestive of the need for further bacteriological monitoring on a watershed-wide basis.

7. RECOMMENDATIONS FOR FURTHER MONITORING

- Further monitoring of microbiological indicators is suggested for community watersheds and watersheds with many licensed domestic water users in the agricultural portions of the Bulkley watershed. In addition to the standard microbiological indicators, such as fecal coliforms and fecal streptococci, Giardia and Cryptosporidium are increasingly a concern in undisinfected drinking water supplies. A number of monitoring sites are suggested by Gaherty and others (1996).

- Further monitoring is needed to elucidate the sources of phosphorus loading to the upper Bulkley River watershed. It is suggested that bacterial and nutrient monitoring be undertaken in tributaries streams as well as the mainstem during the spring runoff period and throughout the growing season, followed by periphyton biomass monitoring in September. In addition, a detailed assessment of land-use activities, particularly percent clear-cut, percent agricultural clearing, riparian condition, slopes and soil types should be assessed.

- Further monitoring of nutrient losses from livestock wintering areas and manure and silage storage sites is suggested for the upper Bulkley and Toboggan Creek watersheds as well. Livestock wintering areas have been identified as the major environmental risk to water bodies in the Skeena region through contaminated run-off. A rating system based on terrain runoff potential, wintering area location and management and livestock numbers has been used successfully in focusing remedial action in other central interior watersheds (Hart and Mayall 1991).

- An assessment of actual irrigation water volumes removed from the upper Bulkley River and other heavily utilized Bulkley River tributaries such as Toboggan and Canyon creeks has been suggested (Remington 1996). Preliminary analysis of irrigation withdrawals upstream of the two hydrometric stations in the agricultural portion of the watershed indicated that a large percentage of flows could potentially be removed for irrigation during dry years. This assessment was based on an estimate of water usage by licensees, rather than actual recorded use. Given the relatively moist central interior climatic regime, actual usage may be much lower. Reduced streamflows may result in conflicts with downstream water users and increase the negative impacts of eutrophication on aquatic life.

- The Kispiox River is another very important fish habitat stream with both forestry and agriculture as major land use activities in the watershed. Preliminary monitoring of bacterial, nutrient and periphytic algae levels is suggested for this system as well.

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Appendix 1 Detailed 1997 water and periphyton sample site descriptions

Site 1 Maxan Cr U/S Bulkley Lake Latitude: N54º 22.712' Photos: 97-6:25-26
Site is +/- 300 m U/S Bulkley Lake Longitude: W126º 09.000'

Date: 01-Oct-97 13:00

Water temperature: 7.0 ºC Dissolved Oxygen: 10.7 mg/L Slope: <0.5º

Substrate: fine gravel 90%, sand/silt 10%

Comments: Fine gravel/sand substrate unsuitable for periphyton sampling.

Observations: Cattle have access to stream throughout lower section. Substrate disturbed by wading cattle. Water samples slightly turbid as result of +/- 1" rain in preceeding two days.

Site 2 Bulkley R D/S Bulkley Lake Latitude: N54º 23.234' Photos: 97-6:30-31
Site is at farm bridge about 350 m D/S lake. Longitude: W126º 08.327'

Date: 01-Oct-97 12:00

Water temperature: 10.7 ºC Dissolved Oxygen: 8.1 mg/L Slope: <0.5º

Comments: Deep incised channel and silt substrate unsuitable for periphyton sampling.

Observations: Cattle have access to stream 400 m U/S of this site. Photos: 97-6:27-29. Water samples slightly turbid as result of +/- 1" rain in preceeding two days.

Site 3* Bulkley R D/S Crow Cr Latitude: N54º 24.113' Photos: 97-6:23-25
Site is adjacent to Rose Lake Cut-off Rd Longitude: W126º 09.900'

Date: 01-Oct-97 11:00

Water temperature: 9.0 ºC Dissolved Oxygen: 8.2 mg/L

Periphyton sampling depth: 10-30 cm Slope: 0.5º Current velocity: 0.45 m/s

Substrate: gravel 90%, sand/silt 10% Aspect: W % Shade: 70%

Comments: Sampled mid-channel gravel bar. Beaver dam no longer present upstream. Water samples slightly turbid as result of +/- 1" rain in preceeding two days.

Site 4* Bulkley R D/S Richfield Cr Latitude: N54º 26.657' Photos: 97-6:21-22
Site is 1 km past end of Poplar Rd, D/S railway bridge. Longitude: W126º 33.499'

Date: 30-Sep-97 13:00

Water temperature: 9.2 ºC Dissolved Oxygen: 9.2 mg/L

Periphyton sampling depth: 10-20 cm Slope: 1.5º Current velocity: 0.75 m/s

Substrate: 90% gravel, 8% cobble, 2% sand/silt Aspect: NE % Shade: 80%

Comments: Sampled L bank, near upstream end of sand/gravel bar.

Observations: Approximately 1/2 " rain previous 24 hours. Periphyton mostly diatoms, +/- 30% coverage of green filamentous, mainly in U/S riffle area. Dead Chinook spawner.

* Site was sampled in 1996.
** Locality was sampled in 1996, but sample site location is changed.

Appendix 1 (continued) Detailed 1997 water and periphyton sample site descriptions

Site 5 Bulkley R at Knockholt Stn** Latitude: N54° 26.694' Photos: 97-6:19-20
Site is 20 m D/S McKilligan Rd bridge. Longitude: W126° 33.584'
(1996 site was U/S bridge.)

Date: 30-Sep-97 11:00

Water temperature: 9.0 °C Dissolved Oxygen: 8.95 mg/L

Periphyton sampling depth: 10-30 cm Slope: <0.5° Current velocity: 0.33 m/s

Substrate: 90% gravel, 10% sand/silt Aspect: N % Shade: 20%

Comments: Sampled along L bank gravel bar.

Observations: Approximately 1/2 " rain previous 24 hours. Periphyton mostly diatoms, some green filamentous.

Site 6* Bulkley R D/S Avalon Creek Latitude: N54° 24.185' Photos: 97-6:14-16
Site is at end of 4th St in Houston Longitude: W126° 39.011' 97-7:1-11

Date: 24-Sep-97 13:00 Water and first periphyton samples.
02-Oct-97 11:00 Second periphyton samples.

Water temperature: 12.0 °C Dissolved Oxygen: 10.1 mg/L Field pH: 7.4

Periphyton sampling depth: 10-30 cm Slope: 0.5° Current velocity: 0.7 m/s

Substrate: 60% cobble, 40% gravel Aspect: NE % Shade: 10%

Comments: First periphyton sample along midstream gravel bar, 2nd sample algae mat in stronger current.

Observations: First sample 60% diatoms 40% green filamentous. 2nd sample 90% green filamentous
Many Trichoptera and Plecoptera (caddisflies and stoneflies).

Site 7* Bulkley R D/S Buck Cr Latitude: N54° 24.053' Photos: 97-6:10-11
MELP SEAM Site 0400297. Longitude: W126° 40.129'
U/S sewage treatment plant.

Date: 23-Sep-97 13:00

Water temperature: 11.6 °C Dissolved Oxygen: 11.6 mg/L Field pH: 7.9

Periphyton sampling depth: 10-30 cm Slope: 1° Current velocity: 0.7 m/s

Substrate: 90% gravel, 5% cobble, 5% sand/silt Aspect: NW % Shade: 55%

Comments: Sampled L bank gravel bar.

Observations: Periphyton diatoms with some green filamentous in stronger current. Periphyton samples had decomposing odour. No salmon redds as observed in previous years.

Site 8 Buck Cr U/S settlement area Latitude: N54° 18.174' Photos: 97-6:17-18
Site is D/S Buck Flats Rd bridge 11.7 km S of Houston Longitude: W126° 38.722'

Date: 29-Sep-97 12:00

Water temperature: 7.1 °C Dissolved Oxygen: 10.2 mg/L

Periphyton sampling depth: 10-30 cm Slope: 0.5° Current velocity: 0.39 m/s

Substrate: 75% gravel, 15% cobble, 8% sand, 2% boulder Aspect: N % Shade: 40%

Comments: Sampled R bank gravel bar. Collected triplicate sequential water samples at this site.

Observations: Many small freshwater mussels.

* Site was sampled in 1996.
** Locality was sampled in 1996, but sample site location is changed.

Appendix 1 (continued) Detailed 1997 water and periphyton sample site descriptions

Site 9* Buck Cr at Houston Latitude: N54° 24.101' Photos: 97-6:12-13
MELP SEAM Site E219804 Longitude: W126° 39.280'

Date: 24-Sep-97 11:00

Water temperature: 11.0 °C Dissolved Oxygen: 9.1 mg/L Field pH: 8.1

Periphyton sampling depth: 10-30 cm Slope: 0.5° Current velocity: 0.3 m/s

Substrate: 80% gravel, 20% cobble Aspect: N % Shade: 15%

Comments: Sampled R bank gravel bar.

Observations: Periphyton mostly diatoms, some green filamentous..

Site 10 Thompson Cr** Latitude: N54° 34.266' Photos: 97-6:8-9
Site is 250 m U/S Walcott Rd culvert. Longitude: W126° 48.523'
(100 m U/S 1996 site.)

Date: 23-Sep-97 11:00

Water temperature: 11.3 °C Dissolved Oxygen: 11.6 mg/L Field pH: 8.3

Periphyton sampling depth: 10-15 cm Slope: 1.5° Current velocity: 0.3 m/s

Substrate: 75% gravel, 15% cobble, 10% boulder Aspect: S % Shade: 45%

Comments: Sampled R bank to mid-stream.

Observations: Periphyton layer much thicker than 1996, consisting of diatoms, green filamentous & moss.

Site 11 Canyon Cr** Latitude: N54° 47.768' Photos: 97-6:3-4
Site is 200 m U/S Old Babine Lake Rd bridge Longitude: W127° 06.895'
(190 m U/S 1996 site.)

Date: 18-Sep-97 10:00

Water temperature: 6.5 °C Dissolved Oxygen: 10.84 mg/L Field pH: 8.0

Periphyton sampling depth: 10-20 cm Slope: 0.5° Current velocity: 0.3 m/s

Substrate: 50% gravel, 40% cobble, 10% boulder Aspect: N % Shade: 35%

Comments: Sampled L bank gravel bar.

Observations: Periphyton thin diatom layer.

Site 12 Kathlyn Cr** Latitude: N54° 48.436' Photos: 97-6:32-34
Site is at Lund Rd.bridge about 1.8 km D/S Lake Longitude: W127° 11.655'
(1996 site was +/-3 km D/S at 10th Ave. bridge.)

Date: 02-Oct-97 15:00

Water temperature: 9.0 °C Dissolved Oxygen: 10.7 mg/L

Substrate: 100% sand/silt

Comments: Incised channel and silt substrate unsuitable for periphyton sampling.

Observations: Water samples turbid as result of 2 1/2 " rain in preceeding 3 days.

* Site was sampled in 1996.
** Locality was sampled in 1996, but sample site location is changed.

Appendix 1 (continued) Detailed 1997 water and periphyton sample site descriptions

Site 13 Toboggan Cr D/S lake** Latitude: N54º 53.368' Photos: 97-6:5
Site is 20 m D/S Evelyn Stn Rd bridge & U/S hatchery. Longitude: W127º 15.854'

Date: 18-Sep-97 10:00

Water temperature: 8.8 ºC Dissolved Oxygen: 9.7 mg/L Field pH: 7.6

Periphyton sampling depth: 10-30 cm Slope: 1º Current velocity: 0.3 m/s

Substrate: 80% gravel, 12% cobble, 8% boulder Aspect: NE % Shade: 25%

Comments: Sampled L bank gravel pockets.

Observations: Periphyton mostly diatoms, some green filamentous.

Site 14* Toboggan Cr D/S Owens Cr Latitude: N54º 55.556' Photos: 97-6:6-7
Site is 40 m U/S farm bridge & DFO counting fence Longitude: W127º 17.521'

Date: 22-Sep-97 12:00

Water temperature: 8.5 ºC Dissolved Oxygen: 10.4 mg/L Field pH: 7.7

Periphyton sampling depth: 15-20 cm Slope: 1º Current velocity: 0.36 m/s

Substrate: 75% gravel, 15% cobble, 9% boulder, 1% sand/silt Aspect: NE % Shade: 20%

Comments: Sampled L bank gravel bar.

Observations: Periphyton mat not as thick as 1996. Some green filamentous.

Site 15* Reiseter Cr Latitude: N54º 54.635' Photos: 97-6:1-2
Site is 10 m U/S Telkwa High Rd Bridge Longitude: W127º 12.246'

Date: 17-Sep-97 14:00
02-Oct-97 11:00 Resampled for phosphorus and bacteriology only.

Water temperature: 8.8 ºC Dissolved Oxygen: 10.6 mg/L Field pH: 8.1

Periphyton sampling depth: 10-15 cm Slope: 2º Current velocity: 0.3 m/s

Substrate: 60% boulder, 30% gravel, 9% cobble, 1% sand Aspect: NW % Shade: 75%

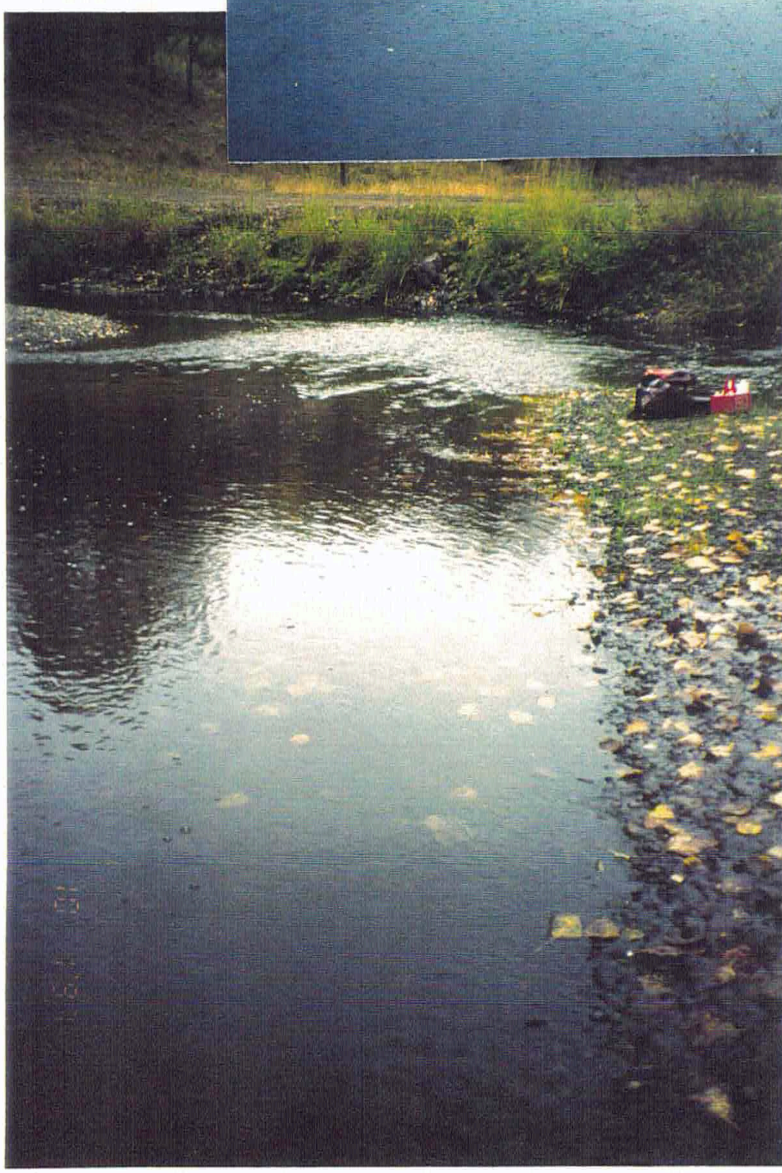
Comments: Sampled L bank gravel pockets. 17-Sep-97 phosphorus samples were contaminated. Resampled for phosphorus and bacteriology on 2-Oct-97. Water samples on that date were turbid as result of 2 1/2 " rain in preceeding 3 days.

Observations: Periphyton extremely thin diatom layer.

* Site was sampled in 1996.
** Locality was sampled in 1996, but sample site location is changed.

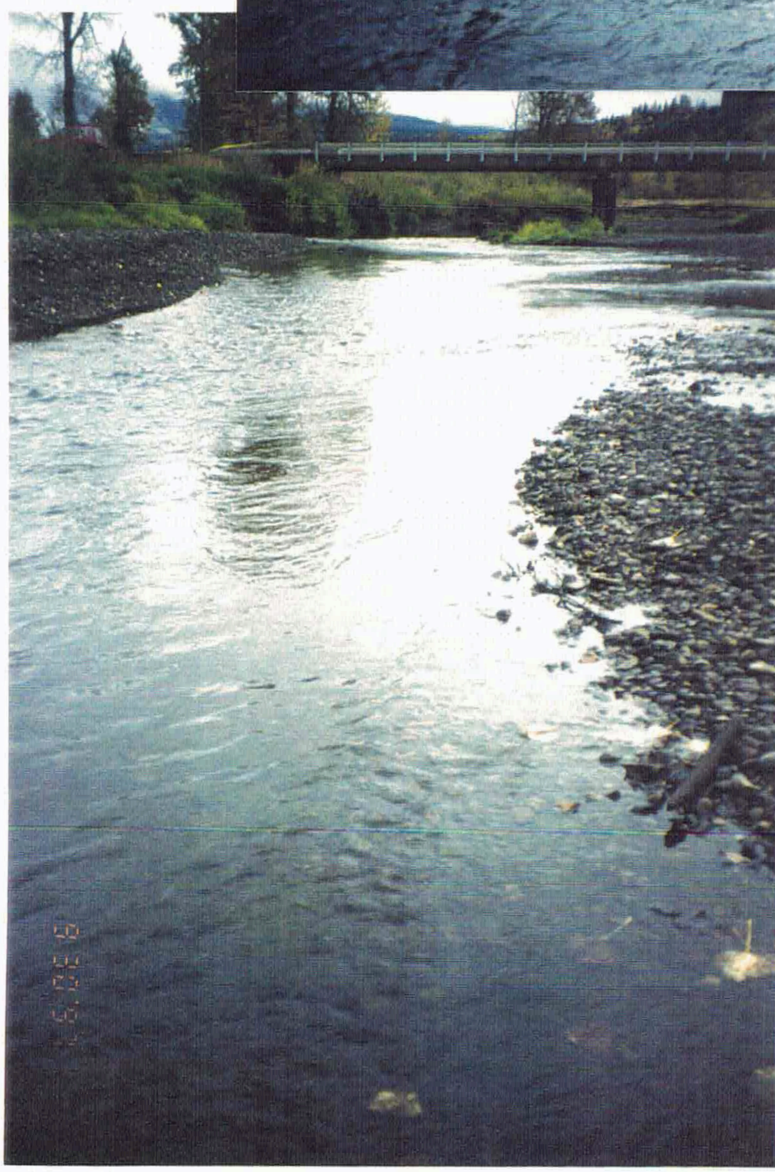
Site 1 Maxan Cr U/S Bulkley Lake 01-Oct-97 (photo 97-6:26)

Cattle watering hole Bulkley River D/S Bulkley Lake 01-Oct-97 (photo 97-6:29)



↑ Site 2
Bulkley R D/S lake 01-Oct-97
(photo 97-6:31)

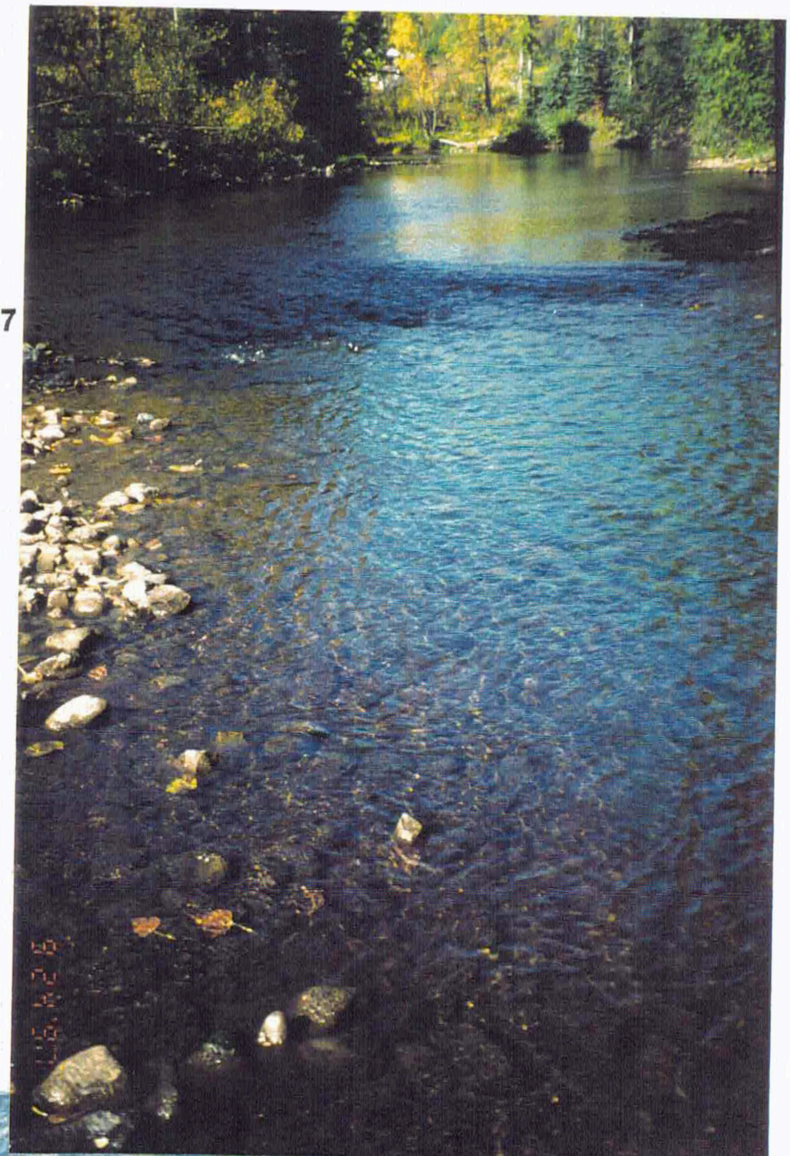
← Site 3
Bulkley R D/S Crow Cr 01-Oct-97
(photo 97-6:29)



↑ **Site 4**
Bulkley R D/S Richfield Cr 30-Sep-97
(photo 97-6:21)

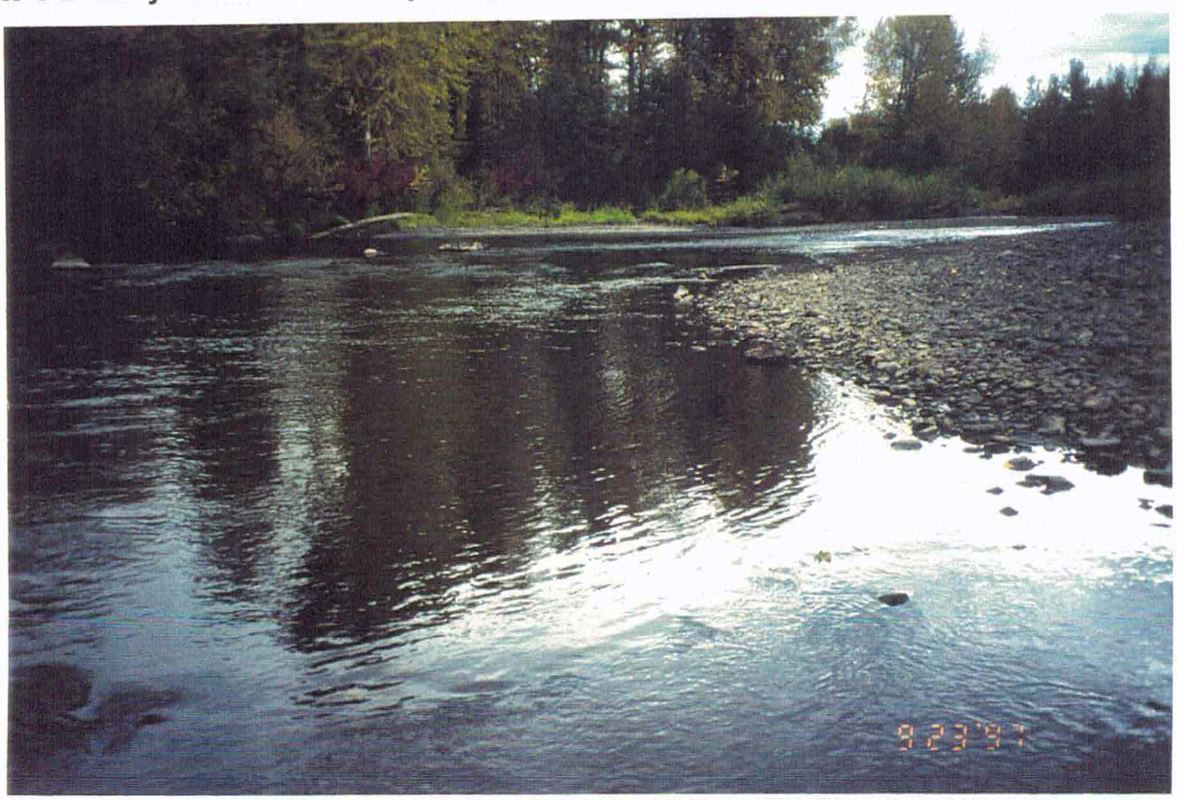
← **Site 5**
Bulkley R at Knockholt Stn 30-Sep-97
(photo 97-6:19)

Site 6 →
Bulkley R D/S Avalon Cr 24-Sep-97
(photo 97-6:16)



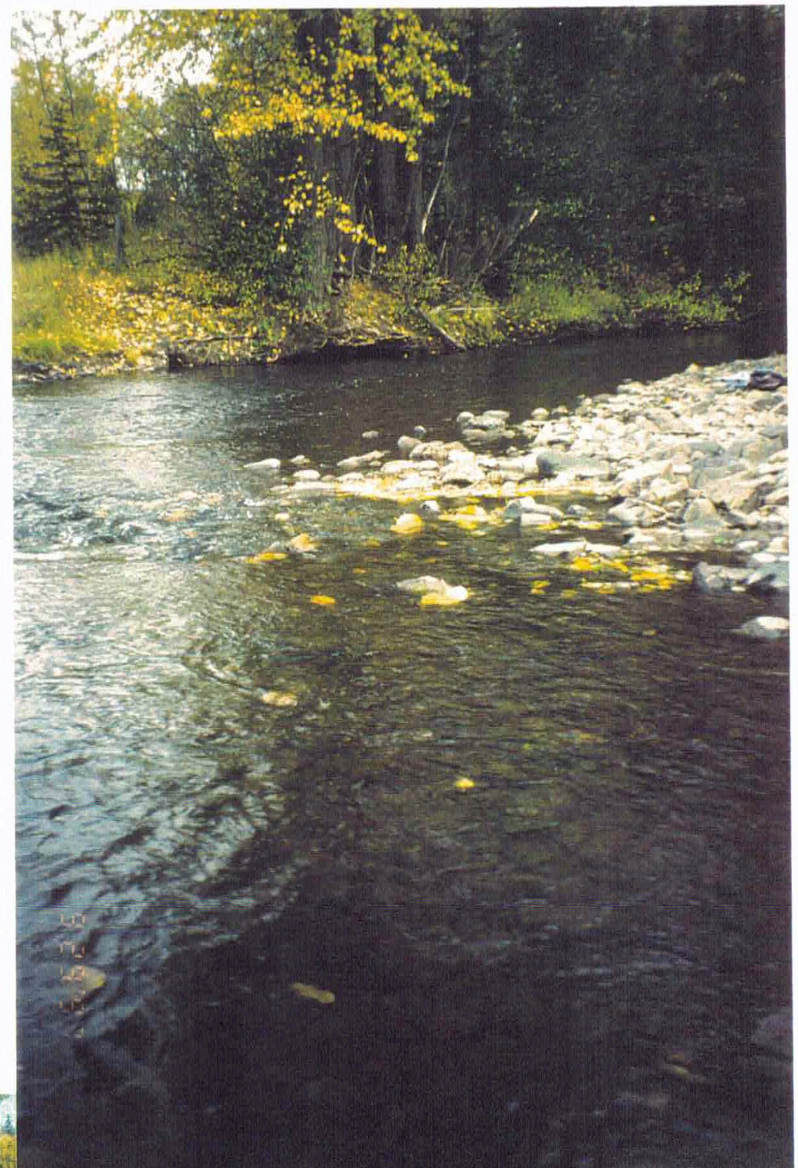
Site 6 ↓
Bulkley R D/S Avalon Cr periphyton sampling site 24-Sep-97
(photo 97-6:15)

Site 6 Bulkley R D/S Avalon Cr photographed with polarizing filter 02-Oct-97 (photo 97-7:10)

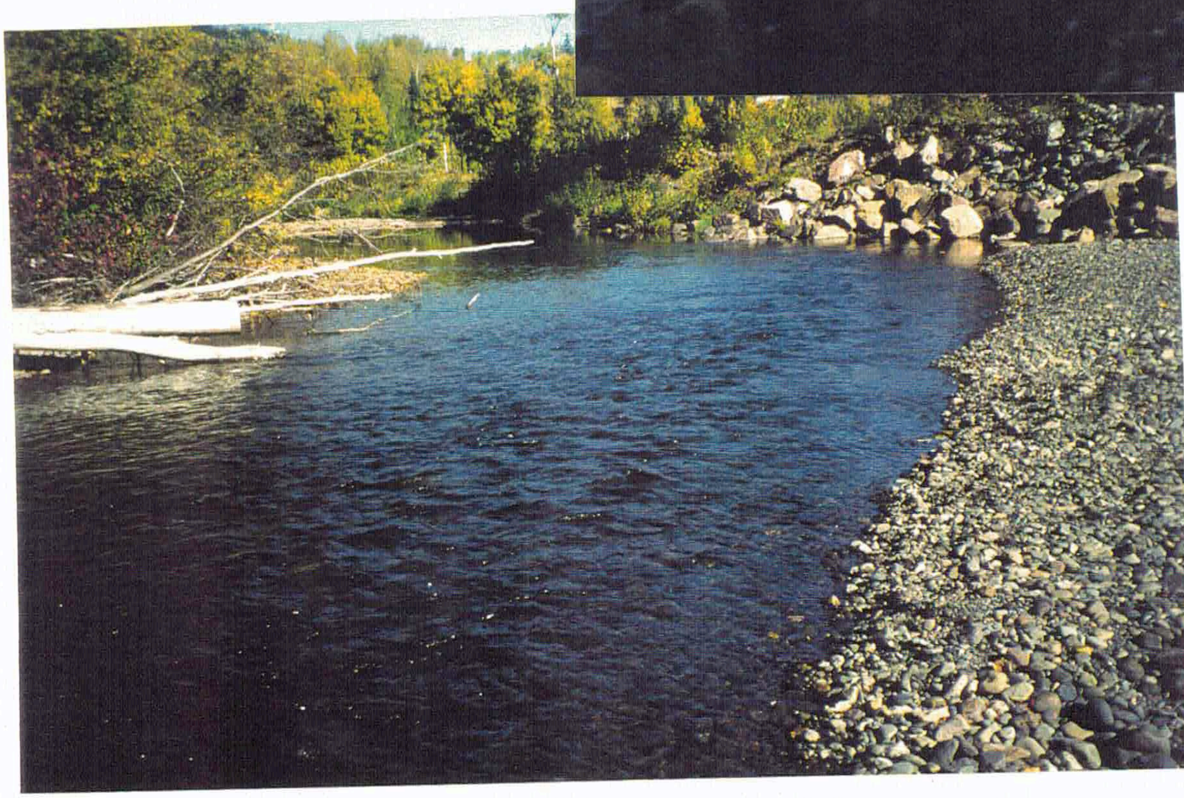


Site 7 Bulkley R D/S Buck Cr 23-Sep-97 (photo 97-6:11)

Site 8 →
Buck Cr U/S settlement area 29-Sep-97
(photo 97-6:18)



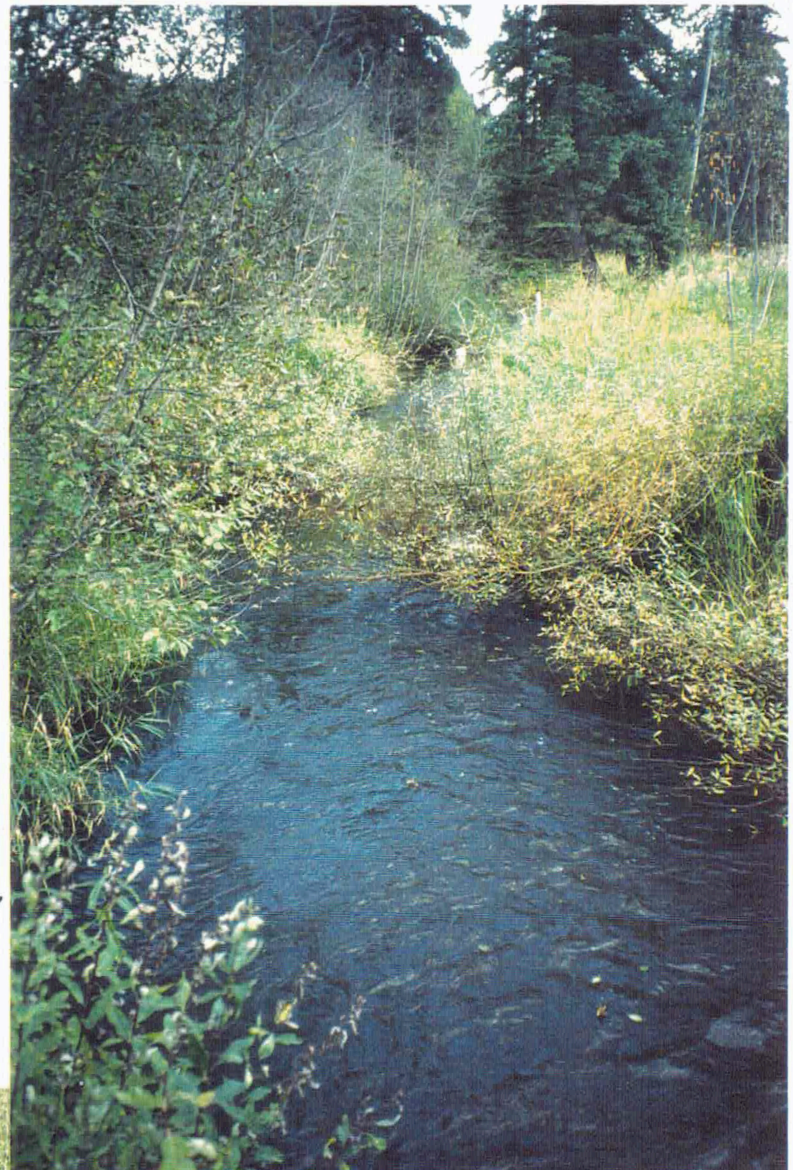
Site 9 ↓
Buck Cr at Houston 24-Sep-97
(photo 97-6:12)



Site 10 Thompson Cr 23-Sep-97 (photo 97-6:9)

Site 11 Canyon Cr 18-Sep-97 (photo 97-6:3)

Site 12➔
Kathlyn Cr 02-Oct-97
(photo 97-6:34)



Site 13 ↓
Toboggan Cr D/S lake 18-Sep-97
(photo 97-6:5)

Site 14 Toboggan Cr D/S Owens Cr 22-Sep-97 (photo 97-6:6)

Site 15 Reiseter Cr 17-Sep-97 (photo 97-6:1)

Appendix 3 Table 1 Analysis of triplicate sequential samples 29-Sep-97 Site 8 Buck Cr U/S settlement
Mean, Standard Deviation and Coefficient of Variation %

Replicate	Units	MDC	1	2	3	Mean	Std.Dev.	CoVar %
pH	pH units	0.1	7.8	7.7	7.7	7.73333	0.05774	1
Specific Conductance	uS/cm	1	99	99	100	99.3333	0.57735	1
Residue Nonfilterable (TSS	mg/L	4	< 4	< 4	< 4	4	0	0
Ammonia-N	mg/L	0.005	< 0.005	< 0.005	< 0.005	0.005	8.2E-11	0
Nitrate + Nitrite (N)	mg/L	0.02	< 0.02	< 0.02	< 0.02	0.02	3.3E-10	0
Nitrate-N	mg/L		< 0.02	< 0.02	< 0.02	0.02	3.3E-10	0
Nitrite-N	mg/L	0.005	< 0.005	< 0.005	< 0.005	0.005	8.2E-11	0
Orthophosphorus (P) Diss.	mg/L	0.001	0.033	0.033	0.034	0.03333	0.00058	2
Phosphorus - Total	mg/L	0.003	0.043	0.044	0.043	0.04333	0.00058	1
Fecal Coliform	QT MPN	1	10	9	3	7.33333	3.78594	52
Fecal Streptococcus	CFU/0.1L	1	< 1	< 1	< 1	1	0	0

Appendix 3 Table 2 Bulkley River and tributaries water quality analyses Sep-Oct 1997

			Site 1	Site 2	Site 3
			Maxan Cr	Bulkley	Bulkley
				D/S Lake	D/S Crow
Sampling date	Unit	MDC	01-Oct-97	01-Oct-97	01-Oct-97
Temperature	°C		7.0	10.7	9.0
Dissolved Oxygen	mg/L		10.7	8.1	8.2
pH	pH units	0.1	7.8	7.4	7.5
Spec. Conductance	uS/cm	1	113	106	114
Residue Nonfilterable (TSS)	mg/L	4	17	5	7
Ammonia-N	mg/L	0.005	< 0.005	< 0.005	< 0.005
Nitrate + Nitrite (N)	mg/L	0.02	< 0.02	< 0.02	< 0.02
Nitrite-N	mg/L	0.005	< 0.005	< 0.005	< 0.005
Nitrate-N Dissolved	mg/L		< 0.02	< 0.02	< 0.02
Dissolved Inorganic Nitrogen	mg/L		< 0.025	< 0.025	< 0.025
Orthophosphorus (P) Diss.	mg/L	0.001	0.037	0.024	0.028
Phosphorus - Total	mg/L	0.003	0.046	0.036	0.038
Fecal Coliform	QT MPN	1	43	23	43
Fecal Streptococcus	CFU/0.1L	1	11	4	3

			Site 4	Site 5	Site 6
			Bulkley	Bulkley at	Bulkley
			D/S	Knockholt	D/S
			Richfield		Avalon
Sampling date	Unit	MDC	30-Sep-97	30-Sep-97	24-Sep-97
Temperature	°C		9.2	9.0	12.0
Dissolved Oxygen	mg/L		9.2	9.0	10.1
Field pH	pH units	0.1	N/A	N/A	N/A
pH	pH units	0.1	7.8	7.8	7.9
Spec. Conductance	uS/cm	1	169	183	190
Residue Nonfilterable (TSS)	mg/L	4	< 4	< 4	< 4
Ammonia-N	mg/L	0.005	< 0.005	< 0.005	0.009
Nitrate + Nitrite (N)	mg/L	0.02	< 0.02	< 0.02	< 0.02
Nitrite-N	mg/L	0.005	< 0.005	< 0.005	< 0.005
Nitrate-N Dissolved	mg/L		< 0.02	< 0.02	< 0.02
Dissolved Inorganic Nitrogen	mg/L		< 0.025	< 0.025	0.029
Orthophosphorus (P) Diss.	mg/L	0.001	0.012	0.008	0.008
Phosphorus - Total	mg/L	0.003	0.022	0.013	0.010
Fecal Coliform	QT MPN	1	< 1	< 1	5
Fecal Streptococcus	CFU/0.1L	1	3	2	1

Appendix 3 Table 2 (continued) Bulkley R and tributaries water quality analyses 1997

Sampling date	Unit	MDC		Site 7 Bulkley D/S Buck 23-Sep-97		Site 8* Buck U/S settlement 29-Sep-97		Site 9 Buck at Houston 24-Sep-97
Temperature	°C			11.6		7.1		11.0
Dissolved Oxygen	mg/L			11.6		10.2		9.1
Field pH	pH units	0.1		N/A		N/A		8.1
pH	pH units	0.1		8		7.7		8.1
Spec. Conductance	uS/cm	1		160		99		110
Residue Nonfilterable (TSS)	mg/L	4	<	4	<	4	<	4
Ammonia-N	mg/L	0.005	<	0.005	<	0.005		0.009
Nitrate + Nitrite (N)	mg/L	0.02	<	0.02	<	0.02	<	0.02
Nitrite-N	mg/L	0.005	<	0.005	<	0.005	<	0.005
Nitrate-N Dissolved	mg/L		<	0.02	<	0.02	<	0.02
Dissolved Inorganic Nitrogen	mg/L		<	0.025	<	0.025		0.029
Orthophosphorus (P) Diss.	mg/L	0.001		0.015		0.033		0.024
Phosphorus - Total	mg/L	0.003		0.016		0.043		0.033
Fecal Coliform	QT MPN	1		200		9		2
Fecal Streptococcus	CFU/0.1L	1		6	<	1	<	1

* Median value of triplicate sequential samples.

Sampling date	Unit	MDC		Site 10 Thompson 23-Sep-97		Site 11 Canyon 18-Sep-97		Site 12 Kathlyn 02-Oct-97
Temperature	°C			11.3		6.5		9.0
Dissolved Oxygen	mg/L			11.6		10.9		10.7
Field pH	pH units	0.1		8.3		8.0		N/A
pH	pH units	0.1		8.2		8.1		7.3
Spec. Conductance	uS/cm	1		274		163		51
Residue Nonfilterable (TSS)	mg/L	4	<	4	<	4		10
Ammonia-N	mg/L	0.005	<	0.005	<	0.005	<	0.005
Nitrate + Nitrite (N)	mg/L	0.02	<	0.02	<	0.02		0.05
Nitrite-N	mg/L	0.005	<	0.005	<	0.005	<	0.005
Nitrate-N Dissolved	mg/L		<	0.02	<	0.02		0.05
Dissolved Inorganic Nitrogen	mg/L		<	0.025	<	0.025		0.055
Orthophosphorus (P) Diss.	mg/L	0.001		0.016		0.004		0.012
Phosphorus - Total	mg/L	0.003		0.022		0.004		0.021
Fecal Coliform	QT MPN	1		5		26		43
Fecal Streptococcus	CFU/0.1L	1		15		180		23

Appendix 3 Table 2 (continued) Bulkley R and tributaries water quality analyses 1997

Sampling date	Unit	MDC		Site 13 Toboggan D/S Lake 18-Sep-97		Site 14 Toboggan D/S Owens 22-Sep-97		Site 15 Reiseter 17-Sep-97
Temperature	°C			8.8		8.5		8.8
Dissolved Oxygen	mg/L			9.7		10.4		10.6
Field pH	pH units	0.1		7.6		7.7		8.1
pH	pH units	0.1		7.3		7.7		8
Spec. Conductance	uS/cm	1		64		74		105
Residue Nonfilterable (TSS)	mg/L	4	<	4		4	<	4
Ammonia-N	mg/L	0.005	<	0.005		0.009		0.007
Nitrate + Nitrite (N)	mg/L	0.02	<	0.02	<	0.02		0.1
Nitrite-N	mg/L	0.005	<	0.005		0.007		0.075
Nitrate-N Dissolved	mg/L		<	0.02	<	0.02		0.03
Dissolved Inorganic Nitrogen	mg/L		<	0.025		0.029		0.037
Orthophosphorus (P) Diss.	mg/L	0.001		0.005		0.006		0.010**
Phosphorus - Total	mg/L	0.003		0.008		0.009		0.009**
Fecal Coliform	QT MPN	1		13		2420	90	23**
Fecal Streptococcus	CFU/0.1L	1		156		70	214	<1**

**Phosphorus and bacteriology resampled 2-Oct-97 because of sample contamination.
Water samples were turbid on that date due to 2 1/2 " rain in preceeding 3 days.

Appendix 3 Table 3 Biologically available nutrients Bulkley River and tributaries 1996-1997

µg/L	Site 1 Maxan	Site 2 Bulkley D/S lake	Site 3 Bulkley D/S Crow				Site 4 Bulkley D/S Richfield			
	1997	1997	1996	1996	1997	Mean	1996	1996	1997	Mean
Ammonia-N	5	5	17	5	5	9	5	5	5	5
Nitrate-N	20	20	20	20	20	20	20	30	20	23
DIN	25	25	37	25	25	29	25	35	25	28
Ortho-P	37	24	14	9	28	17	14	11	12	12
N:P	0.7	1.0				1.7				2.3

µg/L	Site 5 Bulkley at Knockholt				Site 6 Bulkley D/S Avalon				Site 7 Bulkley D/S Buck			
	1996	1996	1997	Mean	1996	1996	1997	Mean	1996	1996	1997	Mean
Ammonia-N	5	7	5	6	5	18	9	11	5	11	5	7
Nitrate-N	20	20	20	20	20	20	20	20	20	20	20	20
DIN	25	27	25	26	25	38	29	31	25	31	25	27
Ortho-P	13	12	8	11	11	9	8	9	19	16	15	17
N:P				2.3				3.3				1.6

µg/L	Site 8 Buck U/S	Site 9 Buck at Houston				Site 10 Thompson				Site 11 Canyon			
	1997	1996	1996	1997	Mean	1996	1996	1997	Mean	1996	1996	1997	Mean
Ammonia-N	5	5	9	9	8	5	14	5	8	5	8	5	6
Nitrate-N	20	20	20	20	20	40	40	20	33	20	20	20	20
DIN	25	25	29	29	28	45	54	25	41	25	28	25	26
Ortho-P	33	36	27	24	29	11	8	16	12	5	4	4	4
N:P	0.8				1.0				3.5				6.0

µg/L	Site 12 Kathlyn				Site 13 Toboggan D/S lake				Site 14 Tobaggan D/S Owens			
	1996	1996	1997	Mean	1996	1996	1997	Mean	1996	1996	1997	Mean
Ammonia-N	8	6	5	6	6	5	5	5	9	11	9	10
Nitrate-N	20	30	50	33	50	30	20	33	30	50	20	33
DIN	28	36	55	40	56	35	25	39	39	61	29	43
Ortho-P	8	4	12	8	3	5	5	4	3	5	6	5
N:P				5.0				8.9				9.2

µg/L	Site 15 Reiseter			
	1996	1996	1997	Mean
Ammonia-N	5	5	7	6
Nitrate-N	20	30	30	27
DIN	25	35	37	32
Ortho-P	4	3	10	6
N:P				5.7

Appendix 4 Table 1 Bulkley R and tributaries periphyton biomass as Chlorophyll *a*
MDC=0.3 mg/m2

	Site 3 Bulkley R D/S Crow Cr	Site 4 Bulkley R D/S Richfield Cr	Site 5 Bulkley R at Knockholt	Site 6 Bulkley R D/S Avalon Cr	
mg/m^2	01-Oct-97	30-Sep-97	30-Sep-97	24-Sep-97	02-Oct-97*
Rep 1	14.40	11.6	17.8	147.0	2380.0
Rep 2	14.9	95.0	87.8	123.0	2150.0
Rep 3	6.9	26.9	36.0	171.0	2850.0
Rep 4	28.3	14.2	53.0	149.0	2260.0
Rep 5	29.1	9.2	33.9	379.0	1150.0
Rep 6	68.2	43.3	3.7	321.0	73.7
Mean	**27.0**	**33.4**	**38.7**	**215.0**	**1810.6**

* Samples were taken by dividing algae mat from one small rock onto 6 filters. Rock area divided by 6.

	Site 7 Bulkley R D/S Buck Cr	Site 8 Buck Cr U/S settlement	Site 9 Buck Cr at Houston	Site 10 Thompson Cr
mg/m^2	23-Sep-97	29-Sep-97	24-Sep-97	23-Sep-97
Rep 1	54.6	181.0	86.3	17.2
Rep 2	42.3	63.6	121.0	31.9
Rep 3	45.1	130.0	127.0	239.0
Rep 4	75.8	129.0	96.1	75.7
Rep 5	222.0	141.0	73.6	74.8
Rep 6	39.0	72.7	166.0	78.2
Mean	**79.8**	**119.6**	**111.7**	**86.1**

	Site 11 Canyon Cr	Site 13 Toboggan Cr D/S lake	Site 14 Toboggan Cr D/S Owens Cr	Site 15 Reiseter Cr
mg/m^2	18-Sep-97	18-Sep-97	22-Sep-97	17-Sep-97
Rep 1	12.7	4.1	72.8	23.3
Rep 2	31.2	142.0	34.8	22.6
Rep 3	21.2	18.8	88.4	9.5
Rep 4	9.0	13.9	49.3	9.7
Rep 5	13.1	10.9	126.0	7.4
Rep 6	9.9	12.1	spilled	9.5
Mean	**16.2**	**33.6**	**74.3**	**13.7**

16 mg
1.6000 mg/m²

Appendix 4 Table 2 Bulkley R and tributaries periphyton community composition 1997

<u>Sample #3</u> Upper Buckley River D/S Crow Creek 01/10/97

<u>Cyanophyta</u>	2%
Merismopedia punctata	30%
Oscillatoria sp.	70%
<u>Chlorophyta</u>	6%
Closterium sp.	40%
Ulothrix sp.	30%
Cosmarium sp.	30%
<u>Chrysophyta</u>	92%
<u>Bacillariophyceae</u>	
Synedra ulna	40%
Rhopalodia gibba	10%
Melosira varians	20%
Cocconeis placentula	10%
Tabellaria fenestrata	5%
Cymbella sp.	5%
Navicula sp.	10%

* Inorganic detritus

<u>Sample #4</u> Upper Bulkley River D/S Richfield Creek 30/09/97

<u>Chlorophyta</u>	40%
Mougeotia sp.	95%
Closterium sp.	5%
<u>Chyrsophyta</u>	60%
<u>Bacillariophyceae</u>	
Epithemia turgida	20%
Melosira varians	25%
Rhopalodia gibba	20%
Epithemia sorex	10%
Synedra ulna	10%
Gomphonema sp.	10%
Cocconeis placentula	5%

* Algal Clumps: Batrachospermum sp.
Melosira varians

Appendix 4 Table 2 (continued) Bulkley R and tributaries periphyton community composition 1997

Sample #5	Upper Bulkley River D/S Knockholt Stn.	30/9/97
Cyanophyta	2%	
Anabaena sp.	100%	
Chlorophyta	15%	
Cosmarium sp.	60%	
Mougeotia sp.	40%	
Chrysophyta	83%	
Bacillariophyceae		
Rhopalodia gibba	25%	
Epithemia turgida	10%	
Epithemia sorex	30%	
Amphipleura pellucida	10%	
Synedra ulna	10%	
Melosira varians	10%	
Navicula sp.	5%	

Sample #6-1	Upper Bulkley River D/S Avalon Creek	24/09/97
Cyanophyta	1%	
Merismopedia punctata	100%	
Chlorophyta	12%	
Cosmarium sp.	30%	
Mougeotia sp.	40%	
Closterium sp.	30%	
Chrysophyta	87%	
Bacillariophyceae		
Melosira varians	50%	
Rhopalodia gibba	10%	
Synedra ulna	10%	
Navicula sp.	10%	
Frustulia rhomboides	10%	
Cymbella sp.	10%	

* Algal Clumps: Rhizoclonium sp.
Mougeotia sp.
Melosira varians
Cymbella sp. in tubes

Appendix 4 Table 2 (continued) Bulkley R and tributaries periphyton community composition 1997

Sample #6-2	Upper Bulkley River D/S Avalon Creek	2/10/97
Chlorophyta	30%	
Mougeotia sp.	100%	
Chrysophyta	70%	
Bacillariophyceae		
Melosira varians	60%	
Epithemia turgida	5%	
Epithemia sorex	5%	
Synedra ulna	5%	
Cocooneis placentula	5%	
Fragilaria vaucheriae	10%	
Cymbella sp.	5%	
Rhopalodia gibba	5%	

* Filamentous material: Mougeotia sp.
Rhizoclonium sp.
Melosira varians
Spirogyra sp.
Ulothrix sp.
Cymbella sp in muscilagenous tubes
Rhizoclonium sp.

Sample #7	Upper Bulkley River D/S Buck Creek	23/09/97
Cyanophyta	2%	
Oscillatoria sp.	100%	
Chlorophyta	10%	
Cosmarium sp.	60%	
Closterium sp.	40%	
Chrysophyta	88%	
Bacillariophyceae		
Melosira varians	15%	
Synedra ulna	35%	
Epithemia sorex	10%	
Rhopalodia gibba	15%	
Epithemia turgida	15%	
Gomphonema sp.	5%	
Navicula sp.	5%	

* Algal Clumps: Rhizoclonium sp.

Appendix 4 Table 2 (continued) Bulkley R and tributaries periphyton community composition 1997

Sample #8 Buck Creek U/S settlement area north of Houston 29/09/97

Chlorophyta	12%
Closterium sp.	100%
Chrysophyta	88%
Bacillariophyceae	
Synedra ulna	40%
Epithemia turgida	25%
Epithemia sorex	10%
Gomphonema sp.	10%
Rhopalodia gibba	15%

Sample #9 Buck Creek at Houston 24/09/97

Chrysophyta	100%
Bacillariophyceae	
Epithemia turgida	35%
Epithemia sorex	20%
Synedra ulna	20%
Rhopalodia gibba	15%
Gomphonema sp.	10%

* Algal Clumps: Gomphonema herculeanum on stalks
Ulothrix sp.

Sample #10 Thompson Creek at Walcott Rd. 23/09/97

Cyanophyta	4%
Oscillatoria sp.	100%
Chrysophyta	96%
Bacillariophyceae	
Synedra ulna	40%
Amphipleura pellucida	10%
Melosira varians	15%
Cymbella sp.	15%
Anomoeneis vitrea	10%
Navicula sp.	10%

* Algal Clumps: Organic detritus
Mat of Oscillatoria sp.

Appendix 4 Table 2 (continued) Bulkley R and tributaries periphyton community composition 1997

Sample #11	Canyon Creek at Babine Lake Rd.	18/09/97
Cyanophyta	1%	
Merismopedia punctata	100%	
Chlorophyta	39%	
Cosmarium sp.	60%	
Ulothrix sp.	20%	
Closterium sp.	20%	
Chrysophyta	60%	
Bacillariophyceae		
Cocconeis placentula	10%	
Achnanthes sp.	15%	
Cymbella sp.	25%	
Synedra ulna	20%	
Amphipleura pellucida	5%	
Gomphonema sp.	10%	
Gomphonema geminatum	5%	
Cymatopleura solea	5%	
Hannaea arcus	5%	

Sample #13	Toboggan Creek D/S Toboggan Lake	18/09/97
Chrysophyta	100%	
Bacillariophyceae		
Synedra ulna	60%	
Gomphonema sp.	20%	
Cymbella sp.	10%	
Tabellaria fenestrata	10%	

* Inorganic sediment

Appendix 4 Table 2 (continued) Bulkley R and tributaries periphyton community composition 1997

Sample #14	Toboggan Creek D/S Owens Creek	22/09/97

Cyanophyta	5%
Oscillatoria sp.	100%
Chrysophyta	95%
Bacillariophyceae	
Gomphonema geminatum	55%
Synedra ulna	20%
Achnanthes sp.	10%
Cymbella sp.	15%

* Algal mat: Gomphonema geminatum on stalks
Spirogyra sp.
Ulothrix sp.
Oscillatoria sp.

Sample #15	Reiseter Creek at Telkwa High Rd.	17/09/97

Chrysophyta	100%
Bacillariophyceae	
Synedra ulna	20%
Gomphonema geminatum	20%
Diatoma tenue v. elongatum	10%
Gomphonema sp.	20%
Cocconeis placentula	5%
Cymbella sp.	15%
Hannaea arcus	5%

* Algal Clumps: Gomphonema geminatum on stalks

Appendix 4 Table 3 References: Periphyton identification

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Appendix 5 Table 1 Farm and livestock density, total animal units in contributing areas of monitoring sites

Site	Location	Farms[1]	Breeding cattle	Other stock	Animal Units[2]	Total AUs in contributing area
1	Maxan Cr U/S Bulkley L			summer range		
2	Bulkley R D/S Bulkley L	}----------1B	158	winter feedlot		
3	Bulkley D/S Crow Cr			winter feedlot	158	158
4	Bulkley D/S Richfield Cr	6B	375		375	533
5	Bulkley at Knockholt	3B	124		124	657
6	Bulkley D/S Avalon Cr	7B	318		318	975
8	Buck Cr U/S settlement	?Hobby				few
9	Buck Cr at Houston	6B	338		338	338
7	Bulkley D/S Buck Cr	0				1313
10	Thompson Cr	2B	339		339	339
11	Canyon Cr	2D 4B1S	400	30 sheep	406	406
12	Kathlyn Cr	? Hobby		40 horses[3]	50	50
13	Toboggan Cr D/S lake	1D 3B	223		223	223
14	Toboggan D/S Owens Cr	2D 5B 1H	353	20 sheep	357	580
15	Reiseter Cr	0				0

Source: MOAFF database, D. Reindeau, personal communication

[1] Type of farm
- B: Beef
- D: Dairy
- H: Hay

[2] Animal unit equivalents
- cow & calf 1.0
- horse 1.25
- domestic sheep 0.2

[3] Estimated