Survey of water quality and periphyton (algal) standing crop in the Bulkley River and tributaries 1996

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1. INTRODUCTION

The Habitat and Enhancement Branch of Fisheries and Oceans wishes to investigate the effects of human activities on water quality in the rural portions of the Bulkley River watershed. Anthropogenic addition of nutrients and bacteria to a stream or lake may result in high organic production rates (eutrophication) which can lead to several undesirable effects, including algal blooms, seasonally low oxygen levels, and reduced survival opportunities for fish.

The objectives of the study are:

- To monitor water quality and periphytic algae standing crop (biomass at the end of the growing season) at 13 sites located in the upper Bulkley River and selected tributaries to the main Bulkley River.

- To record the general land use activities observed in the study watersheds at the time of sampling.

- To report and assess the water quality and periphytic algae standing crop data relative to the MOELP *Bulkley River basin water quality assessment and objectives* (Nijman 1986) and the *Approved and working criteria for water quality* (Nagpal 1994).

- To identify additional parameters and datasets needed to further assess water quality in the Bulkley River watershed.

2. STUDY AREA

2.1 Monitoring Sites

Thirteen monitoring sites were chosen in consultation with Pierre Lemeiux, HEB, based on knowledge of land use activities in the watershed and fish habitat values. The monitoring sites were visited during late July and again in mid-September 1996. Sites 1 through 6 are located along the length of the upper Bulkley River upstream of the Houston sewage treatment plant and the confluence of the Bulkley with the larger Morice River (Figure 1). Site 7 is located on lower Buck Creek, the major tributary of the upper Bulkley River, and within the District of Houston. Buck Creek, on average, supplies about 19% of flows to the upper Bulkley river at Houston.

Sites 8 through 13 are located on tributary streams of the mainstem Bulkley below its confluence with the Morice (Figure 2). Site 11, 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). Two sites were located on Toboggan Creek; Site 12 downstream of Toboggan Lake and upstream of the DFO hatchery, and Site 13 downstream of the confluence of Owens Creek. Detailed sample site descriptions are found in Appendix 1. Photographs of each sample site are found in Appendix 2.

2.2 Streamflows

A comparison of 1996 streamflows in the upper Bulkley River at WSC Station 08EE003 at Houston is found in Table 1. The summer of 1996 in the Bulkley watershed was generally cool and punctuated by occasional periods of heavy precipitation. Record high May and June streamflows were recorded in the upper Bulkley in 1996, dropping to near normal flows in early July. Heavy rains occurred July 22-23 causing a sharp increase in streamflow just prior to the late July sampling event. Streamflow during August was near normal. Heavy rainfall in early September again brought streamflows to a record monthly maximum just prior to the periphyton sampling event scheduled for mid-September.

Table 1 Comparison of 1996 streamflows with average discharge (m^3/s) at Station 08EE003, Bulkley River near Houston

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Monthly Max. [1]	51.0	127	66.9	35.3	11.4	5.00	17.9	10.7
Monthly Mean	27.1	69.9	28.3	10.7	3.36	1.94	6.55	6.51
Monthly Min.	2.49	32.5	10.9	1.92	0.206	0.371	1.14	4.87
1996 Max. [2]		129	110	23.8 [3]	6.40	11.4 [4]		
1996 Mean		80.4	50.9	11.0	3.04	5.71		
1996 Min.		41.3	16.8	0.432	1.41	2.60		

[1] Source: Water Survey of Canada published data. Period of record 1930-1951, 1971, 1980-1993

[2] Source: Water Survey Canada unpublished preliminary 1996 data

[3] 22 July 1996

[4] 9-10 September 1996

3. METHODS

3.1 Sampling Methods

Site reconnaissance and water quality monitoring (first visit) were conducted July 25-30, 1996. The late July sampling period was preceded by heavy rains which resulted in a rapid increase in streamflow on July 22, 1996 (Table 1). Water quality monitoring (second visit) and periphytic algae standing crop monitoring were conducted at every site except Site 2 September 10-19, 1996. Only water quality was monitored at Site 2 because I was unable to locate a suitable periphyton monitoring location downstream of Topley because of sand/silt substrate and low stream velocities. Mid-September is typically the summertime low flow period, however record high flows were observed September 9-10, 1996, again due to heavy rains. While every attempt was made to chose similar sampling sites with reference to other factors which may influence algae growth rates, such as current, shading, aspect, and substrate; it was impossible to completely eliminate all site-specific variables. Scouring due to high streamflow during the growing season would be expected to result in a lower periphyton biomass at the end of the growing season. Some sites may have been more susceptible to scouring during high flows, adding to site-specific variability.

The following observations were made on July 30, 1996 during the first sampling visit to the Thompson Creek monitoring site, which is just upstream of Walcott Road. Thompson Creek meanders through a large hay field about 500 m upstream of the monitoring site. Through the field a narrow riparian strip of willow and other brushy species lines the creek. This hay field was observed to be completely brown and apparently dead on July 30, 1996 (photos 96-7:3-4). A licensed water user who was servicing a pump house located near the monitoring site expressed great concern that the herbicide Round-up® had been applied to the hay field and may have contaminated drinking water supplies, forcing downstream water users to import drinking water. Because the actual herbicide application had taken place several weeks earlier, and heavy rains had occurred in the interim, monitoring for herbicide residues was not attempted.

3.1.1 Water sampling

Water sampling was carried out as per MOELP *Ambient freshwater and effluent sampling manual* (Cavanagh and others, 1994) and *Sampling for water quality* (Environment Canada 1983). Field parameters sampled included water temperature and dissolved oxygen. Dissolved oxygen measurement was conducted with a YSI dissolved oxygen meter which was calibrated daily using the Winkler chemical method (Hach test kit using digital titrator).

Water samples were iced and shipped on the day of sampling by air to Vancouver for analysis at Zenon Laboratories. In one case, a shipment was mistakenly left in the cooler at Vancouver airport for 4 days prior to delivery to Zenon. All other shipments arrived at the laboratory the day following sampling.

3.1.2 Periphyton sampling

Periphyton sampling was based upon those found in the MOELP *Biological Sampling Manual* (Cavanagh and others 1994). Six replicate periphyton samples were collected at each site. The periphyton was scraped and washed from a traced area of natural substrate (stones) and field filtered onto a 0.45 µm filter, and 2-3 drops of $MgCO_3$ suspension added as pH buffer. The samples were immediately placed in a darkened, frozen thermos containing activated desiccant and were transferred to a freezer as soon as possible. Frozen samples were shipped in a cooler containing dry ice to Zenon laboratories. The samples arrived at the laboratory the next day and were kept frozen prior to chlorophyll *a* analysis. The areas sampled were determined by measuring the field tracings with a compensating planimeter.

One periphyton sample for taxonomic composition and was collected at each site and preserved with Lugol's solution. Periphytic algae taxonomic composition was determined for Site 11 Reiseter Creek and Sites 12 & 13 Toboggan Creek. The samples from the remainder of the sites were archived for possible later analysis. Periphyton taxonomic analysis was conducted by Mary Bolin, algae taxonomist, Victoria, BC.

3.2 Analytical Methods

Methods used by Zenon for water quality and biomass 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 taxonomic composition were 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 available upon request.

4. SUMMARY OF EXISTING 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 Skeena watershed sites. Orthophosphorus is the readily available form of phosphorous which is understood to be the main limiting factor to the growth of periphytic algae in streams. Orthophosphorus concentrations of approximately 16 µg/L were reported upstream of the main 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 method detection limit).

Periphytic algal standing crop in the upper Bulkley River, 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 (Remington and others 1993, 1994) and MOELP Environmental Protection (Portman 1995) suggested that further studies were needed to determine the source of nutrients in 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 (Remington and others 1991, 1993, 1994). The *British Columbia Water Quality Status Report* (MOELP 1996) noted that Bulkley River water quality is generally good, but that fecal coliforms at times do not meet acceptable levels for drinking water.

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 (D. Bustard in Remington and others 1993). This pattern occurred upstream and downstream of the sewage treatment plant, 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 attributable to cattle farming, 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. The manager of the fish hatchery has reported incidents of fish disease downstream of Toboggan Creek Hatchery, believed to be caused in part by animal waste in the creek.

5. RESULTS

5.1 QA/QC

Quality control was assessed by the collection of triplicate sequential water samples at Site 6, the Bulkley River downstream Buck Creek, during the July sampling visit. 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 or suite of parameters.

A relatively high degree of variation was found in the replicate samples for TSS and turbidity (12% and 28%, respectively). This is assumed to be a function of the natural variability of sediments and organic matter suspended in the water column. The river stage was dropping during the July sampling period from a rainfall event July 22, 1996 and the samples were noticeably turbid.

The coefficient of variation for orthophosphorus was 26%, considerably higher than those of the other nutrients. *Standard Methods* has computed the acceptance limits of duplicate samples and known additions to water for low-level nutrient analyses to be 25%. Low-level refers to concentrations less than 20 times the Method Detection Limit, which applied to all nutrients sampled in this study. The laboratory analytical method for phosphorus determination for this analysis was the ascorbic acid colorimetric method. Both natural colouration and turbidity in the water sample can interfere in low level colorimetric analyses (considerable variation in turbidity was previously noted).

A relatively high coefficient of variation (35%) was determined for the fecal coliform parameter as well. Microbiological data is intrinsically very variable due to the clumped nature of the distribution of the organisms (Warrington 1988). They tend to be concentrated on particles of organic material rather than evenly dispersed throughout the water column. For this reason numerous samples over time are required to obtain an estimation of microbiological quality. 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 MOELP Bulkley River objectives and water quality criteria

5.2.1 Microbiological indicators

Bulkley basin water quality data July and September 1996 are found in Appendix 3 Table 2. Two microbiological indicator organisms were sampled, fecal coliforms and fecal streptococci (also known as enterococci). Both are indicative of fecal 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. Only two samples per site were obtained in 1996, so direct comparison with criteria is not possible. However individual water samples from every site exhibited one or more microbiological indicator in exceedance of criteria.

The ratio of fecal coliforms (FC) to fecal streptococci (FS) has been used in the past to indicate possible sources of fecal contamination. Ratios of FC/FS of 4.0 or greater were thought to be associated with human feces and wastewater. A ratio of FC/FS less than 0.7 was thought to be associated with animal feces and farm drainage. However, the value of the FC/FS ratio is questioned in the current edition of *Standard Methods*. It is understood, however, that fecal streptococci far exceeding fecal coliforms is a general indicator of animal fecal contamination rather than human (Warrington 1990). Data in Appendix 3 Table 2 show that fecal streptococci outnumbered fecal coliforms in 16 of 26 samples and in least one sample at every site.

5.2.2 Nutrients

Nordin (1985) has identified orthophosphorus and dissolved inorganic nitrogen (DIN) as the forms of phosphorus and nitrogen most important to algae growth in streams. DIN is the sum of nitrate and ammonia. Although phosphorus limits algal growth in the majority of cases, nitrogen can be the limiting form in some circumstances. Summary data for the biologically available nutrients for each site are found in Table 2. It should be stressed that a dataset of only two samples is very limited. Periphytic algae accumulate on the substrate throughout the growing season, whereas this dataset represents nutrient levels only during the later part of the season. Nutrient enrichment from streamside human activities would be predicted to be greatest during the spring runoff season.

The highest orthophosphorus level was found in Buck Creek, mean = 32 μg/L. Orthophosphorus levels at upper Bulkley sites ranged from 10-18 μg/L, with no upstream/downstream trend noticeable. Thompson Creek had an average orthophosphorus level of 10 μg/L. All other tributary streams had orthophosphorus levels of 6 μg/L or less.

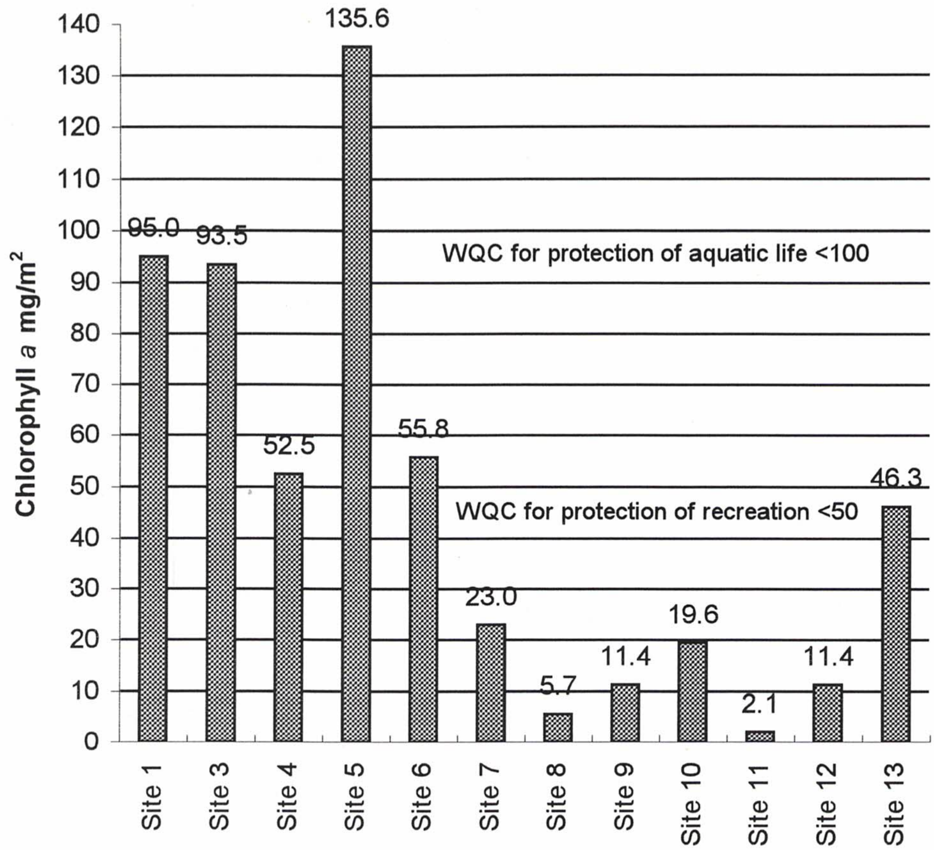
Table 2 Bulkley River and tributaries biologically available nutrients July, September and mean

	Site 1 Bulkley			**Site 2 Bulkley**			**Site 3 Bulkley**		
			Mean			Mean			Mean
DIN	0.037	0.025	0.031	0.025	0.025	0.025	0.025	0.035	0.030
Orthophosphorus	0.014	0.009	0.012	0.017	0.013	0.015	0.014	0.011	0.013
	Site 4 Bulkley			**Site 5 Bulkley**			**Site 6 Bulkley**		
			Mean			Mean			Mean
DIN	0.025	0.027	0.026	0.025	0.038	0.032	0.025	0.031	0.028
Orthophosphorus	0.013	0.012	0.013	0.011	0.009	0.010	0.019	0.016	0.018
	Site 7 Buck			**Site 8 Thompson**			**Site 9 Canyon**		
			Mean						Mean
DIN	0.025	0.029	0.027	0.045	0.054	0.050	0.025	0.028	0.027
Orthophosphorus	0.036	0.027	0.032	0.011	0.008	0.010	0.005	0.004	0.005
	Site 10 Kathlyn			**Site 11 Reiseter**					
			Mean			Mean			
DIN	0.028	0.036	0.032	0.025	0.035	0.030			
Orthophosphorus	0.008	0.004	0.006	0.004	0.003	0.004			
	Site 12 Toboggan			**Site 13 Toboggan**					
			Mean			Mean			
DIN	0.056	0.035	0.046	0.039	0.061	0.050			
Orthophosphorus	0.003	0.005	0.004	0.003	0.005	0.004			

5.2.3 Periphyton biomass

The 1996 periphyton biomass data are found in Appendix 3 Table 3. A comparison of mean biomass levels and water quality objectives and criteria are shown in Figure 3. 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). A value of less than 100 mg/m^2 chlorophyll *a* is the MOELP criterion to protect against undesirable changes in aquatic life (Nordin 1985, Nagpal 1994). The Bulkley River objective and MOELP criteria of <50 mg/m^2 chlorophyll *a* for periphyton standing crop was exceeded at all sites on the upper Bulkley River. Periphyton standing crop at Houston downstream of Avalon Creek also exceeded the MOELP criteria for protection of aquatic life of <100 mg/m^2 chlorophyll *a*. It should be noted that relatively high flows and two major rainfall events were recorded prior to the periphyton standing crop monitoring. High flows may have resulted in scouring or removal of periphyton biomass at some or all sites.

Figure 3 Periphyton biomass Bulkley River & tributaries September 1996



The MOELP criteria for nutrients and algae were specified to protect streams and lakes from degradation by excessive amounts of algae. Nordin discusses the rational for the periphyton biomass criterion. In the overwhelming 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.

5.2.4 Periphyton biomass and community composition Reiseter and Toboggan Creeks

A comparison of the periphyton community composition found in Reiseter Creek (the control site) and Toboggan Creek at two sites is shown in Appendix 3 Table 4. Periphyton standing crop in Reiseter Creek (control site) was very low, mean = 2.1 mg/m^2 chlorophyll *a*. The periphyton community at Site 11, Reiseter Creek, was composed of a variety of diatoms common to clean water streams.

The periphyton standing crop at Site 12 Toboggan Creek downstream of Toboggan Lake was also fairly low, mean = 11.4 mg/m^2 chlorophyll *a*. The periphyton community was composed of 99.5% diatoms and 0.5% the green filamentous algae *Cladophora* sp. *Cladophora* is a widespread and common algae which has been associated with eutrophication and which can cause nuisance algae growth in streams (Palmer 1977). *Cladophora* is thought to typically respond to increasing nutrient levels, particularly phosphorus (Hellawell 1986). It is not a genera reported to be tolerant of heavy organic pollution however.

The periphyton standing crop at Site 13 Toboggan Creek downstream of Owens Creek, mean = 46.3 mg/m^2 was near the objective level for protection of recreation of $\leq$50 mg/m^2 chlorophyll *a*. The periphyton community at Site 13 was 75% diatoms and 25% green algae, largely the green filamentous algae *Spirogyra* sp. Hellawell reports that *Spirogyra* is also a genera association with organic enrichment in streams. *Spirogyra* is not reported to be a "nuisance algae" by Palmer. It should be noted that the Toboggan Creek periphyton had a large amount of inorganic sediment present in the samples, likely the result of high streamflows preceding the sampling event.

5.3 Land Use Activities

The predominant land use activities in the contributing areas of the 13 monitoring sites are described in Table 3. Detailed livestock density and animal unit calculations are found in Appendix 3 Table 5. Forestry and cattle ranching are to predominant human 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 low density habitation are the primary activities in this watershed. The Reiseter Creek watershed is an active logging area, but has little or no ranching or other human activity in the vicinity of the creek.

Table 3 Major land use activities observed in contributing areas of monitoring sites

Site	Location	Land Use Activities	Total Animal Units[1]
1	Bulkley d/s Crow Cr	Forestry, cattle ranching, closed mine	158
2	Bulkley d/s Topley	Forestry, cattle ranching, septic tanks at Topley	358
3	Bulkley d/s Richfield Cr	Forestry, cattle ranching	533
4	Bulkley at Knockholt	Forestry, cattle ranching	657
5	Bulkley d/s Avalon Cr	Forestry, cattle ranching	975
7	Buck Cr	Forestry, cattle ranching, closed mine	338
6	Bulkley d/s Buck Cr	Forestry, cattle ranching	1313
8	Thompson Cr	Forestry, cattle ranching	339
9	Canyon Cr	Forestry, cattle ranching	406
10	Kathlyn Cr	Hobby farms, septic tanks, golf course	50
11	Reiseter Cr	Forestry	0
12	Toboggan Cr d/s lake	Forestry, cattle ranching	223
13	Toboggan d/s Owens Cr	Forestry, cattle ranching, fish hatchery	580

[1] Total animal units in contributing area of monitoring site.

6. DISCUSSION

6.1 Microbiological indicators

Direct application of 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 in at least one sample from every site, 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

There are signs of eutrophication of the upper Bulkley River upstream of Houston. In addition to elevated microbiological indicators, periphyton standing crop in the upper Bulkley River exceeded the objective for the protection of aesthetics and recreation at all sites. In addition, the criterion for the protection of aquatic life was exceeded at Site 5 within Houston. No upstream/downstream trend in biomass was apparent. However natural growing site variation and scouring caused by record high streamflows prior to sampling may have affected biomass accumulation. Orthophosphorus levels were generally elevated at upper Bulkley compared to all other sites except Buck Creek. Regular nutrient sampling throughout the growing season would be necessary in order to detect a correlation between growing season nutrient levels and periphyton standing crop. Field observations of green filamentous algae at upper Bulkley River sites (Appendix 1) are also suggestive of eutrophication.

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 at present seems unlikely. Studies show that nutrient increases (mostly nitrate) are fairly limited after logging and usually persist for only a few years (Meehan 1991).

Agriculture 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) manure build-up due to high cattle densities as an environmental risk to water bodies 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.

6.3 Toboggan Creek

There are also signs of eutrophication of the lower Toboggan Creek drainage. In addition to elevated microbiological indicators, periphyton standing crop was very close to the criterion level for protection of aesthetics and recreation at the lower Toboggan Creek site (Site 13 downstream of Owens Creek). In addition, the presence of abundant green filamentous algae, particularly at the downstream site, may be indicative of eutrophication. Orthophosphorus levels were not elevated during the sampling period however.

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 suggested.

6.4 Thompson Creek

The very low periphyton standing crop in Thompson Creek seems somewhat surprising given the presence of 339 breeding beef cattle in a relatively small watershed. Thompson Creek meanders through a large hay field about 500 m upstream of the monitoring site. A narrow riparian strip of willow and other brushy species line the creek bank through the field. This hay field was observed to be completely brown and apparently dead on July 30, 1996 (Appendix 1). A licensed water user who was servicing a pump house located near the monitoring site expressed great concern that the herbicide Round-up® had been applied to the hay field and may have contaminated drinking water supplies, forcing downstream water users to import drinking water. If sufficient quantities had entered the stream, Round-up® (a water soluble phyto-toxic substance) could possibly have had a toxic effect on the periphytic algae. Since the actual herbicide application had taken place several weeks earlier, and heavy rains had occurred in the interim, monitoring for herbicide residues was not attempted. This incident suggests that both education and monitoring/enforcement may be appropriate regarding the use of herbicides in community watersheds.

6.5 Kathlyn Creek

Periphyton standing-crop in Kathlyn Creek appears to be somewhat elevated considering the very low livestock density found in this watershed. Possible nutrient sources to this watercourse are septic tanks, and fertilizer use on hobby farms and the golf course.

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 bacterial and nutrient (phosphorus) loading to the upper Bulkley River and Toboggan Creek watersheds. 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 1996 water and periphyton sample site descriptions

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Site 1 Bulkley R D/S Crow Cr Latitude: N54º 24.113' Photos: 96-10:22-23
Site is adjacent to Rose Lake Cut-off Rd Longitude: W126º 09.900'

Date: 19-Sep-96 11:00 Discharge WSC Sta. 08EE003 (Bulkley R at Houston): 5.92 m^3/s

Water temperature: 10.9 ºC Dissolved Oxygen: 8.7 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 downstream of beaver dam.

Observations: Periphyton mostly diatoms with small percentage filamentous green.

Site 2 Bulkley R D/S Topley Latitude: N54º 30.126' Photos: 96-10:21
Site is 0.5 km d/s of Sunset Lake Rd Bridge Longitude: W126º 18.448'

Date: 18-Sep-96 14:00 Discharge WSC Sta. 08EE003 (Bulkley R. at Houston): 5.89 m^3/s

Water temperature: 11.2 ºC Dissolved Oxygen: 9.6 mg/L

Periphyton sampling depth: N/A Slope: 0.5º Current velocity: N/A

Substrate: 95% sand/silt, 5% fine gravel Aspect: NW % Shade: N/A

Comments: Sand/silt substrate not suitable for periphyton sampling.

Site 3 Bulkley R D/S Richfield Cr Latitude: N54º 26.657' Photos: 96-10:18-20
Site is 1 km past end of Poplar Rd Longitude: W126º 33.499'

Date: 18-Sep-96 10:00 Discharge WSC Sta. 08EE003 (Bulkley R. at Houston): 5.89 m^3/s

Water temperature: 9.9 ºC Dissolved Oxygen: 9.6 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, downstream CN bridge.

Observations: Periphyton mostly diatoms, 15-20% coverage of green filamentous.

Site 4 Bulkley R at Knockholt Stn Latitude: N54º 26.656' Photos: 96-10:15-17
Site is 100 m U/S McKilligan Rd Bridge Longitude: W126º 33.502'

Date: 17-Sep-96 13:00 Discharge WSC Sta. 08EE003 (Bulkley R. at Houston): 6.31 m^3/s

Water temperature: 9.7 ºC Dissolved Oxygen: 10.1 mg/L

Periphyton sampling depth: 10-30 cm Slope: 0.5º Current velocity: 0.8 m/s

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

Comments: Sampled between braiding mid-channel gravel bars.

Observations: Periphyton mostly diatoms, some green filamentous.

Appendix 1 (continued) Detailed 1996 water and periphyton sample site descriptions

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Site 5 Bulkley R D/S Avalon Creek Latitude: N54º 24.185' Photos: 96-10:11-14
Site is at end of 4th St in Houston Longitude: W126º 39.011'

Date: 17-Sep-96 09:00 Discharge WSC Sta. 08EE003 (Bulkley R. at Houston): 6.31 m^3/s

Water temperature: 8.7 ºC Dissolved Oxygen: 9.5 mg/L

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

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

Comments: Sampled between L bank (ripraped) and midstream gravel bar.

Observations: Periphyton mostly diatoms with 40% coverage of green filamentous (80% green filamentous and some moss along shoreline). Lots of caddisflies and stoneflies.

Site 6 Bulkley R D/S Buck Cr Latitude: N54º 24.053' Photos: 96-10:5-7
MELP SEAM Site 0400297 Longitude: W126º 40.129'

Date: 16-Sep-96 09:00 Discharge WSC Sta. 08EE003 (Bulkley R. at Houston): 6.40 m^3/s

Water temperature: 8.2 ºC Dissolved Oxygen: 9.7 mg/L

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

Substrate: 50% gravel, 45% cobble, 3% boulder, 2% sand Aspect: NW % Shade: 55%

Comments: Sampled L bank, lee gravel bar. Discharge is high for late summer.

Observations: Periphyton diatoms and green filamentous. Lots of caddisflies and stoneflies.

Site 7 Buck Cr Latitude: N54º 24.101' Photos: 96-10:8-10
MELP SEAM Site E219804 Longitude: W126º 39.280'

Date: 16-Sep-96 12:00

Water temperature: 8.7 ºC Dissolved Oxygen: 9.6 mg/L

Periphyton sampling depth: 10-30 cm Slope: 0.5º Current velocity: 0.6 m/s

Substrate: 90% gravel, 8% cobble, 2% sand Aspect: N % Shade: 50%

Comments: Sampled R bank, point gravel bar. Discharge is high for late summer.

Observations: Periphyton mostly diatoms.

Site 8 Thompson Cr Latitude: N54º 34.266' Photos: 96-10:2-4
Site is 150 m u/s Walcott Rd culvert Longitude: W126º 48.523' 96-7:3-4

Date: 12-Sep-96 12:00

Water temperature: 10.0 ºC Dissolved Oxygen: 10.4 mg/L

Periphyton sampling depth: 10-12 cm Slope: 1.5º Current velocity: 0.3 m/s

Substrate: 70% cobble, 20% gravel, 10% boulder Aspect: SW % Shade: 60%

Comments: Sampled mid-stream. 1m grass banks on both sides.

Observations: Periphyton very thin diatom layer, much partially submerged moss, some green filamentous. Hay field 500 m U/S treated with Round-up herbicide July 1996. Concern expressed by licensed water user concerning safety of domestic drinking water.

Appendix 1 (continued) Detailed 1996 water and periphyton sample site descriptions

Site 9 Canyon Cr Latitude: N54º 47.768' Photos: 96-9:23-24
Site is 10 m U/S Babine Lake Rd Bridge Longitude: W127º 06.895' 96-10:1

Date: 12-Sep-96 08:00

Water temperature: 8.7 ºC Dissolved Oxygen: 10.5 mg/L

Periphyton sampling depth: 10-30 cm Slope: 0.5º Current velocity: 0.4 m/s

Substrate: 50% boulder, 25% cobble, 20% gravel, 5% sand Aspect: SW % Shade: 40%

Comments: Sampled R bank side bar.

Observations: Periphyton thin diatom layer, narrow strip of green filamentous along shoreline.
Rust-coloured ferric hydroxide precipitate in side channels.

Site 10 Kathlyn Cr Latitude: N54º 47.734' Photos: 96-9:9-10
Site is 10 m U/S 10th Ave Bridge in Smithers Longitude: W127º 09.767'

Date: 10-Sep-96 15:30

Water temperature: 10.6 ºC Dissolved Oxygen: 9.8 mg/L

Periphyton sampling depth: 10-30 cm Slope: 1º Current velocity: 0.6 m/s

Substrate: 58% gravel, 40% cobble, 2% sand Aspect: NW % Shade: 55%

Comments: Sampled R bank side bar. L bank ripraped.

Observations: Periphyton very thin diatom layer.

Site 11 Reiseter Cr Latitude: N54º 54.635' Photos: 96-9:15-16
Site is 10 m U/S Telkwa High Rd Bridge Longitude: W127º 12.246'

Date: 11-Sep-96 08:00

Water temperature: 7.9 ºC Dissolved Oxygen: 11.0 mg/L

Periphyton sampling depth: 10-30 cm Slope: 4º Current velocity: 0.3 m/s

Substrate: 60% boulder, 30% gravel, 9% cobble, 1% sand Aspect: NW % Shade: 70%

Comments: Sampled L bank gravel pockets.

Observations: Periphyton extremely thin diatom layer.

Appendix 1 (continued) Detailed 1996 water and periphyton sample site descriptions

Site 12 Toboggan Cr D/S lake Latitude: N54º 53.368' Photos: 96-9:11-14
Site is 80 m D/S Evelyn Stn Rd Bridge and U/S Tobaggan Cr Hatchery Longitude: W127º 15.854'

Date: 10-Sep-96 10:00

Water temperature: 10.2 ºC Dissolved Oxygen: 9.4 mg/L

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

Substrate: 90% gravel, 10% sand/silt Aspect: NE % Shade: 40%

Comments: Sampled L bank U/S of rock dam. Shoreline and banks are fine silt/sand.

Observations: Periphyton mostly diatoms, some green filamentous clumps, submerged macrophytes along shoreline in sheltered locations.

Site 13 Toboggan Cr D/S Owens Cr Latitude: N54º 55.556' Photos: 96-9:17-21
Site is 40 m U/S farm bridge & DFO counting fence Longitude: W127º 17.521'

Date: 11-Sep-96 13:00

Water temperature: 10.3 ºC Dissolved Oxygen: 10.5 mg/L

Periphyton sampling depth: 20-30 cm Slope: 1º Current velocity: 0.7 m/s

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

Comments: Sampled L bank point bar. R bank ripraped.

Observations: Thick periphyton mat, many green filamentous clumps, also grey-white filamentous mats.

Appendix 3 Table 1 Analysis of triplicate sequential samples 30 July, 1996
Coefficient of variation %

Replicate	1	2	3	Mean	Std.Dev.	CoVar %
pH	7.8	7.8	7.8	7.8	0	0
Specific Conductance µ/S/cm	117	118	118	117.7	0.58	0.5
Residue Nonfilterable (TSS)	5	4	5	4.7	0.58	12
Turbidity NTU	3.72	2.90	2.10	2.907	0.8100	28
Ammonia-N mg/L	0.005	0.005	0.005	0.005	0	0
Nitrate-N mg/L	0.02	0.02	0.02	0.02	0	0
Nitrite-N mg/L	0.005	0.005	0.005	0.005	0	0
Phosphorus - Total mg/L	0.026	0.028	0.029	0.0277	0.00153	6
Orthophosphorus (P) mg/L	0.019	0.015	0.025	0.0197	0.00503	26
Fecal Coliform CFU/0.1L	8	4	8	6.7	2.31	35
Fecal Streptococcus CFU/0.1L	14	11	14	13.0	1.73	13

Appendix 3 Table 2 Bulkley River and tributaries water quality analyses July & Sept 1996

	Site 1 Bulkley R d/s Crow Cr		Site 2 Bulkley R d/s Topley		Site 3 Bulkley R d/s Richfield Cr	
Sampling date	29-Jul-96	19-Sep-96	29-Jul-96	18-Sep-96	29-Jul-96	18-Sep-96
Temperature °C	21.2	10.9	21.0	11.2	20.8	9.9
Dissolved Oxygen mg/L	8.8	8.7	7.2	9.6	7.0	9.6
pH	8.6	7.6	7.7	7.8	7.7	7.8
Spec. Conductance μ/S/cm	87	94	106	110	104	105
Residue Nonfilterable (TSS)	9	< 4	6	< 4	6	< 4
Turbidity NTU	4.69	1.80	4.61	2.45	4.36	2.23
Ammonia-N mg/L	0.017	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Nitrate-N mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03
Nitrite-N mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus - Total mg/L	0.035	0.028	0.043	0.021	0.038	0.018
Orthophosphorus (P) mg/L	0.014	0.009	0.017	0.013	0.014	0.011
Fecal Coliform CFU/0.1L	16	8	8	8	8	32
Fecal Streptococcus CFU/0.1L	34	152	2	96	7	64

	Site 4 Bulkley R at Knockholt		Site 5 Bulkley R d/s Avalon Cr		Site 6 Bulkley R d/s Buck Cr	
Sampling date	29-Jul-96	17-Sep-96	30-Jul-96	17-Sep-96	30-Jul-96*	16-Sep-96
Temperature °C	20.0	9.7	17.1	8.7	17.0	8.2
Dissolved Oxygen mg/L	7.5	10.1	7.7	9.5	8.1	9.7
pH	7.8	7.7	7.8	7.7	7.8	7.8
Spec. Conductance μ/S/cm	111	116	127	126	118	121
Residue Nonfilterable (TSS)	6	< 4	7	< 4	5	< 4
Turbidity NTU	3.66	1.49	4.42	1.98	2.90	1.50
Ammonia-N mg/L	< 0.005	0.007	< 0.005	0.018	< 0.005	0.011
Nitrate-N mg/L	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nitrite-N mg/L	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus - Total mg/L	0.031	0.013	0.022	0.013	0.028	0.021
Orthophosphorus (P) mg/L	0.013	0.012	0.011	0.009	0.019	0.016
Fecal Coliform CFU/0.1L	16	12	8	8	8	44
Fecal Streptococcus CFU/0.1L	8	60	2	64	14	104

* Median of triplicate samples

	Site 7 Buck Cr		Site 8 Thompson Cr		Site 9 Canyon Creek	
Sampling date	30-Jul-96	16-Sep-96	30-Jul-96	12-Sep-96	25-Jul-96	12-Sep-96
Temperature °C	15.2	8.7	11.7	10.0	12.4	8.7
Dissolved Oxygen mg/L	8.8	9.6	9.2	10.4	8.4	10.5
pH	7.9	7.9	8.1	8.1	7.8	7.9
Spec. Conductance μ/S/cm	101	111	205	259	95	131
Residue Nonfilterable (TSS)	< 4	< 4	< 4	< 4	6	< 4
Turbidity NTU	2.95	1.93	1.91	4.29	2.42	1.02
Ammonia-N mg/L	< 0.005	0.009	< 0.005	0.014	0.005	0.008
Nitrate-N mg/L	< 0.02	< 0.02	0.04	0.04	< 0.02	< 0.02
Nitrite-N mg/L	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus - Total mg/L	0.039	0.032	0.013	0.013	0.007	0.004
Orthophosphorus (P) mg/L	0.036	0.027	0.011	0.008	0.005	0.004
Fecal Coliform CFU/0.1L	24	< 1	52	8	40	8
Fecal Streptococcus CFU/0.1L	6	< 1	17	112	14	104

Appendix 3 Table 2 (continued) Bulkley R and tributaries water quality analyses 1996

	Site 10 Kathlyn Cr		Site 11 Reiseter Cr	
Sampling date	25-Jul-96	10-Sep-96	30-Jul-96	11-Sep-96
Temperature °C	13.3	10.6	9.7	7.9
Dissolved Oxygen mg/L	8.5	9.8	9.8	11.0
pH	7.3	7.3	7.9	7.9
Spec. Conductance μS/cm	45	55	83	118
Residue Nonfilterable (TSS)	17	11	5	10
Turbidity NTU	7.40	5.62	4.70	0.89
Ammonia-N mg/L	0.008	0.006	< 0.005	< 0.005
Nitrate-N mg/L	< 0.02	0.03	< 0.02	0.03
Nitrite-N mg/L	< 0.005	< 0.005	< 0.005	< 0.005
Phosphorus - Total mg/L	0.021	0.018	0.007	< 0.003
Orthophosphorus (P) mg/L	0.008	0.004	0.004	< 0.003
Fecal Coliform CFU/0.1L	36	68	12	20
Fecal Streptococcus CFU/0.1L	80	216	4	152

	Site 12 Toboggan Cr d/s lake		Site 13 Toboggan Cr d/s Owens Cr	
Sampling date	25-Jul-96	10-Sep-96	25-Jul-96	11-Sep-96
Temperature °C	13.3	10.2	13.9	10.3
Dissolved Oxygen mg/L	8.4	9.4	8.3	10.5
pH	7.2	7.3	7.5	7.4
Spec. Conductance μS/cm	50	59	59	73
Residue Nonfilterable (TSS)	15	< 4	16	9
Turbidity NTU	6.69	2.49	5.11	3.51
Ammonia-N mg/L	0.006	< 0.005	0.009	0.011
Nitrate-N mg/L	0.05	0.03	0.03	0.05
Nitrite-N mg/L	< 0.005	< 0.005	< 0.005	0.005
Phosphorus - Total mg/L	0.014	0.009	0.015	0.009
Orthophosphorus (P) mg/L	< 0.003	0.005	< 0.003	0.005
Fecal Coliform CFU/0.1L	80	4	36	16
Fecal Streptococcus CFU/0.1L	130	72	14	124

Appendix 3 Table 3 Bulkley R and tributaries periphyton biomass September 1996

mg/m² Chlorophyll *a*	Site 1 Bulkley R d/s Crow Cr 19-Sep-96	Site 3 Bulkley R d/s Richfield Cr 18-Sep-96	Site 4 Bulkley R at Knockholt 17-Sep-96	Site 5 Bulkley R d/s Avalon Cr 17-Sep-96
Rep 1	114.0	166.0	35.8	47.8
Rep 2	140.0	39.4	96.1	106.0
Rep 3	35.5	127.0	67.1	169.0
Rep 4	150.0	98.2	44.9	104.0
Rep 5	70.7	72.3	49.6	174.0
Rep 6	59.9	58.0	21.6	213.0
Mean	**95.0**	**93.5**	**52.5**	**135.6**

mg/m² Chlorophyll *a*	Site 6 Bulkley R d/s Buck Cr 16-Sep-96	Site 7 Buck Cr 16-Sep-96	Site 8 Thompson Cr 12-Sep-96	Site 9 Canyon Cr 12-Sep-96
Rep 1	39.4	22.5	7.2	11.6
Rep 2	85.0	25.3	9.4	14.3
Rep 3	48.0	21.6	1.9	4.9
Rep 4	33.9	15.4	5.1	13.5
Rep 5	78.4	20.9	4.7	16.4
Rep 6	50.0	32.2	5.7	7.4
Mean	**55.8**	**23.0**	**5.7**	**11.4**

mg/m² Chlorophyll *a*	Site 10 Kathlyn Cr 10-Sep-96	Site 11 Reiseter Cr 11-Sep-96	Site 12 Toboggan Cr d/s lake 10-Sep-96	Site 13 Toboggan Cr d/s Owens Cr 11-Sep-96
Rep 1	5.4	1.9	14.5	11.9
Rep 2	16.3	2.2	5.8	70.1
Rep 3	2.0	3.1	7.1	108.0
Rep 4	16.8	1.7	2.8	12.6
Rep 5	29.2	2.3	11.7	56.5
Rep 6	47.7	1.6	26.4	18.5
Mean	**19.6**	**2.1**	**11.4**	**46.3**

Appendix 3 Table 4 Periphyton taxonomic composition Reiseter & Toboggan Cr sites

Site 11 Reiseter Cr (control site) 11-Sep-96

Chrysophyta	100 %
Bacillariophyceae	
Gomphonema geminatum	30 %
Synedra ulna	10 %
Hannaea arcus	10 %
Achnanthes spp.	20 %
Gomphonema spp.	20 %
Fragilaria spp.	10 %

Site 12 Toboggan Cr d/s lake 10-Sep-96

Chlorophyta	0.5 %
Cladophora sp.	100 %
Chrysophyta	99.5 %
Bacillariophyceae	
Synedra ulna	20 %
Achnanthes spp.	20 %
Cymbella caespitosa	10 %
Gomphonema spp.	10 %
Surirella angustata	10 %
Fragilaria spp.	20 %
Epithemia sorex	10 %

Comment: Large amount of inorganic sediment present in sample.

Site 13 Toboggan Cr d/s Owens Cr 11-Sep-96

Chlorophyta	25 %
Cosmarium sp.	2 %
Spirogyra sp.	98 %
Chrysophyta	75 %
Bacillariophyceae	
Fragilaria spp.	6 %
Gomphonema geminatum	70 %
Cymbella spp.	10 %
Achnanthes spp.	7 %
Gomphonema spp.	5 %
Stauroneis phoenicentron	2 %

Comment: Algal mats composed of Spirogyra sp. & Gomphonema geminatum on stalks.
Large amount of inorganic sediment present in sample.

Appendix 3 Table 5 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	Bulkley d/s Crow Cr	1B	158		158	158
2	Bulkley d/s Topley	2B	200		200	358
3	Bulkley d/s Richfield Cr	4B	175		175	533
4	Bulkley at Knockholt	3B	124		124	657
5	Bulkley d/s Avalon Cr	7B	318		318	975
7	Buck Cr	6B	338		338	338
6	Bulkley d/s Buck Cr	0	0		0	1313
8	Thompson Cr	2B	339		339	339
9	Canyon Cr	2D 4B1S	400	30 sheep	406	406
10	Kathlyn Cr	? Hobby		40 horses[3]	50	50
11	Reiseter Cr	0	0		0	0
12	Toboggan Cr d/s lake	1D 3B	223		223	223
13	Toboggan d/s Owens Cr	2D 5B 1H	353	20 sheep	357	580

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

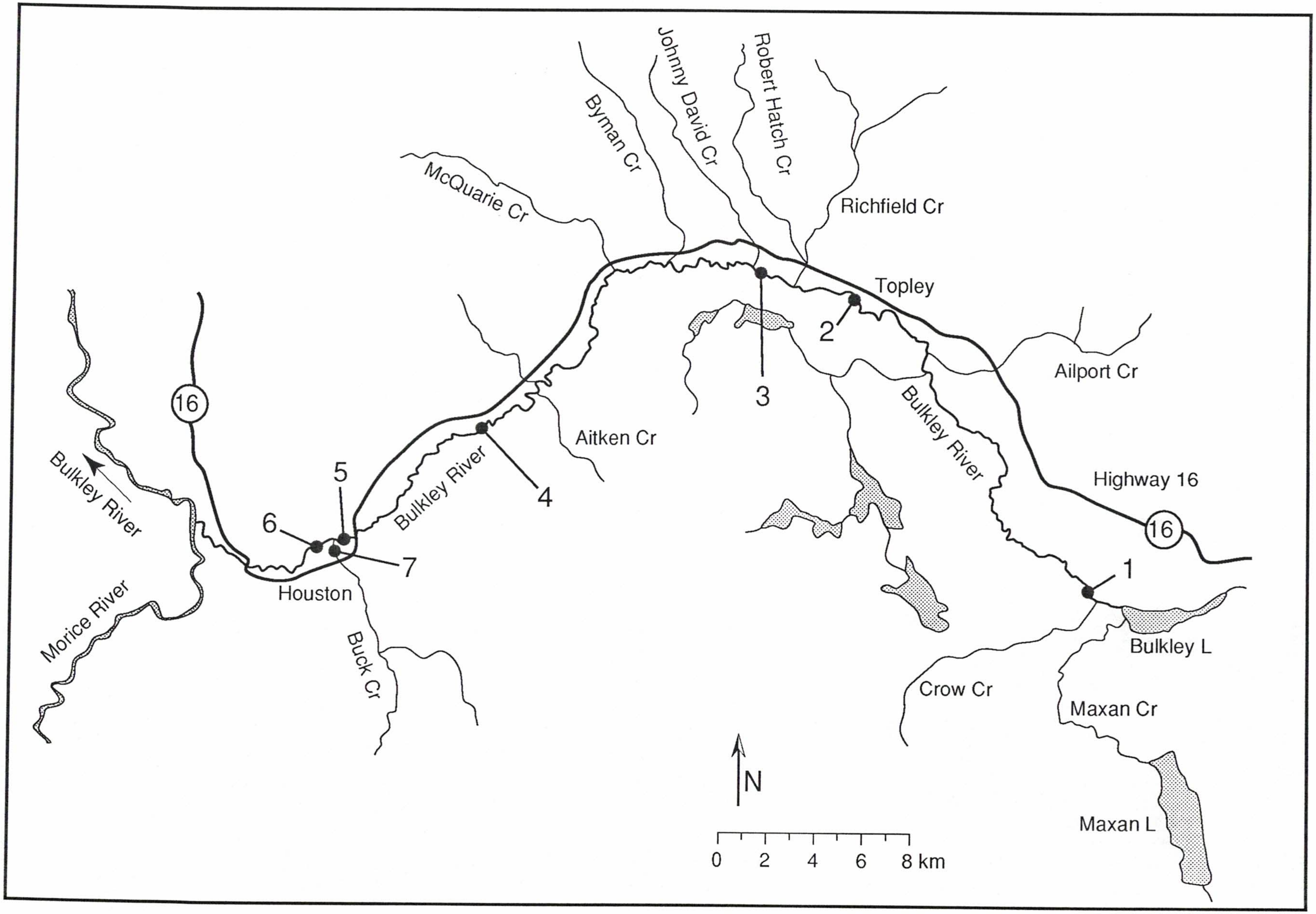


Figure 1 Upper Bulkley River water quality and periphyton monitoring sites 1996

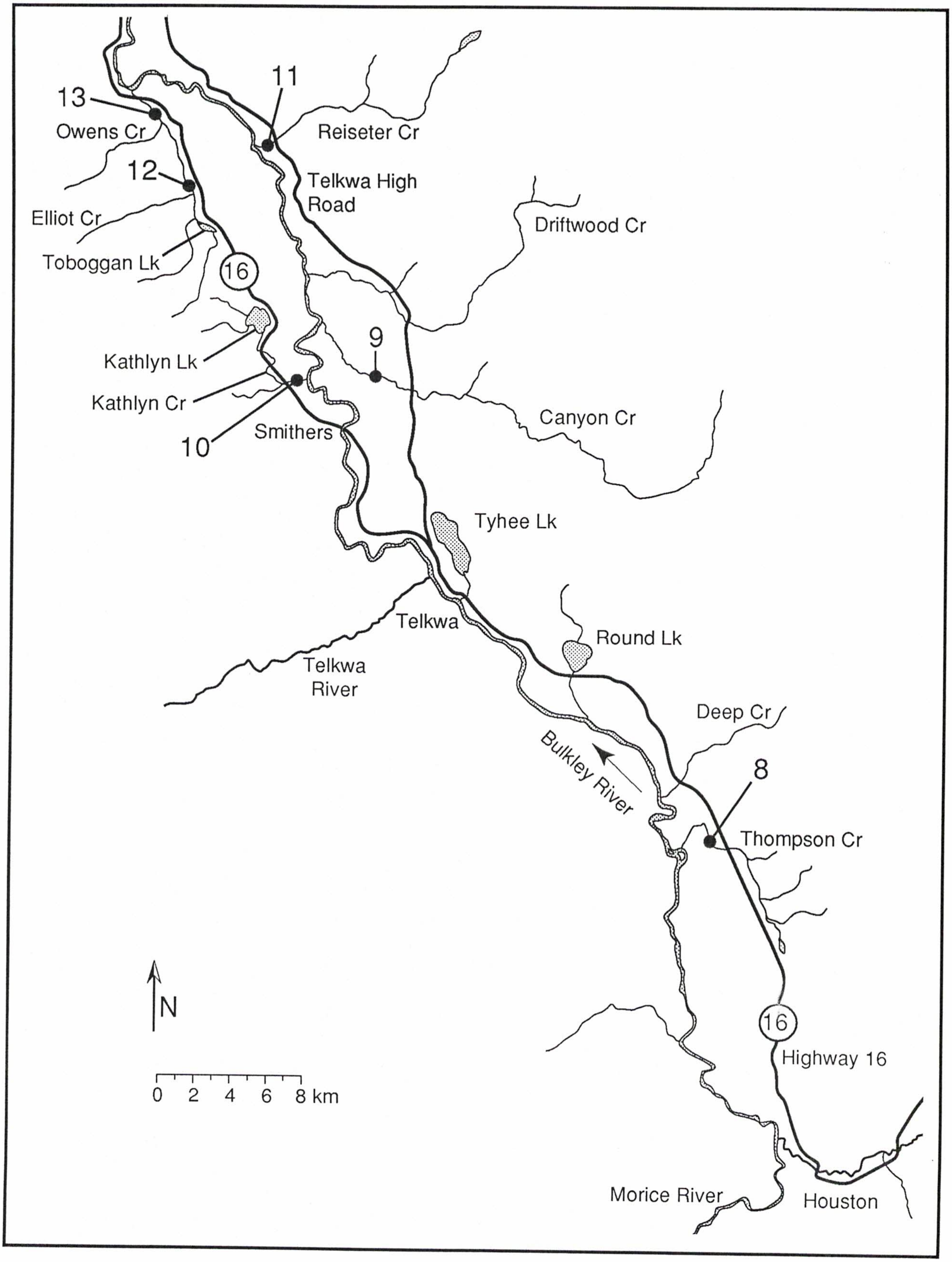
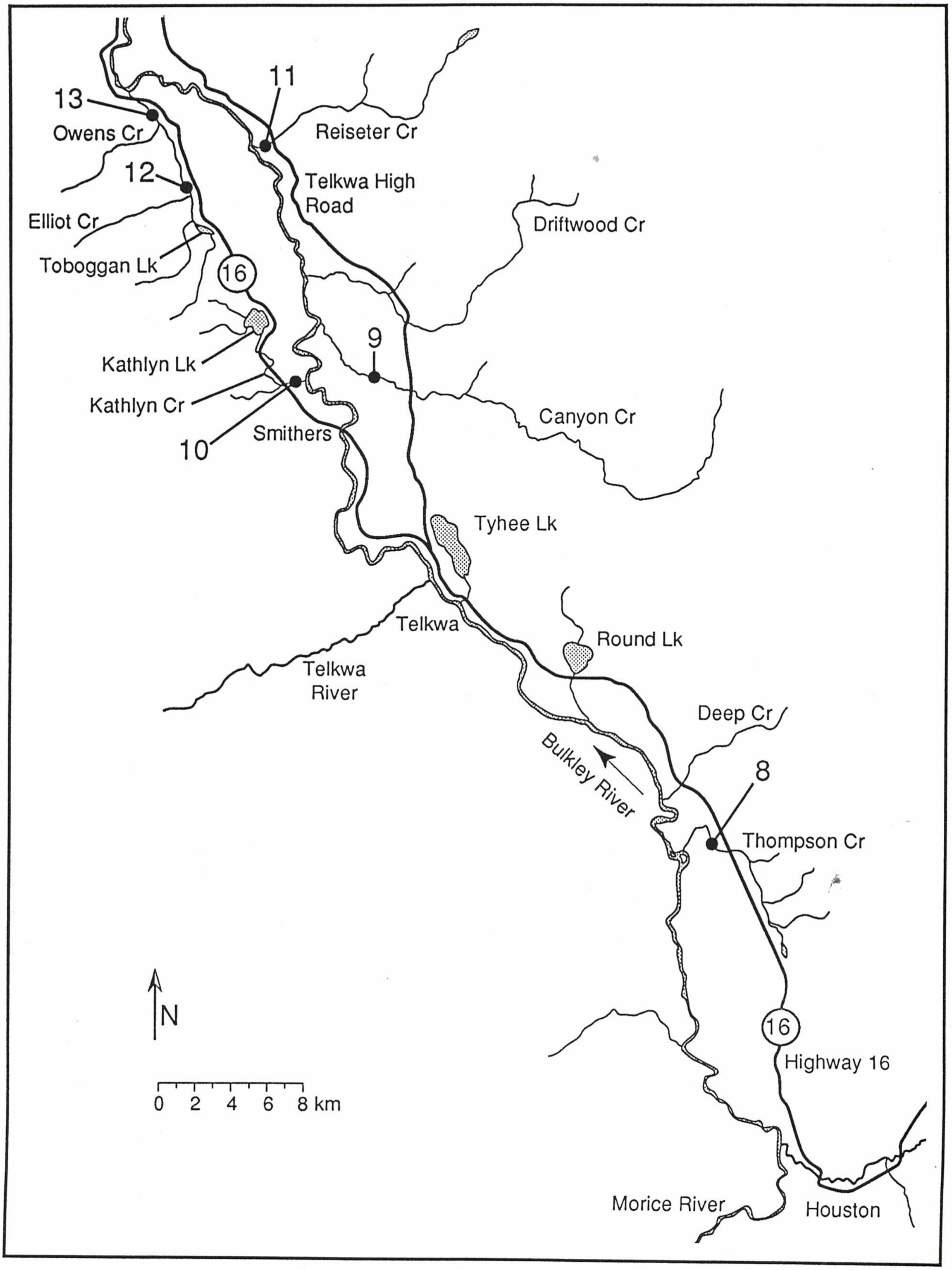


Figure 2 Bulkley River tributaries water quality and periphyton monitoring sites 1996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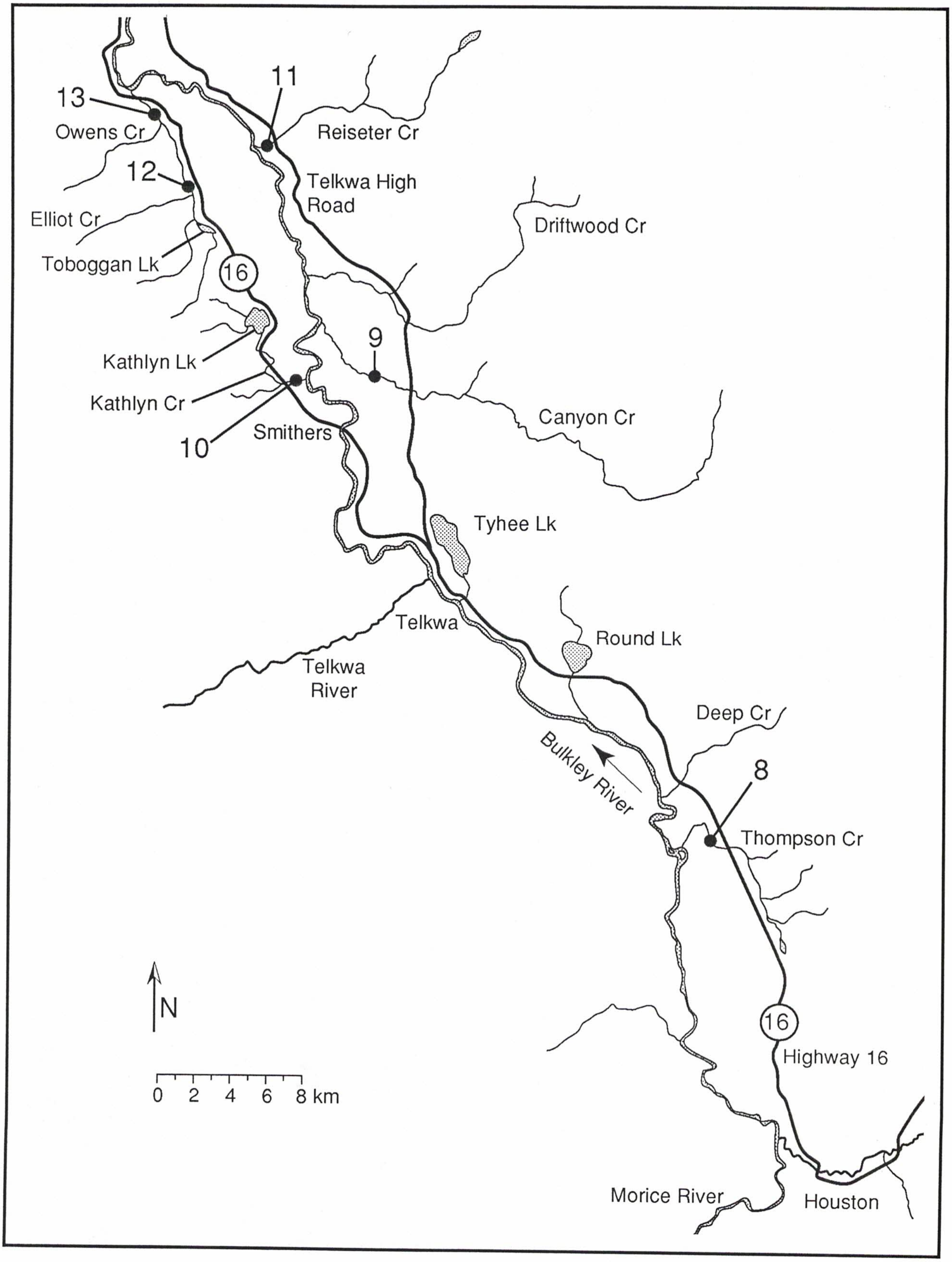
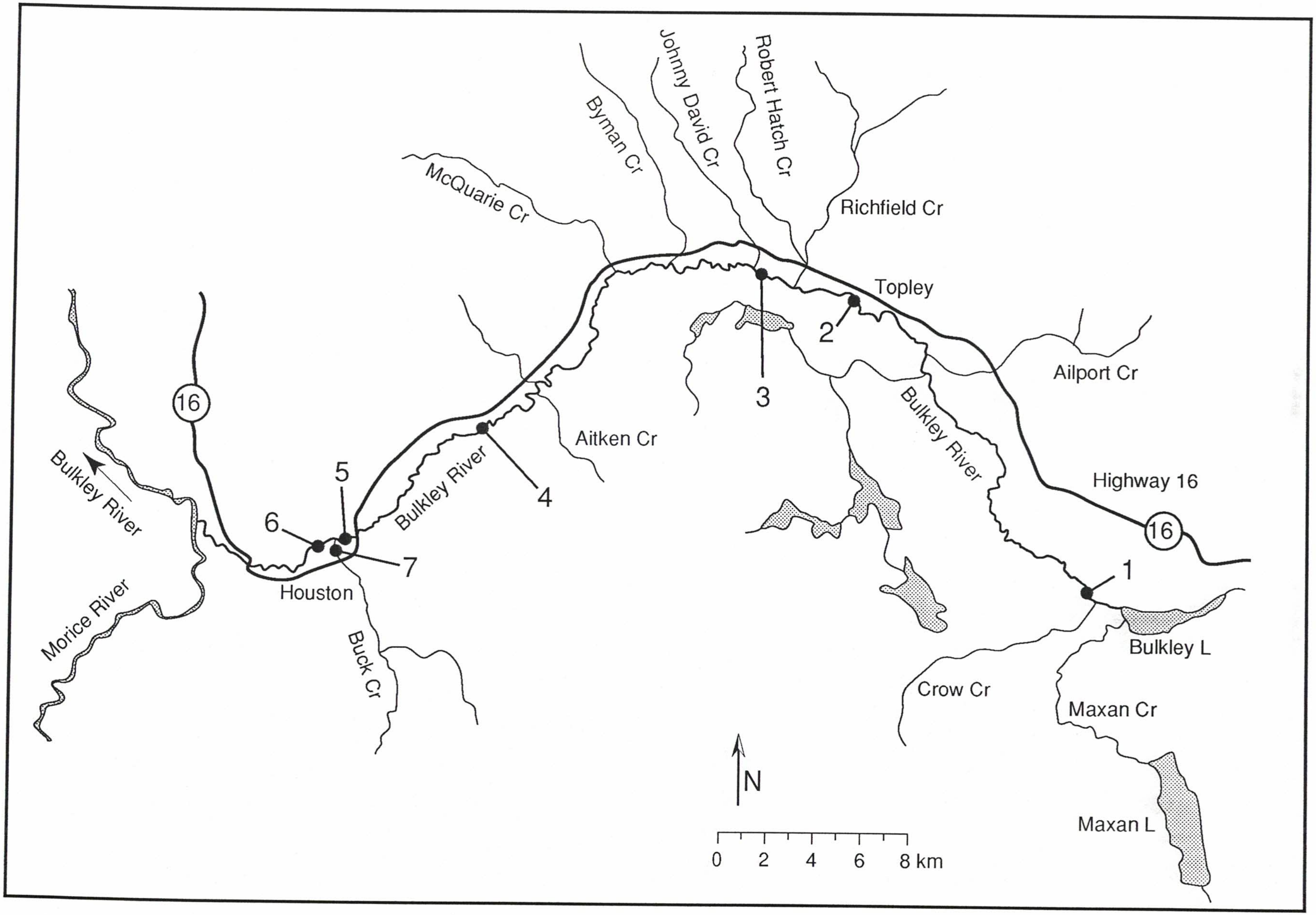
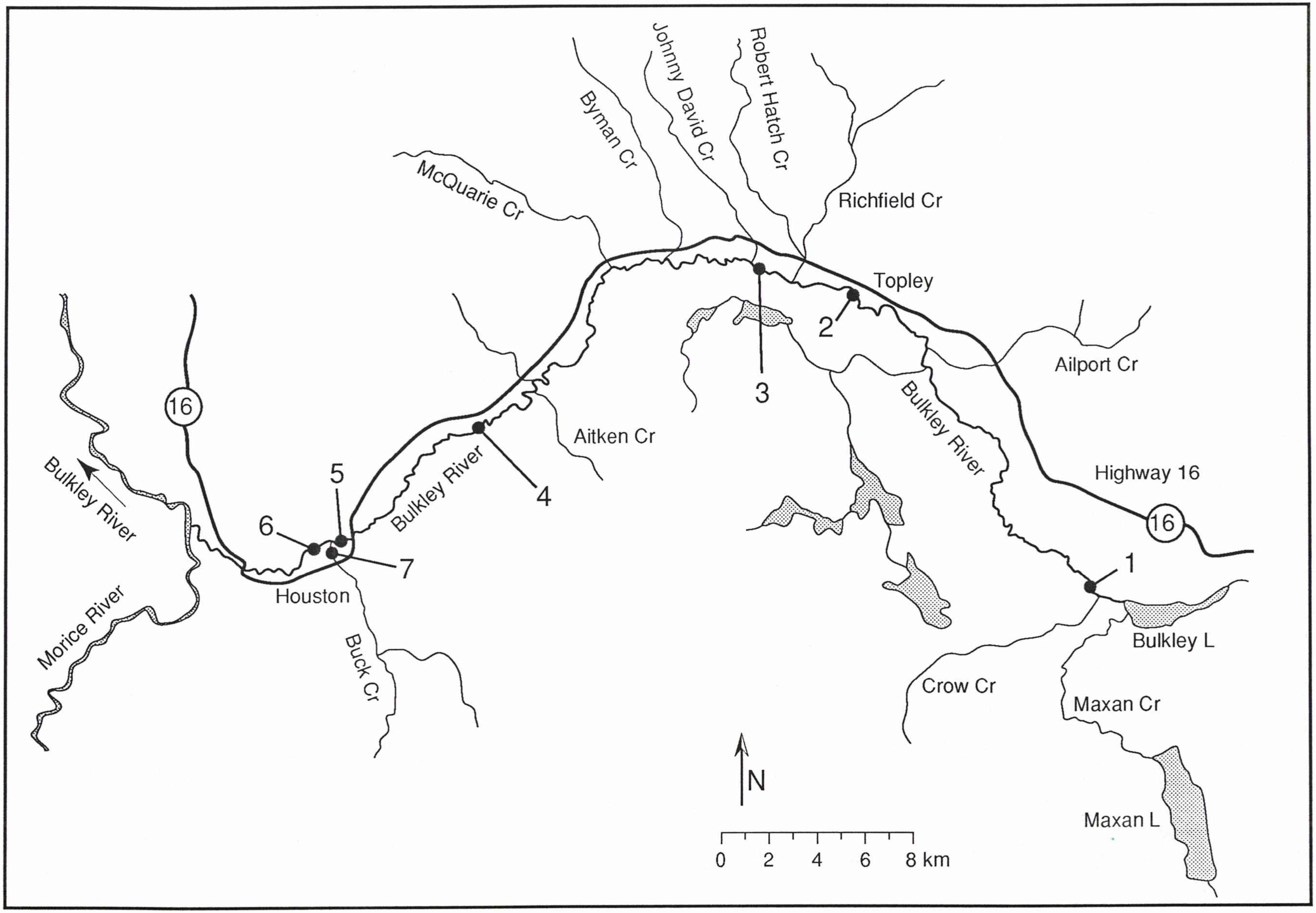
Owens Cr
11
Reiseter Cr
12
Telkwa High
Road
Elliot Cr
Driftwood Cr
Toboggan Lk
16
9
Kathlyn Lk
Kathlyn Cr
Canyon Cr
Smithers
10
Tyhee Lk
Round Lk
Telkwa
Telkwa
River
Deep Cr
Bulkley River
8
Thompson Cr
N
16
Highway 16
0 2 4 6 8 km
Morice River
Houston


13
Owens Cr
11
Reiseter Cr
12
Telkwa High Road
Elliot Cr
Driftwood Cr
Toboggan Lk
16
Kathlyn Lk
9
Kathlyn Cr
Canyon Cr
Smithers
10
Tyhee Lk
Telkwa
Round Lk
Telkwa River
Deep Cr
Bulkley River
8
Thompson Cr
N
16
Highway 16
0 2 4 6 8 km
Morice River
Houston


Johnny David Cr
Robert Hatch Cr
Byman Cr
McQuarie Cr
Richfield Cr
Topley
2
3
Ailport Cr
Bulkley River
Aitken Cr
Highway 16
16
4
5
6
7
Bulkley River
Bulkley River
Houston
Morice River
Buck Cr
1
Bulkley L
Crow Cr
Maxan Cr
Maxan L
N
0
2
4
6
8 km


Johnny David Cr
Robert Hatch Cr
Byman Cr
McQuarie Cr
Richfield Cr
Topley
Ailport Cr
Aitken Cr
Bulkley River
Highway 16
16
Bulkley River
Morice River
Houston
Buck Cr
Bulkley L
Crow Cr
Maxan Cr
Maxan L
N
0 2 4 6 8 km
1
2
3
4
5
6
7

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 1 Bulkley River downstream Crow Creek 19 Sep 96 (Photo 96-10:22)

Site 2 Bulkley River downstream Topley 18 Sep 96 (Photo 96-10:21)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 3 Bulkley River downstream Richfield Creek 18 Sep 96 (Photo 96-10:18)

Site 4 Bulkley River at Knockholt Station 17 Sep 96 (Photo 96-10:16)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 5 Bulkley River downstream Avalon Creek 17 Sep 96 (Photo 96-10:14)

Site 5 Substrate 17 Sep 96 (Photo 96-10:13)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 6 Bulkley River downstream Buck Creek 16 Sep 96 (Photo 96-10:7)

Site 7 Buck Creek 16 Sep 96 (Photo 96-10:10)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 8 Thompson Creek 12 Sep 96 (Photo 96-10:2)

Site 9 Canyon Creek 12 Sep 96 (Photo 96-10:1)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 10 Kathlyn Creek 10 Sep 96 (Photo 96-9:9)

Site 11 Reiseter Creek 11 Sep 96 (Photo 96-9:15)

Appendix 2 Photographs of 1996 water and periphyton sample sites

Site 12 Toboggan Creek downstream lake 10 Sep 96 (Photo 96-9:12)

Site 13 Toboggan Creek downstream Owens Creek 11 Sep 96 (Photo 96-9:19)