Water Quality Branch
Environmental Protection Department
MINISTRY OF ENVIRONMENT, LANDS AND PARKS

WATER QUALITY ASSESSMENT AND OBJECTIVES FOR THE BULKLEY RIVER HEADWATERS

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1. INTRODUCTION

1.1 Background

Equity Silver Mines Ltd. (parent company Placer Dome) operated a surface mining and 9000-tonne-per-day milling complex in the central interior of British Columbia, about 35 km southeast of the town of Houston (Figure 1). Final products of the mine were copper and silver concentrates as well as gold and silver bars. The mine is located at an elevation of about 1300 m in the west-central Nechako Plateau, where summers are warm and short (less than 60 frost-free days) and winters long and cold. Average annual precipitation is 710 mm, consisting of 300 mm rain and 410 mm snow (snow accounting for about 70% of precipitation). Mine operations began in 1980 with mining of the Southern Tail orebody, followed progressively by the Main Zone and Waterline Zone orebodies (Figure 2) (Equity Silver Mines Environmental Reports, 1985-1994). The mine was initially scheduled to be closed in 1992, but the closure was later pushed back to late 1993 with the mining of an additional underground ore body. Details of the mine reclamation and closure plans are discussed in Section 5 (Mine Reclamation).

Acid Rock ~~mine~~ drainage (A~~M~~RD) from the main waste rock dump became apparent on the Equity property in 1981. A~~M~~RD is formed from the natural oxidation of pyritic rock when exposed to air and water, and accelerated by action of the bacterium *Thiobacillus ferrooxidans*. The phenomenon is also accelerated by fragmentation of the rock, which exposes more surface area to the process. The chemical and biological reactions yield low pH water which mobilizes heavy metals into solution. This drainage can seriously impact the water quality in the receiving environment, with toxicity to biota from both the low pH as well as elevated heavy metals. Details of the acid generation process can be found in the Acid Rock Drainage Technical Guide from the British Columbia Acid Mine Drainage Task Force (Robertson and Kirsten, 1989).

Equity collects all of the A~~M~~RD from the property, and add lime at the treatment plant to raise the pH to 8.5. As the pH increases to this level, metal complexes settle out as calcium sulphate and metal hydroxide sludge. Supernatant from the sludge settling pond is discharged into Buck and/or Foxy Creeks (located on either side of a drainage divide) when metal concentrations are within permit specifications, and only during freshet (high flows).

The potential impact of untreated AMD to the aquatic environment is evident in the following summary of AMD volume and quality from the Equity mine site (Equity Silver Mines Limited Fact Sheet, 1992). The extremely low pH measured in the Main Pond, coupled with very high concentrations of heavy metals leached from ore/waste rock/tailings, are sufficient to have an enormous impact on both the fisheries and aquatic life in nearby watersheds in an untreated form.

Mean volume of AMD from 1987-1991: 889,186 m^3/yr.
Seepage volume from the Tailings Pond Dam (mean 1988-1991): 128,927 m^3/yr.
Average Quality of AMD at the Main (AMD collection) Pond:

pH	2.62
Acidity	10 714 mg/L
Sulphate	15 238 mg/L
Copper (D)	164 mg/L
Iron (D)	1 808 mg/L
Zinc (D)	185 mg/L

AMD generated at the Equity Silver Mine poses a significant threat to the Bulkley River. The river is the focus of recreational and agricultural activities in the Bulkley valley, and is particularly important for both commercial and recreational fisheries. Salmon originating from the Bulkley River are utilized by the north coast commercial fishery, and steelhead production supports a provincially significant sport fishery. Wilkes and Roberts (1987) estimated the net economic value of all fisheries in the Bulkley River system in 1986 at \$1.6 million, and the present value over 60 years at between \$23 and \$40 million. These figures did not include other important values such as recreation, domestic and agricultural water supplies or wildlife.

The purposes of this report are:

(i) to assess the present quality of the headwaters to the Bulkley River affected by the Equity mine using available information on waste discharges, water quality, streamflows and water use;

(ii) to determine which water uses require protection in the headwaters, and to recommend provisional water quality objectives to protect those uses (as well as water uses in the Bulkley River downstream, for which water quality objectives have previously been set; see Nijman, 1986).

1.2 Description of the Bulkley River Headwaters

1.2.1 General

The Equity mine site straddles a drainage divide, and includes headwaters for the Foxy-Maxan Creek system flowing to the north, and the Bessemer-Buck Creek system flowing to the south. Foxy Creek flows into Maxan Creek above Bulkley Lake, which forms the top end of the Bulkley River (Upper Bulkley River). Bessemer Creek flows into Buck Creek above Goosly Lake, and Buck Creek flows to the Bulkley River just downstream of the Township of Houston (Figure 1).

The Bulkley River flows to the junction with the Morice River, then continues downstream through the interior plateau to enter the Skeena River near Hazelton.

1.2.2 Bessemer/Buck Creeks

Bessemer Creek originates above the Southern Tail and Main Zone pits (Figure 2). The upper reach was diverted to Foxy Creek through the Berzelius Creek diversion. Since the diversion, lower Bessemer Creek flows from the area of the pits to a siltcheck dam above its confluence with Buck Creek located about 4 km from the pit. The flow course of Bessemer Creek below the dam is often indefinite, with both swamps and distinct channels depending on flow conditions. The drainage area is about 8 km^2.

Upper Buck Creek flows past its confluence with Bessemer Creek to Goosly Lake, and continues approximately 55 km northwest to join with the Bulkley River near Houston (Figure 1). Below Goosly Lake there are swampy areas that flood during high flows, as well as ponds created by beaver activity. The total drainage area of Upper Buck Creek is about 580 km^2, of which 64 km^2 is above Goosly Lake and 55 km^2 above the Bessemer Creek confluence.

1.2.3 Foxy/Maxan Creeks

Foxy Creek flows through sub-alpine meadows in its headwaters, along the northern border of the mine site, about 30 km northeast of its junction with Maxan Creek. The upper creek is generally slow flowing, but flow rates begin to increase past the tailings pond and continue to do so through steep gorges located on the lower section of the creek. A series of chutes and falls impassable to fish occur about 6 km below the mine site, above the confluence with Maxan Creek. Both the Lu Creek and Berzelius Creek diversions to Foxy Creek alter natural flows around the mine site. The drainage area of Maxan Creek above Bulkley Lake (including Foxy Creek) is about 368 km^2. The drainage area of Upper Foxy Creek, above the point of treated water discharge (Lu Creek diversion), is 13.8 km^2.

2.0 HYDROLOGY

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A general estimate of runoff and streamflows in the vicinity of the Equity mine site has been made by Ker Priestman and Associates (1983). They have determined an average annual runoff factor of 14 L/s/km^2, which is supported by Equity Silver.

The following limited mean monthly flow data for Bessemer, Buck and Foxy Creeks has been provided by Equity Silver Mines Ltd. (Aziz, 1992 pers. comm.). The majority of monitoring occurred between April and November in order to determine the appropriate discharge rates for treated AMD (see Section 4, Waste Discharges). Flow data for the Bulkley River is from Environment Canada (Environment Canada, 1991)

2.1 Bessemer Creek

Flow rates in Bessemer Creek were measured at the siltcheck (settling pond) from a flat bottomed weir. The drainage area of the watershed to this point is 8.1 km^2. Values shown in the table below are the mean monthly flow rates recorded between October, 1984 and July, 1992. The majority of measurements were collected between April and October, the period in which water volume is generally sufficient to allow discharge of treated mine drainage (see section 4. Waste Discharges). Although there are insufficient data to allow the generation of a hydrograph, in general the peak flows occur between April and June.

Bessemer Creek Flows (m^3/sec) at Siltcheck
1984-1992

Month	Mean Monthly Flows	Range	N
January	0.003	0.001	1
February	0.001	0.001	1
March	0.007	0.001-0.010	3
April	0.155	0.034-0.390	6
May	0.435	0.148-1.000	8
June	0.198	0.063-0.435	7
July	0.111	0.011-0.285	7
August	0.046	0.012-0.132	5
September	0.055	0.013-0.098	5
October	0.058	0.009-0.142	5
November	0.025	0.010-0.037	3
December	0.010	0.010	1

2.2 Buck and Foxy Creeks

During the early periods of mine operation the flow rates at upper Buck and upper Foxy Creeks were measured at weirs, with subsequent measurements made from staff gauges which survived high flow periods better. Staged curves have been developed for both creeks. Equity has provided flow data collected between 1984 and 1992 for upper Foxy Creek and from 1985 to

1992 for upper Buck Creek. Drainage areas for Buck and Foxy Creeks at the flow monitoring stations are 55 km^2 and 13.8 km^2, respectively. It can be seen from the limited data tabulated below that flows peak April through June in both Buck and Foxy creeks.

Upper Buck Creek Flows (m^3/sec)
1985-1992

Month	Mean Monthly Flows	Range	N
January	--	--	0
February	--	--	0
March	--	--	0
April	1.376	0.677-1.920	3
May	2.417	2.070-2.92	7
June	1.061	0.490-1.567	7
July	0.394	0.208-0.840	6
August	0.146	0.007-0.350	5
September	0.234	0.012-0.546	4
October	0.285	0.100-0.530	3
November	0.119	0.119	1
December	--	--	0

Upper Foxy Creek Flows (m^3/sec)
1984-1992

Month	Mean Monthly Flows	Range	N
January	0.004	0.004	1
February	0.002	0.002	1
March	0.003	0.003	1
April	0.601	0.004-0.900	3
May	1.016	0.580-1.520	9
June	0.739	0.228-1.301	6
July	0.178	0.050-0.638	7
August	0.073	0.004-0.222	6
September	0.085	0.002-0.42	6
October	0.092	0.040-0.217	5
November	0.073	0.041-0.102	3
December	0.013	0.013	1

Although peak water flows occur between April through June in Bessemer, Buck and Foxy Creeks, the maximum AMD flows are in April and May. This shorter peak flow period is due to the accelerated rate of snow melt from areas generating AMD and other areas disturbed by mining activity (Equity Silver Mines Environmental Reports, 1985-1995).

2.3 Bulkley River

Bessemer, Buck and Foxy creeks all flow into the Bulkley River. Flow data collected from gauged Station No. 08EE001 of the Federal network is provided below for the Bulkley River near Houston to indicate the relative contribution of these creeks to Bulkley River flow. The drainage area of the Bulkley River watershed to the gauged station is 2 380 km^2. Flow data was collected between 1930 and 1990, and show peak periods similar to those seen in Bessemer, Buck and Foxy creeks.

Bulkley River Flows, Station 08EE001 at Houston (m^3/sec)

Month	Mean Monthly Flows	Range	N
January	1.03	1.03	1
February	1.53	1.53	1
March1	.32	1.32	1
April	18.2	2.49-51.0	15
May	71.1	32.5-127	27
June	28.5	10.9-66.9	29
July	10.8	1.92-35.3	22
August	3.23	0.77-10.1	22
September	2.08	0.40-5.00	22
October	4.33	1.14-17.9	18
November	6.91	4.87-10.7	5
December	4.93	4.93	1

The following table shows low-flow estimates for various reaches of the Bulkley River (from Obedkoff, 1983).

Low-Flow Estimates, Bulkley River Basin, November to April
Minimum 7-Day Average Daily Discharge

Stream Site	Drainage Area (km^2)	Recurrence Interval Mean Year (m^3/s)	Recurrence Interval 10-Year (m^3/s)
Bulkley R. above Morice R. near Houston (gauged station 08EE003)	1 740	0.5	0.1
Morice R. at mouth	4 270	11.0	7.4
Bulkley R.immediately downstream of junction with the Morice R.	6 010	11.5	7.5
Bulkley R. near Quick	7 360	22.8	13.7

The above table shows that flows in the upper Bulkley River occasionally decrease to very low rates. For this reason, discharges of treated acid mine drainage from the Equity mine site to the Bulkley River headwater streams (Buck and Foxy Creeks) are only permitted during periods of higher flow to maximize dilution and minimize impacts (see Section 4).

3. WATER USES

3.1 Fisheries Use

Although one of the primary concerns of this report is the potential impact of runoff from the Equity mine on nearby headwater streams, there is also some concern that the effects of acid mine drainage or treated discharges will extend to the mainstem Bulkley River and have a negative impact on it's fisheries. Therefore, the significance of fish in the Bulkley River is also discussed below.

3.1.1 Bulkley River Mainstem

The Bulkley River is utilized year-round by various fish species. It is used as a migration route by steelhead and all salmon species except chum. Between 1970 and 1980, for example, the Bulkley River supported an annual escapement of up to 930 chinook, 2 500 coho, 300 sockeye, and 2 500 pink salmon (Le, 1983). Wilkes and Roberts (1987) estimated the Bulkley River's contribution to the commercial fishery on the north coast of British Columbia to be 24 000 salmon of various species per year. Some adult salmon remain in the Bulkley River through winter. In addition, some spawning is known to occur by pinks and chinook although the Bulkley River is more important as a juvenile rearing area. The Bulkley River also supports resident cutthroat trout, Dolly Varden char, and rainbow trout, although mainstem spawning by these species is unlikely (Bailey, 1983).

Total steelhead production for the Morice and Bulkley Rivers is between 6 000 and 9 000 adult fish with an annual escapement of 2 000 to 3 000 following commercial, native, and sport fisheries. Adult steelhead enter the Bulkley River from the Skeena River in mid-August through the fall, and then overwinter. Spawning occurs in May and June in the Bulkley River and its tributaries; however, most production of juvenile steelhead fry is attributed to tributary and mainstem habitats of the Morice River between Gosnell and Lamprey Creeks. Parr tend to leave the tributaries and side channels in their first and second year, and rear and overwinter in the lower mainstem habitats (in particular the Bulkley River below Houston) prior to smolting (Envirocon Ltd., 1981; Tredger, 1981; Wilkes and McLean, 1987).

Wilkes and Roberts (1987) state that the Bulkley River supports one of the most intensive steelhead fisheries in British Columbia, accounting for the majority of the estimated 19 000 angler days on the Bulkley River in 1986. The number of angling days on the river were projected to increase 2.8% per year, to a total of 56% (or about 30 000 angler days) by the year 2006.

The following table shows the 1986 dollar value of the various fisheries, with over half of the total value contributed by steelhead:

1986 Dollar Values of the Various Fisheries, Bulkley River System

Fishery	Species	1986 Net Value ($)
Recreation	steelhead resident trout salmon spp.	807 302 142 250 255 987
Tidal Commercial, Indian and Sport	salmon spp.	318 000
Commercial, incidental	steelhead	78 302
Aboriginal food fishery	steelhead	9 786
Total 1986 Net Value		**$1 611 627**

(From Wilkes and Roberts, 1987)

As shown above, the economic value of the Bulkley River's contribution to the commercial salmon fishery of the north coast is about $318 000, from an estimated 24 000 harvestable salmon of various species (based on the net wholesale price of fish excluding harvesting and processing).

In addition to the commercial fishery, there is an aboriginal food fishery which harvests both salmon and steelhead from the Bulkley River region. The estimated total of about $10 000 was based on the value of the fish if they were to be purchased commercially. The true value is difficult to estimate because of the cultural significance of fishing, as well as the fact that the total is based on only a rough estimate of the number of fish caught by the aboriginal fishery. The estimate is based on the food fishery taking about 6% of the returning steelhead.

The table above shows the estimated value of the various fisheries in the Bulkley River system (1986) to be about $1.6 million. The following table shows the present value of the fishery in the Bulkley River system over 60 years to be between $23 and $40 million, depending on the discount rate used:

Total Present Value (1986, $ Millions) of All Fisheries, Bulkley System

Fishery	Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Steelhead	22.3	16.8	13.3
Resident trout	3.1	2.3	1.8
Salmon	12.8	9.6	7.4
Totals	**38.2**	**28.7**	**22.5**

(from Wilkes and Roberts, 1987)

It is evident from the previous two tables that the value of the recreational steelhead fishery is much higher than that of all other fisheries. 1986 figures show that a steelhead caught (and usually released) by an angler was worth about $80, whereas a steelhead killed in the commercial fishery was worth about $9.

3.1.2 Headwater Lakes and Streams

Buck Creek System:

(i) Lower Buck Creek is a major spawning and rearing stream for salmon, steelhead and resident trout (Wilkes and McLean, 1987). Buck Creek escapement records from the Department of Fisheries and Oceans indicate that chinook, coho, and pink salmon spawn in Lower Buck Creek with maximums of 50, 600, and 100 spawners, respectively, over the period of record (Norecol Environmental Consultants, 1984). Hallam *et al.* (1975) also recorded steelhead trout and Kokanee in the creek. In addition to fisheries uses, Lower Buck Creek also serves as a domestic water supply for residents of Buck Flats near Houston (Wilkes and McLean, 1987).

Upper Buck Creek supports primarily rainbow trout, along with largescale sucker, longnose dace, redside shiner, mountain whitefish, and sculpins between Goosly Lake and just above Bessemer Creek (Bustard and Associates, 1984). Norecol found rainbow trout densities in Buck Creek comparable to densities in most other tributary streams of the Bulkley and Morice Rivers (Norecol Environmental Consultants, 1984).

According to Tredger (1982), Buck Creek is a very important area for the spawning and rearing of steelhead. For example, in 1981, steelhead from Buck Creek accounted for about 46% of the 0+ and 59.9% of the 1+ age-class steelhead in the upper Bulkley River below Bulkley Lake.

(ii) Goosly Lake was reported by Osborne and Hallam (1982) to contain redside shiners, peamouth chub, longnose suckers, largescale suckers, rainbow trout, mountain whitefish, and kokanee. The rainbow trout in Goosly Lake support only a minor, local, recreational fishery (Wilkes and McLean, 1987). The outlet of Goosly Lake is suitable for kolanee spawning, with this species identified in both Buck Creek and Goosly Lake (Osborne and Hallam, 1982).

(iii) Bessemer Creek: No fish have been documented in Bessemer Creek before or after the start of mining (R. Hallam, pers. comm.).

Maxan Creek System:

(i) Maxan Creek supports a variety of resident species including redside shiners, peamouth chub, longnose suckers, largescale suckers, prickly sculpin, rainbow trout, mountain whitefish, squawfish, and Dolly Varden char. Anadromous species including sockeye and coho have also been recorded (Osborne and Hallam, 1982). Hancock *et al.* (1975) state that the majority of the upper Bulkley River sockeye spawning in the Maxan Creek system occurs in the area extending from 1 km below its confluence with Foxy Creek to 2 km above that point.

(ii) Lu Lake in the headwaters was barren of fish species (Beak, 1976; Bustard and Associates, 1984).

(iii) Foxy Creek has rainbow trout and Dolly Varden char upstream of it's confluence with Maxan Creek, and the area below the falls (located at about kilometer 15) is used for spawning and rearing (Beak, 1976). The falls are impassable to anadromous fish. Bustard and Associates (1984) found the majority of fish were rainbow trout fry and parr, mostly restricted to the lower 3 km above Maxan Creek due to its good spawning gravel and rearing habitat. They also observed juvenile chinook, Dolly Varden char and longnose dace. The reach from km 3 to the falls is descried by Bustard as a canyon with poor spawning and rearing habitat.
Norecol described rainbow trout densities in lower Foxy Creek to be extremely high compared to those in other Bulkley and Morice River tributaries, due to excellent spawning and rearing conditions (Norecol Environmental Consultants, 1984). Bustard and Associates (1984) documented juvenile chinook salmon in lower Foxy Creek.

(iv) Bulkley Lake has limited access for recreational fishing through farmer's fields, with cartop boats able to launch at the lake outlet. Historical lake survey data indicate the presence of steelhead and rainbow trout, as well as redside shiner, squawfish, and peamouth chub (Tredger and Caw, 1974). There would also be transient use by salmonids to spawning areas in the Maxan Creek system upstream.

3.1.3 Recreational Use of Fisheries

Hatfield Consultants Ltd. (1983) reported limited use of the Buck and Maxan systems as anglers tended to use the Bulkley River and its tributaries due to their relatively easy access. Beak Consultants (1976) also reported limited recreational fishing in the Buck Creek system. The rainbow trout in Goosly Lake are a recreational fishery but of minor (local) importance (Wilkes and McLean, 1987).

3.2 Licensed/Unlicensed Water Use

3.2.1 Buck Creek Drainage

Goosly Lake: no water licenses are reported.

Buck Creek: There are nine water licenses reported for Buck Creek. Eight are domestic licenses totaling 6907 m^3/yr with the points of diversion near Houston, and one is for 617 m^3/yr for irrigation, the point of diversion near Buck Flats located about halfway between Goosly Lake and Houston.

Additionally, there were about 20 households on Buck Flats who drew water for domestic use from Buck Creek, but switched to water pumped from wells due to water quality concerns when the Equity mine began operation. Buck Creek water is also used in Buck Flats for livestock watering, an unlicensed use (Rhebergen, 1986).

Lu Creek and Bessemer Creek: Licenses are held by Equity Silver Mines Limited which allow diversion of both creeks for land improvement.

Lu Lake: This lake is committed to mining use with one license for 704 612 m^3/yr for industrial and mining use, and another for 838 440 m^3/yr for storage.

3.2.2 Foxy Creek Drainage

Foxy Creek: no water licenses are reported for Foxy Creek.

Maxan Creek: There are two licenses for waterfowl habitat enhancement (a conservation project) with Ducks Unlimited (Canada).

Bulkley Lake: Although there are no water licenses reported, there is unlicensed use for livestock watering at the lake outlet and marshes (R. Nijman, personal observation).

3.3 Wildlife

There is little information on wildlife use of the Bulkley River headwaters. However, the Bulkley River Valley is a major wintering area for moose, and mule deer use the area year-round. The Bulkley River Valley is also utilized by beaver, muskrat, and a number of bird species including mergansers, belted kingfishers, bald eagles, and Canada geese (Water Use Inventory - Bulkley River to 1983). Equity Silver Mines Ltd. has documented deer and black bear as well as seasonal use by moose of the mine site in the Bulkley River headwaters, and geese and ducks in the nearby ponds and wetlands (Equity Silver Mines Environmental Reports, 1985-1994). Ducks Unlimited has two licenses on Maxan Creek for waterfowl enhancement to encourage the use of the marshland by more breeding pairs of ducks. Ducks Unlimited has also documented the use of the Bulkley Lake outlet and it's marshes by a few thousand Canada Geese during their spring and fall migrations (Clark, 1994, pers. comm.).

4. WASTE DISCHARGES

The disposal of acid producing waste materials from preproduction mining was not perceived to be a problem (Beak, 1976) and it wasn't until the end of 1981 that AMD was identified as being of environmental concern in the Equity Silver Mine area. The nature and extent of the problem wasn't identified until extensive monitoring took place to evaluate stream quality following a sulphuric acid spill from the leach plant in November of 1981. Samples meant to reflect ambient conditions, collected above the plant drainage on Bessemer Creek, revealed water with very low pH and elevated metal levels. The mine had a permit for waste discharge, which is described in the follow section:

4.1 Permit PE4475 Equity Silver

Permit No. PE-4475 was issued to Equity Silver Mines Limited on June 14, 1977 and was last amended March 30, 1994. The permit states that the permittee "...is authorized to discharge sludge to an open pit and effluent from an acid mine drainage collection and treatment system and a sewage treatment facility at a decommissioned mine/mill complex located 32 km southeast of Houston, British Columbia to Buck Creek and Foxy Creek." A description of the permit follows:

Permit Section 1.1 Discharge of Runoff, Excess Tailings Pond Supernatant, Treated AMD, and Treated Sewage from the Silt Check Dam Facility to Bessemer Creek:

Discharge consists of treated AMD and treated sewage effluent discharged from the Diversion Pond (treated water storage), excess tailings pond supernatant, and surface runoff from the mine site areas outside the confines of the acid mine drainage collection system. The maximum and average authorized rates of discharge are 422 092 m^3/d and 3 585 000 m^3/yr, respectively. Characteristics of the effluent at the last point of control (*i.e.*, the Silt Check Dam Spillway) shall be equivalent to or better than:

Characteristic	Concentration (mg/L)
Metal:	
aluminum (diss.)	0.50
antimony (diss.)	0.25
arsenic (diss.)	0.05
cadmium (diss.)	0.01
copper (diss.)	0.05
iron (diss.)	0.30
zinc (diss.)	0.20
Other:	
nitrate/nitrite-N	20
total suspended solids	75*
toxicity (96-hr LC_{50})	100%
pH	6.5-8.5

*Total Suspended Solids = 75 mg/L until August 31, 1995 and 50 mg/L thereafter.

The works authorized are a settling pond (also known as the Silt Check Dam Facility) on lower Bessemer Creek and related appurtenances.

Permit Section 1.2 Discharge of Excess Tailings Pond Supernatant, Treated AMD, and Treated Sewage from the Diversion Pond to Foxy Creek:

The maximum rate that effluent may be discharged from the Diversion Pond to the Lu Creek Diversion Channel and then to Foxy Creek is 400 000 m^3/yr, and is subject to the measured dissolved copper concentrations of the effluent and dilution ratios as follows:

Copper Concentration in Effluent (mg/L)	Dilution Ratio Foxy Creek: Discharge
0.050	20:1
0.040	16:1
0.030	12:1
0.020	7:1
0.010	3:1

The characteristics of the effluent shall be equivalent to or better than:

Characteristic	Concentration (mg/L)
Metal:	
aluminum (diss.)	0.50
antimony (diss.)	0.25
arsenic (diss.)	0.05
cadmium (diss.)	0.01
copper (diss.)	0.05
iron (diss.) 0.30	
zinc (diss.) 0.20	
Other:	
nitrate/nitrite-N	20
total suspended solids	75*
toxicity (96-hr LC_{50})	100%
pH	6.5-8.5

*Total Suspended Solids = 75 mg/L until August 31, 1995 and 50 mg/L thereafter.

Should the pH of the combined treated AMD and runoff be within the range of 8.5 -9.0, the limits for As, Cd, Cu, Sb, and Zn listed in the previous table remain the same but refer to total (not dissolved) metal concentrations.

The works authorized are a sewage treatment lagoon, an acid mine drainage collection system, an acid mine drainage treatment plant, two sludge settling ponds, an effluent polishing pond (also known as the Diversion Pond), pumps, pipes and related appurtenances.

Permit Section 1.3 Discharge of Excess Tailings Pond Supernatant, Treated AMD and Treated Sewage from the Diversion Pond to Bessemer Creek, thence to Buck Creek:

The maximum rate at which effluent may be discharged from the Diversion Pond to Bessemer Creek, thence to Buck Creek, is 800 000 m3/yr, and is subject to the measured dissolved copper concentrations of the effluent and dilution ratios as follows:

Copper Concentration in Effluent (mg/L)	Dilution Ratio Foxy Creek: Discharge
0.050	33:1
0.040	26:1
0.030	19:1
0.020	12:1
0.010	5:1

The characteristics of the effluent shall be equivalent to or better than:

Characteristic	Concentration (mg/L)
Metal:	
aluminum (diss.)	0.50
antimony (diss.)	0.25
arsenic (diss.)	0.05
cadmium (diss.)	0.01
copper (diss.)	0.05
iron (diss.)	0.30
zinc (diss.)	0.20
Other:	
nitrate/nitrite-N	20
total suspended solids	75*
toxicity (96-hr LC_{50})	100%
pH	6.5-8.5

*Total Suspended Solids = 75 mg/L until August 31, 1995 and 50 mg/L thereafter.

Should the pH of the combined treated AMD and runoff be within the range of 8.5 -9.0, the limits for As, Cd, Cu, Sb, and Zn listed in the previous table remain the same but refer to total (not dissolved) metal concentrations.

The works authorized are a sewage treatment lagoon, an acid mine drainage collection system, an acid mine drainage treatment plant, two sludge settling ponds, an effluent polishing pond (also known as the Diversion Pond) pumps, pipes and related appurtenances.

Permit Section 1.4 Discharge of AMD Sludge to Main Zone Pit:

There is no restriction on discharge rates for AMD sludge, and the characteristics of the effluent shall be AMD treatment plant sludge (complexes of calcium sulphate-metal hydroxides).

The works authorized are two sludge settling ponds, a sludge booster pump, a sludge conveyance pipeline, and related appurtenances.

4.2 Loadings to Foxy and Buck Creeks

As mentioned previously, all discharges of treated water before October of 1983 were to the Bessemer/Buck Creek system, while discharges after this time were to both Buck Creek and Foxy Creek. Equity's records show the following flows from the diversion and polishing pond for treated AMD and sewage effluent to the Bessemer/Buck and Foxy Creek systems since 1983.

Treated AMD to Foxy and Buck Creeks, and the Main Zone Pit (m^3)

a) 1983 - 1988

Year	1983	1984	1985	1985	1986	1986	1987	1987	1988
Month	Foxy	Foxy	Foxy	Buck	Foxy	Buck	Foxy	Buck	Foxy
January									
February									
March									
April		30100						66400	
May		230800	33400	146500	66900	51600	147000	120900	296900
June		589000	169500	321800	143200	301500	68200	37600	142300
July		207200	53600	76700	42300	43500	37500	43300	
August		149400		12300					73400
September		197100		29700					
October	11700	125700		27100	64300	64700			11500
November	7900	71000		19900	6700	7300			
December	5400	11600							
TOTAL (m^3/y)	**25000**	**1611900**	**256 500**	**634 000**	**323 400**	**468 600**	**252 700**	**268 200**	**524 100**

b) 1989-1992

Year	1989	1989	1990	1990	1991	1992	1992	1992
Month	Foxy	Buck	Foxy	Buck	MZPit	Foxy	Buck	MZPit
January								114000
February								21245
March								
April			65000	122000		53990	80580	
May			194600	341200		218450	309100	
June			8350	191400			52775	
July	21600	78400		150300				
August	6900							
September	4300							
October								
November					12000			
December				115000				
TOTAL (m^3/y)	**32 800**	**78 400**	**267 950**	**804 900**	**127 000**	**272 440**	**442 455**	**135 245**

850 140 m^3 of treated water was discharged in 1992, consisting of 272 444 m^3 to Foxy Creek, 442 455 m^3 to Buck Creek, and 135 245 m^3 pumped to the Main Zone pit to continue lake creation and the flooding of acid generating waste rock. Flooding of the Main Zone pit began in 1991 with the pumping of 127 000 m^3 of treated discharge; there was no additional discharge to Bessemer/Buck or Foxy Creeks in 1991 as it was a dry year.

The above table shows that discharge flows to the receiving creeks have varied significantly over the life of the mine. Discharges to Foxy Creek have varied from a low of 25 000 m^3(1983) to 1 611 900 m^3(1984), with discharges to Buck Creek varying from 78 400 m^3 (1989) to 804 900 m^3 (1990). The table also shows that in 1983, 1984, and 1988 treated water was discharged only to Foxy Creek. Prior to 1983, treated water was discharged only to Buck Creek. Also evident from the table is the fact that most of the treated water was discharged between April and July, during peak flows.

Table 4.2.1 shows the theoretical loadings of the dissolved fraction of various permitted chemicals in the treated water discharges to the two creeks, assuming maximum concentrations of metals allowed in the permit, calculated for both the minimum and maximum annual discharge flows from 1983 to 1992. The loadings for copper are based on the minimum permitted concentration of copper of 0.010 mg/L, although up to 0.05 mg/L is permitted under higher dilution conditions. Loadings are not calculated for metals other than copper for Foxy Creek, since the concentration of other metals was not regulated under the permit until the 1994 amendment.

These theoretical loadings are termed annual loadings in the table, but actually are loadings restricted to the discharge period (some or all of April to November). For example, 0.3 kg of dissolved copper was discharged in 25 000 m^3 of treated water to Foxy Creek in 1983, but all within the three months October through December (before the permit was amended to November). The 16.1 kg discharged to Foxy Creek was within nine months, April through December.

Actual loadings to Buck and Foxy Creeks based on the annual discharge flows listed previously and actual average concentrations of parameters in the treated water discharges (provided by Equity Mines Ltd.) are summarized in Table 4.2.2. With the exception of aluminum, concentrations listed are for total metals, the same form as the BC working criteria used in the discussion of water quality and the setting of water quality objectives. As evident in Table 4.2.1, these loadings were restricted to the permitted discharge period of May 1 to November 30, but most of the treated water was discharged between May and July during spring freshet. The table shows that the highest loadings usually correspond to the highest discharge volume years, with discharge volume usually more important than parameter concentration. For example, peak loadings to Foxy Creek occurred in 1984 when 1 611 900 m^3 of treated water contributed the following: 12 090 kg suspended solids, 3 100 000 m^3 sulphate, 6577 kg nitrate, 9.7 kg cyanide, 303 kg aluminum (dissolved), 4.35 kg arsenic, 1.77 kg cadmium, 61.3 kg copper, 851 kg iron, 2.42 kg antimony, and 102 kg zinc. Peak loadings to Bessemer/Buck Creek occurred in two different years, dependent on parameter, in (i) 1990, when 8129 kg of suspended solids, 1 300 000 kg of sulphate, and 193 kg of zinc were discharged with 804 900 m^3 of treated water; and (ii) in 1985 with peak loading of 2301 kg nitrate, 76 kg aluminum (dissolved), 42.5 kg copper, and 2.22 kg antimony from 634 000 m^3 of treated discharge.

5. MINE RECLAMATION

Depletion of ore reserves from the three known mineralized zones and plant decommissioning/ mine closure was to have been completed by 1992. Open pit mining of the southern tail orebody occurred between 1980 and 1984; the Main Zone was mined between 1983 and 1991; and open pit mining of the Waterline Zone occurred from 1988 to 1992. However, an underground mining operation in the Waterline Zone began in August of 1993 with two exploration drifts driven north from the northern end. Mining of this North Zone was expected to continue until the end of 1993 unless exploration drilling found additional reserves. Stockpiled low grade ore (a major source of AMD) located between the Main and Bessemer waste dumps, had been milled by the fall of 1992. Problems with milling this material cut the project short of the expected tonnage, and for most of 1992 the Equity facility was used to process ore from the Dome Mountain Mine near Smithers. The remainder of the low grade ore stockpile and completion of till cover over waste dumps was scheduled for completion in 1993.

Equity had posted a \$37.5 million bond with the government to cover reclamation and long-term AMD treatment costs (Equity Silver Mines Environmental Reports, 1985-1994). This total consisted of \$2.17 million to be returned with the completion of plantsite reclamation, \$3.33 million upon placement of a compacted till cover, and \$32 million to finance the long-term AMD collection and treatment costs after the waste dump had been covered.

The ongoing reclamation program focused on recontouring the waste dumps, followed by placement of a compacted glacial till cover, seeding and fertilizing. This program is intended to both promote evapotranspiration processes and to reduce water infiltration into the waste rock piles, as well as to inhibit oxygen entry into the waste rock/AMD formation process through the retention of a moist clay cover over the till. The objective was to reduce the quantity of contaminated water flowing from the property with subsequent reduction in AMD treatment costs.

The Tailings Pond as well as the Main Zone and Waterline pits will have control structures built and become or be maintained as lakes to prohibit acid generation. The Main Zone pit (lake) will be used as a repository for an estimated 4.5 million tonnes of waste rock, as well as for sludge pumped from the AMD treatment plant following decommissioning of the tailings pond. Plant site structures and unnecessary roads will be removed followed by reclamation.

Projected use of the property following reclamation is wildlife habitat. Reclamation sites have already been documented as grazing area for deer, moose (seasonal) and black bear. Geese and ducks apparently utilize ponds and wetlands on the mine site.

Preliminary results from the reclamation program are evident in AMD treatment plant lime consumption results. Lime consumption was reduced in 1992 by 12.8% over 1991 and 20.5% over 1990 due to a combination of reduced runoff from the reclaimed waste dumps, increased lime plant efficiency, and a lower amount of rainfall over the year (Equity Silver Mines Environmental Reports, 1985-1994).

6. WATER USE DESIGNATIONS

This section of the report designates water uses to be protected by water quality objectives, which by definition protect the most sensitive water use.

6.1 Buck Creek System

The following designated uses apply to Buck Creek and Goosly Lake, but not to Bessemer Creek: **(i) fisheries, (ii) (other) aquatic life and (iii) wildlife** for all of Buck Creek, with the addition of **(iv) irrigation** and **(v) livestock watering** for Goosly Lake and the reach of Buck Creek downstream to the Bulkley River. Although there is no drinking water use of Goosly Lake, it could be made a designated use to protect downstream users on Buck Creek.

6.2 Foxy Creek System (includes Foxy and Maxan Creeks, Bulkley Lake).

Designated uses in the Foxy Creek system include **(i) fisheries, (ii) (other) aquatic life, (iii) wildlife, (iv) drinking water and (v) recreation.** Although there is presently unlicensed use of the Bulkley Lake for livestock watering with cattle drinking directly from the lake, this should not be a designated use due to possible contamination by fecal coliforms, thus contributing to levels which may exceed provincial criteria for other water uses (*e.g.*, drinking water). The two licenses currently held by Ducks Unlimited for waterfowl enhancement on Maxan Creek, may also contribute to dangerously high coliform levels.

7. WATER QUALITY MONITORING AND OBJECTIVES

Water quality objectives are set by the Ministry of Environment, Lands and Parks to protect the designated water uses of waterbodies that would be potentially impacted by anthropogenic activity. Objectives are based upon approved water quality criteria for British Columbia or upon working (temporary) criteria from the literature or other jurisdictions to protect the most sensitive water uses. Should a waterbody have exceptionally valuable resources of provincial significance and good existing water quality, the water quality objectives are set to avoid degradation.

Water quality objectives are to be met 100% of the time between the streamflow extremes for which the water and waste management measures are designed with regards to effluent discharges and water quality, in this case the 1-in-10-year high and low flows. A water quality objective that is exceeded would indicate that a potential problem has occurred that needs correcting. Objectives based on water use protection criteria are designed to be a conservative estimate of the water quality conditions needed to protect the environment (*i.e.*, a conservative estimate of the threshold of some detrimental effect to the environment and its uses).

Water quality objectives are site-specific and based on the best available information. As such, objectives are provisional and will be reviewed as more monitoring information becomes available and the Ministry of Environment, Lands and Parks establishes more approved water quality criteria for British Columbia.

Water quality objectives apply immediately outside of initial dilution zones of either entire water bodies or designated reaches of creeks or rivers. Initial dilution zones are usually small areas where initial mixing occurs between the waste discharge and the receiving waters. Although initial dilution zones are site specific, they are typically less than 100 m long, and occupying less than 25 to 50% of the width of the waterbody. They are located, sized, and shaped to minimize the impact of waste discharges on aquatic populations. Although water quality objectives do not apply in initial dilution zones, objectives for contaminants in biological tissue apply throughout the waterbody. No acutely toxic or nuisance conditions are allowed inside initial dilution zones (for more details see "Principles" document, Water Management Branch, 1986). Processes such as chemical changes, precipitation, adsorption, and microbiological action, as well as dilution, take place in these zones to ensure that water quality objectives are met at their border. Objectives in terms of 30-day average and maximum concentrations are calculated from a minimum of 5 samples in 30 days.

Water quality data were collected from the two drainages, Foxy and Buck Creeks, that receive treated water discharges from the diversion pond. These data are discussed in this section, and compared with water quality criteria that protect various water uses. These criteria are either British Columbia criteria or criteria taken from other jurisdictions, and are summarized in Nagpal *et al.* (1995). It should be noted that not all data collected at upstream sites have paired data at sites downstream of the discharges (i.e., collected at about the same time), as the upstream sites were sampled more intensively to determine ambient conditions. Records kept by the permittee of when treated water was actually discharged to the receiving environments of Foxy and Buck Creeks were consulted to determine when the downstream site was potentially impacted. These records are summarized annually in Equity Silver Mines Environmental Reports (1985-1994). Water quality data from these sites is generally only discussed in this document if they exceed levels which will protect the most sensitive water use in the area.

7.1 Foxy Creek Drainage

7.1.1 Comparison of Upper Foxy Creek Site 0400763 (U/S Lu Creek Diversion) and Lower Foxy Creek Site 0400764 (D/S Berzelius Diversion)

Site 0400763 (U/S Lu Creek Diversion) was used as the ambient/background site for Lower Foxy Creek. Treated water is discharged to the Lu Creek Diversion and enters Foxy Creek downstream of this site. Potential impacts to water quality by the discharge are measured primarily at Site 0400764 downstream. Data for these sites collected between 1980 and 1995 are summarized in Table 7.1.1, and their locations indicated on Figures 1 and 2.

There was a frequent lack of paired samples (*i.e.*, samples collected both upstream and downstream of the discharge on the same day) to allow identification of potential downstream impacts of the discharge.

The pH at upstream Site 0400763 ranged from 5.6 to 8.1, with a mean of 7.1. Only 12 of the 182 samples were less than the water quality criterion lower limit of 6.5 to protect aquatic life (McKean and Nagpal, 1991). Nine of these 12 data were sufficiently close to the criterion (6.3 to 6.4) to be of little concern, with the minimum value of 5.6 measured on May 22, 1990. At the downstream site (0400764) the pH ranged from <1 to 8.1, with a mean of 7.3. Only the minimum pH of <1 (measured on January 6, 1986) was outside the range of the aquatic life criteria, and appears to be an anomaly. No upstream value was measured on this date, but the pH measured upstream on January 20 was 7.0 and supports the theory that the value below the detection limit was an anomaly During the period of record when treated water was discharged to Foxy Creek, the paired data indicates that the pH at the downstream site was consistently (but only slightly) higher, as to be expected by the addition of a lime-neutralized effluent. The difference ranged from 0 to 1.0 pH units for the 30 paired samples, and this small difference was probably due to the fact that effluent was discharged during periods of high flow and therefore was well diluted. Therefore, it does not appear that low pH is a problem as long as liming of the effluent continues, and no criterion is proposed for pH for this reach of Foxy Creek.

Ambient levels of suspended solids measured at Site 0400763 ranged from <0.5 to 28 mg/L, with a mean of 4 mg/L. Concentrations of suspended solids at the downstream site (0400764) ranged from <0.5 to 133 mg/L, with a mean of 6 mg/L. There were few paired data (n=4) collected while effluent was being discharged to compare levels with BC criteria. The criterion is 10 mg/L above background levels to protect aquatic life when background concentrations are < 100 mg/L (as in Foxy Creek) (Singleton, 1985). Differences between the two sites did not exceed 3 mg/L suspended solids for the four paired samples.

Alkalinity at the upstream site (0400763) ranged from 8.6 to 32.4 mg/L (as $CaCO_3$), with a mean of 22.9 mg/L. At this level, the water is considered to have low to moderate sensitivity to acidic inputs with regards to aquatic life (Swain, 1987). Site 0400764 downstream had alkalinities ranging from 14.9 to 257 mg/L, with a mean of 42.3 mg/L, which indicates low sensitivity to acidic inputs. These higher alkalinity levels are expected due to the fact that the effluent is lime-neutralized. Paired upstream to downstream data during periods of treated discharges are few, however (n=6), with means of 31.5 and 63.6 mg/L for upstream and downstream sites, respectively. The increased alkalinity through the input of lime-neutralized effluents close to the headwaters of Foxy Creek provides protection to aquatic life downstream from the possible input of untreated acid mine drainage from outside the collection and treatment system. Therefore, alkalinity is not a concern at the downstream site.

There is an extensive database for WAD cyanide concentrations at Site 0400764 downstream of the treated AMD discharge (n=170), but there is essentially no ambient data from the upstream site (0400763) (n=1) and therefore no paired data. It is expected that cyanide concentrations would be lower at background site 0400763 as cyanide addition is part of the metals extraction process and would therefore be introduced to the stream in the treated effluent. However, there were elevated levels at the downstream site both during and between periods of treated water discharges. These cyanide levels ranged from less than the detection limit (<5 μg/L) to a maximum of 120 μg/L, with a mean level of 9 μg/L. This mean concentration is slightly below the water quality criterion maximum concentration for the protection of aquatic life of 10 μg/L. Twenty values exceeded this maximum criterion, but only 8 of these occurred while treated water was being discharged from the diversion pond. The source(s) of the high levels when the treated water was not being discharged is not known. Analysis for cyanide did not occur after 1989 at downstream Site 0400764, probably due to elimination of cyanidation in the metals removal process and a reduction of concentrations in the receiving environment to at or near the limit of detection (5 μg/L) after 1987.

Total hardness levels measured at background Site 0400763 ranged from 5.8 to 44.0 mg/L $CaCO_3$, with a mean of 21.9 mg/L. Levels at Site 0400764 were higher, which would be expected downstream of a lime-neutralized effluent discharge, ranging from <0.1 to 113 mg/L and with a mean of 27.3 mg/L. Levels at both sites were generally less than the 100 mg/L maximum considered acceptable for drinking water (Health and Welfare Canada, 1989). Elevated downstream levels are helpful in ameliorating the impacts of copper and other metals, which are less toxic at higher hardness concentrations. Hardness concentrations can also be estimated using concentrations of calcium and magnesium, and three additional values (ranging from 21.8 to 28.9 mg/L) were calculated for background Site 0400763. Similarly, nine values were calculated for Site 0400764, ranging from 51.3 to 376.4 mg/L. These higher downstream values were due primarily to very high calcium concentrations (maximum 116 mg/L total calcium) from the addition of lime-neutralized effluent.

Data on levels of dissolved sulphate are few. Background levels at Site 0400763 were very low, and all <5 mg/L. Dissolved sulphate levels below the treated discharge were much higher, with a maximum concentration of 310 mg/L and a mean concentration of 122 mg/L. These elevated levels were probably due to the lime-treated acid mine drainage. Actual paired data, comparing ambient concentrations with those downstream of the effluent discharge, are limited to one sample where the level increased from 1.8 mg/L upstream to 33.0 mg/L downstream. The highest measured concentration of 310 mg/L at the downstream site is difficult to explain, however, as no treated water discharge occurred on that date (Aug. 26, 1991) according to Equity Mine records. The water quality working criterion is 100 mg/L maximum for the protection of aquatic life (Nijman, 1993) and was exceeded in seven of 11 samples collected at the downstream site. Since it appears that levels exceeding the working criterion downstream are due to the effluent discharge, a water quality objective is proposed for Foxy Creek. The objective states that the maximum concentration of dissolved sulphate downstream of the discharge should not exceed 100 mg/L outside of the initial dilution zone (as defined in Section 7.).

Ambient total sulphate levels measured at Site 0400763 ranged from <1 to 20.5 mg/L, with a mean of 2.6 mg/L. Most of the total sulphate present at this site would probably be in the dissolved form. Downstream total sulphate levels at Site 0400764 were much higher, with a maximum value of 267 mg/L and a mean of 37.7 mg/L. These elevated levels are characteristic of sites downstream of treated acid mine drainage discharges. A large proportion of the total sulphate downstream of the lime-treated discharge is expected to be associated with particulate matter, which makes a comparison of concentrations with the working criterion (which is in terms of dissolved sulphate concentrations) difficult. However, the objective previously set for dissolved sulphate should also address the problem of elevated total sulphate levels.

Dissolved aluminum levels at background Site 0400763 ranged from 0.012 to 0.449 mg/L with a mean of 0.135 mg/L, whereas Site 0400764 downstream of the discharge had a slightly higher maximum level (0.490 mg/L) but a lower mean concentration (0.094 mg/L). Of the 31 paired samples collected during treated water discharge periods, only six showed higher levels downstream. A total of 85 of 152 samples (or 56%) collected from the ambient site exceeded the aquatic life criterion maximum of 0.1 mg/L dissolved aluminum (Butcher, 1988), while only 54 of 161 samples (34%) collected at the downstream site exceeded the criterion. High levels of total aluminum were also measured at both sites (maximum concentrations of 2.69 and 5.31 mg/L at the upstream Site 0400763, and to 6.04 and 10.0 mg/L at downstream Site 0400764) though no water quality criterion exists for total aluminum concentrations to put these relatively high levels into perspective. Since ambient levels appear to be high, and do not appear to be affected by the mine discharge, no water quality objective is proposed for dissolved aluminum concentrations in lower Foxy Creek.

Levels of total arsenic ranged from below detection limits (between <0.0001 and <0.25 mg/L) to a recorded maximum of 0.019 mg/L at background Site 0400763. The mean at the downstream site was 0.004 mg/L, with a maximum value of 0.110 mg/L. This maximum concentration (0.110 mg/L) was the only value to exceed the aquatic life criterion of 0.05 mg/L maximum (CCREM, 1987). No paired upstream sample was collected on the same day, so it is unclear if the high concentration was due to discharged effluent or high ambient concentrations. The mean concentration of total arsenic at both the upstream and downstream sites was less than the Health and Welfare Canada (1993) proposed interim maximum acceptable criterion (IMAC) of

0.025 mg/L for drinking water, so it does not appear that arsenic concentrations are a concern in Foxy Creek.

The concentration of total cadmium at the upstream site (0400763) was generally below detection limits (ranging from <0.0002 to <0.01), though total cadmium was detected in 11 of the 49 samples with a maximum level of 0.002 mg/L. In nine of the 11 samples exceeding detection limits, the water quality criterion for the protection of aquatic life (0.0002 mg/L total cadmium at a hardness ≤60 mg/L as is generally the case at both the upstream and downstream sites) (CCREM, 1987) was exceeded. Concentrations measured at the downstream sites were similar to levels upstream when paired samples were collected, and the water quality criterion was exceeded in 36 of 103 samples collected at Site 0400764. However, the maximum recorded concentration at the downstream site was only 0.0009 mg/L, so it does not appear that total cadmium concentrations were very high in the effluent. Total cadmium concentrations were no longer measured after 1991 at either site on Foxy Creek, so it is not known if cadmium concentrations remained low. However, it does not appear that cadmium is a concern in Foxy Creek, and therefore no objective is proposed.

Ambient levels of total copper at Site 0400763 ranged from less than the detection limit (<0.001 mg/L) to a maximum of 0.1 mg/L, with a mean concentration of 0.006 mg/L. The 30-day average aquatic life criterion at the mean hardness level of upper Foxy Creek (≤50 mg/L) is 0.002 mg/L total copper (Singleton, 1987), and was exceeded in 69 of 182 (about 38%) of the samples collected. These high values are probably due to copper mineralization in the watershed. Levels downstream ranged from below detection limits (<0.001 mg/L) to 0.27 mg/L, with a mean value of 0.010 mg/L, and with 119 of 188 values exceeding the 30-day average criterion. Where paired data are available (n=30), downstream levels were generally higher than at the control site, presumably due to the treated water discharge. The largest difference between downstream and upstream total copper concentrations during the periods of treated effluent discharge was 0.035 mg/L. This occurred on April 23, 1990, when the concentration at the upstream site was 0.002 mg/L compared with 0.037 mg/L at the downstream site. Although it appears that ambient concentrations of total copper are high enough to exceed the water quality criterion for the protection of aquatic life, these levels may be further elevated by effluent discharged from the mine. Any increase over the already high levels may have a disproportionally negative effect on aquatic life, so a water quality objective is proposed for total copper concentrations in upper Foxy Creek. The objective states that <u>concentrations measured on any one day at the downstream site (0400764) should not exceed 110% of concentrations measured at Site 0400763 on the same day, and total copper concentrations measured at this site should not be significantly higher than those at the ambient site using a 2-tailed t-test and a minimum of five samples collected in a 30-day period</u>.

Levels of dissolved iron ranged from 0.03 to 7.22 mg/L at upstream Site 0400763, with a mean of 0.26 mg/L. At the downstream site, values ranged from 0.01 to 1.41 mg/L, with a mean of 0.13 mg/L. Although the mean concentration of dissolved iron downstream of the treated discharge is lower than that of the upstream site, the few paired data collected while effluent was being discharged are equal or slightly higher in concentration at the downstream station. The mean concentration at the upstream site exceeds the water quality criterion of 0.3 mg/L total iron for the protection of aquatic life. However, as downstream concentrations are not elevated by treated effluent and criterion exceedences appear to be due to high natural levels, no objective is proposed for iron concentrations in upper Foxy Creek.

Some data on mercury levels in water were collected from 1980 to 1983 at both the upstream and downstream sites. Due to the many potential sources of mercury contamination as well as the problem of accurately measuring mercury levels in water (see Pommen, 1994), these data will not be discussed other than to say that the majority of values were below detection limits at both sites. Mercury in biological tissue is considered to be the key indicator of mercury contamination, and is discussed in Section 8 of this report. Mercury analyses were part of an annual fish sampling program on the Equity property.

Levels of total lead at upstream Site 0400763 were generally low, ranging from below detection limits (between <0.001 and <0.1 mg/L) to a maximum measured concentration of

0.004 mg/L. With an average hardness at this site of <30 mg/L, the 30-day average criterion is 0.004 mg/L and the maximum criterion is 0.018 mg/L (Nagpal, 1987), so all values were below these criteria. Values at downstream Site 0400764 ranged from less than detection limits (<0.001 to <0.1 mg/L) to a maximum of 0.01 mg/L. The maximum criterion was exceeded only once (by the maximum recorded value) at the downstream site, and the median concentration was below detection limits (and therefore the 30-day average criterion). Therefore, it does not appear that the effluent from the mine runoff contains significant levels of lead, and no objective is proposed for this metal in the Foxy Creek.

Relatively few samples were analyzed for nickel concentrations at either the upstream or downstream sampling sites, apparently due to the fact that all samples that were taken had concentrations below the detection limit (which ranged from <0.01 to <0.05 mg/L). Data analyzed at the higher detection limit are difficult to interpret, since they exceeds the water quality criterion of 0.025 mg/L for the protection of aquatic life applicable at a hardness ≤60 mg/L (CCREM, 1987). More sample analyses, using a lower detection limit, are necessary to determine if there is any potential impact to water quality due to nickel concentrations in the treated effluent. However, since the single value at each site analyzed at the lower detection limit (<0.01 mg/L) was below this limit, it does not appear that nickel concentrations are a concern and no objective is proposed.

Background levels of total zinc measured at Site 0400763 ranged from below the detection limits (<0.005 to <0.010 mg/L) to a maximum of 0.160 mg/L, with a mean concentration of 0.012 mg/L. Eleven of the 183 samples had levels of total zinc exceeding the working aquatic life criterion on 0.03 mg/L maximum (CCREM, 1987). Levels at downstream Site 0400764 were higher than at the ambient site, ranging from 0.003 to 0.43 mg/L with a mean concentration of 0.016 mg/L. The suspended solids concentration measured on the date when the maximum concentration occurred was only 1.5 mg/L, which makes it unlikely that the high concentration was due to particulate matter. Eighteen of 190 samples had concentrations which exceeded the 0.03 mg/L criterion. Of the 31 paired samples during the treated water discharge period (data collected at sites both upstream and downstream of the discharge), 12 sample concentrations at the downstream site had higher concentrations of total zinc than at the upstream site, possible due to the treated water discharge. This trend is not consistent, however, as levels at the downstream site are often the same as ambient levels even though treated water was being discharged. Finally, the three occasions when the greatest increases occurred in downstream concentrations compared to ambient levels (0.430 mg/L compared to 0.025 mg/L, 0.340 mg/L compared to 0.029 mg/L, and 0.224 mg/L compared to 0.005 mg/L) occurred during periods when no treated water was discharged. Therefore, it does not appear that the treated effluent is negatively affecting the concentrations of zinc in upper Foxy Creek, and no objective is proposed for this metal.

7.1.2 Foxy Creek Site 0700108 Above Maxan Creek/Below Fish Barriers

The location of Site 0700108 is indicated on Figure 2. Data for this site collected between 1980 and 1995 are summarized in Table 7.1.2. The number of samples analyzed at this site is much lower than those collected at Stations 0400763 and 0400764 upstream. This site is located below the falls in Foxy Creek, which act as a barrier to anadromous fish. Therefore, this site represents the first area where anadromous fish may be impacted by mine effluents discharged into Foxy Creek, compared to sites upstream of the falls in which only local, non-anadromous species are potentially affected. The permittee has regarded this site as the compliance point for meeting receiving environment standards/permit limits.

The pH at this site ranged from 6.8 to 7.9 with a mean of 7.3. All values fall within the water quality criterion range suitable for aquatic life of 6.5-9.0 (McKean and Nagpal, 1991). The more extreme values measured at the upstream sites were not evidenced here, due in part to the smaller number of samples as well as the larger amount of dilution which would minimize the impacts of the lime-neutralized effluents. The few dates on which samples were collected at this site and at Site 0400764 upstream showed a slight increase in pH at the downstream site.

Alkalinity was measured in only 17 samples, with values ranging from 21.8 to 60.6 mg/L and with a mean level of 45.6 mg/L. This mean value is higher than at either of the upstream sites, and reflects the addition of lime to effluent released above Site 0400764. The addition of these effluents imparts protection to aquatic life from any additional acidic inputs by increasing the alkalinity of the receiving environment. British Columbia aquatic life criteria indicate that waters with alkalinity >20 mg/L have low sensitivity to acidic inputs (Swain, 1987) and alkalinity concentrations at this site are generally well above this threshold.

Dissolved sulphate concentrations ranged from 36.3 to 80.6 mg/L, with a mean of 58.4 mg/L. All values are below the water quality working criterion of 100 mg/L for the protection of aquatic life (Nijman, 1993). Only one of the samples was collected while in a period when effluent was discharged upstream, and the mean of a triplicate sample collected at that time was 80.0 mg/L. After 1990, samples were analyzed for total rather than dissolved sulphate concentrations, with levels ranging from 3 mg/L to 81 mg/L and a mean concentration of 14.0 mg/L. Therefore, the dissolved fraction in these samples would have also been well below the 100 mg/L criterion. It appears that sulphate concentrations are not a problem at this site, and no objective is proposed.

The concentration of dissolved aluminum measured at Site 0700108 varied considerably, ranging from 0.005 mg/L to 0.59 mg/L with a mean concentration of 0.1 mg/L. This mean value is similar to those measured at the upstream sites, and only 29% of samples exceeded the maximum criterion for the protection of aquatic life of 0.1 mg/L (Butcher, 1988). This compares favorably to the 34% of samples exceeding the criterion at Site 0400764 and 56% of samples at the ambient site (0400763). Therefore, it appears that high concentrations of aluminum in the creek are due to natural background levels and not mine effluent, so no objective need be set for dissolved aluminum concentrations at this site.

Arsenic levels, both dissolved and total, were all near or below the 1 µg/L detection limit in samples collected prior to 1987. All values were well below the aquatic life criterion of 25 µg/L total arsenic for the protection of drinking water (Health and Welfare Canada, 1993), so arsenic concentrations are not a concern.

Total cadmium concentrations were at or below detection limits (ranging from <0.0002 to <0.0005 mg/L) for all samples. The higher detection limit exceeds the 0.2 μg/L aquatic life criterion at a hardness of < 60 mg/L (CCREM, 1987), so the four values equal to this detection limit exceeded the criterion and other samples less than this limit may also have exceeded the criterion. Half of the 26 samples were collected after April, 1994 and all of these values were below the <0.0002 mg/L detection limit (and therefore the criterion). Therefore, cadmium concentrations appear to be decreasing, and no criterion is required at this site.

Concentrations of total copper ranged from below the 0.001 mg/L detection limit to a maximum of 0.02 mg/L, with a mean concentration of 0.003 mg/L. Total copper levels exceeded the 0.002 mg/L aquatic life criterion (Singleton, 1987) in 49% of samples at this site even when the treated acid mine drainage wasn't being discharged, presumably due to copper mineralization in the watershed. In fact, the maximum level of 0.020 mg/L occurred on Sept. 12, 1987, when no effluent was being discharged. No samples were collected from upstream sites on this date so it is not possible to confirm that the high levels were due to ambient concentrations and not to additions to Foxy Creek from treated or untreated discharges. Levels are considerably lower here than at the upstream sites, and probably due to increased dilution, however a similar objective to that proposed for Site 0400764 is proposed for the sake of caution. This objective states that concentrations of total copper measured on any one day at this site should not exceed 110% of concentrations measured at Site 0400763 on the same day, and concentrations of total copper should not be significantly higher here than at the upstream ambient site using a 2-tailed t-test and a minimum of five samples collected in a 30-day period.

Total iron levels at Site 0700108 ranged from 0.03 to 2.65 mg/L. Although these data have a high mean of 0.29 mg/L, the data are skewed by the high maximum value of 2.65 mg/L that occurred on May 21, 1985. Suspended solids were also high on that occasion at 74 mg/L. The concentration of dissolved iron on this date was low (0.10 mg/L) suggesting that the high total concentration was due to iron in particulate matter which is not harmful to aquatic life. Removal of the maximum value from the data set leaves all remaining values below 0.19 mg/L, which is less than the 0.30 mg/L maximum total iron aquatic life criterion (CCREM, 1987). Therefore, iron concentrations are not a concern at this site.

Samples collected at this site were not analyzed for lead after 1987. All data collected to this point in time, for both dissolved and total concentrations, were less than the 0.1 mg/L detection limit. However, this detection limit is much too high to show whether ambient levels conflict with the aquatic life criteria, which range from a 0.004 mg/L 30-day average to a 0.018 mg/L maximum concentration based on the average hardness of about 30 mg/L found at this site (Nagpal, 1987). Ideally, further data are necessary and with a detection limit lower than the criteria, to determine if lead concentrations are a concern at this site. However, since lead concentrations at upstream sites were fairly low it is unlikely that lead is a concern.

Similarly, analyses for nickel were suspended after 1987, presumably due to levels below detection. However, the 0.05 mg/L detection limit used in the analyses to this point was too high to compare with the aquatic life criterion, which for hardness of <60 mg/L as found at this site is 0.025 mg/L (CCREM, 1987). Therefore, additional samples must be collected and analyzed with a detection limit less than the 0.025 mg/L criterion to determine if nickel concentrations are a problem.

Levels of total zinc at Site 0700108 were low. In contrast to upstream sites, none of the 62 samples exceeded the 0.03 mg/L maximum total zinc aquatic life criterion (CCREM, 1987). In fact, most samples were below or near the 5 µg/L detection limit, and ranged to a maximum of 0.03 mg/L with a mean of 0.01 mg/L. This is somewhat surprising as 11 of 183 samples at the background Site 0400763 exceeded the 0.03 mg/L criterion. Some of the data collected from the three sites on the same day show that the higher levels upstream were lowered by dilution and presumably precipitation, to levels below the criterion and were of no concern to aquatic life at this site. For example, one of the two largest changes from upstream to downstream during periods of treated water discharge (and where there are data from all three sites) occurred on June 23, 1986. On this date, concentrations increased from 0.005 mg/L (at the detection limit) at Site 0400763 to 0.017 mg/L at Site 0400764, and then decreased to 0.006 mg/L at Site 0700108.

An increase in concentration from the ambient levels from treated water discharge, followed by dilution before measurement at Site 0700108 is apparent. As zinc levels are not a problem upstream and concentrations appear to decrease in a downstream direction, no objective is necessary at this site.

7.1.3 Maxan Creek Site E207068 at Junction with Bulkley Lake

This site was sampled on only four dates in 1987 from July through October. Two of these samples involved triplicate measurements for some variables. No further sampling has occurred since that date. The following discussion is based on these limited data, summarized in Table 7.1.3. This site should show some effects of mixing Foxy Creek water with water from Maxan Lake via Maxan Creek. Only the first triplicate samples (July 30, 1987) occurred during discharge of treated acid mine drainage to Foxy Creek upstream, however. Considering the limited sample size at this site, it is regrettable that treated water was not being discharged from the Equity mine site upstream during all the sampling to better indicate the impact of these discharges on Maxan Creek and Bulkley Lake.

The pH of water during these limited sampling dates ranged from 7.6 to 7.8, well within the 6.5-8.5 drinking water criteria range as well as the 6.5-9.0 pH range suitable for aquatic life (McKean and Nagpal, 1991).

Alkalinity was sampled on two dates, one of which was the triplicate sample collected during the discharge of treated water to Foxy Creek. Measurements ranged from 48.4 to 57.8 mg/L with a mean of 51 mg/L. This value represents a good buffering capacity to acidic inputs (Swain, 1987).

Dissolved sulphate levels at this site ranged from 30.4 mg/L during a period of no treated water discharge upstream to a maximum of 45.6 mg/L during the July period of mine discharge, with a mean of 38.5 mg/L. There was only one occasion when data was collected at another site on the same day, at Foxy Creek Site 0700108 upstream. Here, the concentration of sulphate was 79.8

mg/L in comparison to a mean concentration for the triplicate sample collected at Maxan Creek of 45.5 mg/L on July 30, 1987. This reduction of from 79.8 to 45.5 mg/L dissolved sulphate could have been due to dilution and precipitation effects. These few sulphate data for Maxan Creek are less than aquatic life criterion of 100 mg/L (Nijman, 1993) and of no concern.

Levels of dissolved aluminum were low, ranging from 0.05 to 0.14 mg/L with a mean of 0.09 mg/L. Only two of eight samples collected exceeded the 0.1 mg/L maximum dissolved aluminum aquatic life criterion (Butcher, 1988) and then only marginally. All samples were less than the 0.2 mg/L maximum dissolved aluminum drinking water criterion (Butcher, 1988). Although only one sample was analyzed for total aluminum (0.13 mg/L) it seems likely that levels in all samples would have been well below the 5 mg/L wildlife and livestock watering criterion (Butcher, 1988). Therefore, dissolved aluminum concentrations are not a concern in Maxan Creek.

Of the eight samples analyzed for total cadmium, seven were below the 0.5 µg/L detection limit while the remaining sample had a concentration of 6 µg/L. The sample with the highest concentration was one of the first triplicate samples collected, and the other two samples collected at the same time had concentrations below detection. Hardness values calculated using calcium and magnesium concentrations yielded values ranging from 72.8 to 92.8 mg/L with a mean of 82.4 mg/L. Under this mean hardness value, the aquatic life criterion would be 0.8 µg/L (CCREM, 1987), so seven of the eight values which were below detection limits would also be less than the criterion. It would appear the one high value of 6 µg/L is an anomaly, and probably represents sample contamination. Therefore, it does not appear that cadmium concentrations are a concern at this site.

Total copper levels at this site ranged from the 0.001 mg/L detection limit to 0.008 mg/L, with a mean of 0.004 mg/L. All dissolved copper levels were at the 1 µg/L detection limit. With a mean hardness of 82.4 mg/L at this site, three of eight samples (38%) exceeded the water quality criterion of 0.003 mg/L total copper 30-day average for the protection of aquatic life (Singleton, 1987). A similar percentage of samples exceeded criteria at the upstream Foxy Creek sites (including the ambient Site 0400763), probably due to copper mineralization in the watershed exacerbated by copper in mine discharges. However, copper levels decrease with distance downstream, and are probably not a concern at this site due to the relatively high ambient levels.

Total iron in the few data at this site ranged from 0.05 to 0.42 mg/L with a mean of 0.18 mg/L, exceeding the 0.3 mg/L maximum total iron aquatic life criterion (CCREM, 1987) in only one sample. This highest level occurred on Sept. 16, 1987 when levels of non-filterable residue were also the highest, indicating the iron was associated with suspended sediments and therefore not of concern. This is similar to the relatively low levels documented at Foxy Creek sites upstream, with the exception of presumably high flow events with corresponding elevated levels of suspended sediment. Iron concentrations are therefore not a concern.

Assuming an average hardness of about 80 mg/L, the water quality criterion for nickel for the protection of fresh water aquatic life is 0.065 mg/L total nickel (CCREM, 1987). All values were below the <0.05 mg/L detection limit, and therefore below the criterion, indication nickel levels were not a concern at this site.

Total lead concentrations were also below the detection limit of 0.1 mg/L used to measure this metal, but this limit is considerably higher than either the 30-day average or maximum criteria of 0.006 and 0.061 mg/L, respectively (Nagpal, 1987). Therefore, lead must be measured with a lower detection limit to determine if concentrations are a concern at this site.

The few zinc data were all less than the 5 µg/L detection limit for both dissolved and total zinc, and therefore well below the 30 µg/L aquatic life criterion (CCREM, 1987). Levels at Foxy Creek Site 0700108 upstream were also low, presumably following dilution/precipitation of zinc from treated mine drainage discharged upstream.

7.1.4 Bulkley Lake Site E206292 at Center

As mentioned in Section 3, Bulkley Lake is quite small (about 240 ha) and has a mean depth of 7.7 m. Site E206292 is located at about the center of the lake, at the deepest point (about 15 m). Water quality data from Bulkley Lake are limited, with between 4 and 12 samples (depending on the characteristic) collected in 1985 and 1987. On six occasions the site was sampled from three different depths: surface (specifically for chlorophyll a); near-surface (1m); and from between 11 and 13 m. Only on 2 of these 6 occasions, however, was the Equity mine discharging treated drainage. As the residence time of Bulkley Lake is quite low (about 3 months), potential impacts of the upstream discharges would not necessarily have been documented on the other 4 sampling dates. These few data are summarized in Table 7.1.4.

The pH of Bulkley Lake water in the few samples collected from 1985 to 1987 ranged from 7.0 to 8.8, with a mean of 7.4. These values are within the 6.5-9.0 range considered suitable for aquatic life, and generally also within the range of 6.5-8.5 considered suitable for drinking water (McKean and Nagpal, 1991), and therefore of no concern.

Alkalinity in Bulkley Lake ranged from 30.4 to 48.5 mg/L, with a mean concentration of 38.2 mg/L. These levels indicate low sensitivity of Bulkley Lake water to acidic inputs during the sampled periods (Swain, 1987) due to the buffering capacity provided by the relatively high alkalinity levels.

Ammonia levels ranged from <0.005 to 0.407 mg/L with a mean of 0.093 mg/L. Total nitrate/nitrite levels were also low, ranging from <0.02 to 0.09 mg/L with a mean of 0.03 mg/L. These nitrogen levels were suitable for all water uses (including aquatic life, drinking water, livestock watering, wildlife, and recreation and aesthetics) on the sampling dates, as detailed in the Provincial criteria document (Nordin, 1985).

The drinking water criterion for phosphorus in lakes is a maximum of 10 μg/L total phosphorus (Nordin, 1985), to ensure that acceptable concentrations of algae are not exceeded. Criteria in

BC are set to protect water resources from degradation caused by excessive amounts of algae which may impair human use of lakes. Limits are set for phosphorus in lakes because a clear relationship exists between phosphorus and algal biomass (a relationship that does not exist in streams). This criterion level of phosphorus and the resultant algae minimizes water treatment costs and reduces the risk of taste and odour problems in the supply source. The criterion also minimizes low oxygen concentration in deeper water (often used as a supply source) from excessive algal growth. The residence time of Bulkley Lake is about 0.25 years, or 3 months, from the following calculation:

Residence Time = volume/mean annual flow
= surface area x mean depth/mean annual flow
= 240 ha x 7.7 m/81 700 dam^3 (from Environment Canada, 1991)
= 0.23 years, or about 3 months

With a residence time for Bulkley Lake of less than 6 months, the mean epilimnetic growing season concentration criterion is 10 µg/L for total phosphorus. Only ortho-phosphorus data was collected for the Bulkley Lake site. If near-surface samples (1m, versus the 12 or 13m near-bottom samples) are isolated from the data set, the mean of the three samples is 11 µg/L dissolved ortho-phosphorus. As ortho-phosphorus represents only a fraction of the total phosphorus concentration, and since this concentration already exceeds the drinking water criterion (10 µg/L), these few data suggest that the total phosphorus drinking water criterion was exceeded on the three sample dates in 1987. Therefore, a water quality objective is proposed for total phosphorus concentrations in Bulkley Lake. This objective states that <u>the mean epilimnetic growing season concentration of total phosphorus should not exceed 10 µg/L since the residence time of the water is less than 6 months.</u>

Algal biomass samples were collected on six occasions from June through October in 1987. Expressed in terms of chlorophyll <u>a</u>, levels ranged from 2.2 µg/L in June to 19.8 µg/L in August, with a mean of 10.0 µg/L. Recommended guidelines suggest that concentrations of chlorophyll <u>a</u> should not exceed a mean of about 2 µg/L based on bi-weekly samples at several depths in the photic zone. Thus, the concentrations at the Bulkley Lake site were generally much higher than the guideline, so an objective is recommended. The objective states that <u>concentrations of</u>

chlorophyll a should not exceed a mean of about 2 µg/L based on bi-weekly samples at several depths in the photic zone.

Dissolved sulphate levels ranged from 8.6 to 56.6 mg/L, with a mean of 19.9 mg/L. These levels are lower than at upstream sites on both Maxan and Foxy Creeks, decreasing presumably due to dilution and precipitation. Levels remained higher than at the headwater Foxy Creek site 0400763, indicating that presumably effects of treated mine drainage extend as far as Bulkley Lake. Lake concentrations were less than the 100 mg/L aquatic life criterion (Nijman, 1993) and not of concern.

Levels of dissolved aluminum were low, ranging from less than the 0.02 mg/L detection limit to a maximum of 0.09 mg/L with a mean of 0.05 mg/L. These few data indicate concentrations were less than both the aquatic life and drinking water criteria of 0.1 and 0.2 mg/L maximum dissolved aluminum, respectively (Butcher, 1988). Levels of total aluminum ranged to a maximum of 0.57 mg/L with a mean of 0.23 mg/L and all samples were below the 5 mg/L maximum total aluminum criterion for wildlife (Butcher, 1988). Aluminum concentrations are therefore not a concern in Bulkley Lake.

Total cadmium levels ranged from less than the 0.5 µg/L detection limit to a maximum of 0.7 µg/L. Only this maximum value exceeded the detection limit. The high detection limit used in the cadmium analysis precludes comparison with the aquatic life criteria (0.2 µg/L for hardness of less than 60 mg/L (CCREM, 1987)). Therefore, samples must be analyzed using a lower detection limit to determine if cadmium concentrations are a concern.

Though only limited data exists, total copper levels appear lower in Bulkley Lake than at upstream sites monitored in Maxan and Foxy Creeks. Levels ranged from less than the 1 µg/L detection limit to a maximum of 5 µg/L. At a mean hardness concentration of 51.9 (calculated from calcium and magnesium concentrations), the 30-day average of 2 µg/L (Singleton, 1987) was exceeded in seven of the 12 samples. The maximum concentration of 5 µg/L barely exceeded the maximum criterion of 4.9 µg/L (Singleton, 1987). Considering that copper mineralization in the watershed appears to result in background levels in the headwaters exceeding the criterion, the slightly elevated levels recorded in Bulkley Lake are not considered a problem.

Levels of total iron ranged from 0.08 to 2.80 mg/L, with 8 of the 12 samples exceeding the drinking water and aquatic life maximum criterion of 0.3 mg/L (Health and Welfare Canada, 1989; CCREM, 1987). Elevated levels of total iron have been described upstream in Foxy Creek, and were usually associated with elevated levels of suspended sediment and therefore not a problem. This is similarly the case in Bulkley Lake: for example, the 2.8 mg/L total iron concentration on Sept. 23, 1987 corresponded to a measurement of 13 mg/L suspended sediment. Iron concentrations are not considered to be a concern in Bulkley Lake.

Manganese levels in Bulkley Lake were surprisingly high, ranging from <0.01 to 2.07 mg/L for the dissolved fraction with a mean of 0.57 mg/L. Total manganese ranged from 0.02 to 2.33 mg/L with a mean of 0.65 mg/L. Examination of these data, however, show that it is only in the samples collected near the bottom (from 12 or 13m) that levels exceeded the drinking water and aquatic life criteria of 0.05 mg/L and 0.1-1.0 mg/L, respectively (Health and Welfare Canada, 1989; American Fisheries Society, 1979). As levels of manganese in samples collected near the surface of the lake were at or near the 0.01 mg/L detection limit, these samples collected near the bottom must be reflecting high concentrations in sediment and are therefore of no concern.

All 12 sample analyses for nickel (dissolved and total) were below the 0.05 mg/L detection limit. This detection limit was too high to compare to the aquatic life criterion of 0.025 mg/L at a hardness of ≤50 mg/L (CCREM, 1987). The 0.05 mg/L detection limit masks any samples that exceeded this concentration. Samples should be collected and analyzed with a detection limit low enough to determine if the aquatic life criterion is being met.

Excluding the 1985 data which was analyzed with a high detection limit of 100 µg/L, levels of total lead ranged from 1 to 5 µg/L. Assuming an average hardness of 50 mg/L, the water quality criterion for the protection of freshwater aquatic life is 5 µg/L for a 30-day average total lead and

34 µg/L maximum concentration (Nagpal, 1987). Therefore, lead concentrations are not a concern at Bulkley Lake.

Levels of zinc were generally low. All but one sample of dissolved zinc were below the 5 µg/L detection limit, with the single measurable concentration of 6 µg/L. Two of 12 samples had levels of total zinc above this detection limit: these were 11 µg/L (from a near surface sample) and 30 µg/L (from a near bottom sample). Neither of these sample concentrations exceeded the 30 µg/L tentative maximum total zinc aquatic life criterion (CCREM, 1987).

7.2 Buck Creek Drainage

7.2.1 Bessemer Creek Site 0700081 At Siltcheck

The location of Site 0700081 is indicated in Figures 2 and 3, with the data summarized in Table 7.2.1. Bessemer Creek is utilized for initial dilution of treated discharges from the 'polishing pond' to the Buck Creek side of drainage of the Equity mine operation. There were no uses designated for Bessemer Creek (see Section 6) and therefore no water quality objectives are proposed for this waterway. Consequently the water quality data for Bessemer Creek will not be discussed specifically, except in relation to its contribution to specific variables found in high concentrations in Buck Creek.

7.2.2 Upper Buck Creek Site 0400765 (u/s Bessemer Creek) and Lower Buck Creek Site 0400766 (at Inlet to Goosly Lake)

The locations of Sites 0400765 and 0400766 are indicated in Figures 2 and 3, with the data summarized in Table 7.2.2.

The pH at background Site 0400765 varied from 6.2 to 8.0, with a mean of 7.3. An extremely low value occurred at both this site and at Site 0400766 downstream of the treated mine discharge to Bessemer Creek water on July 4, 1989. The pH on this date was <1.0 at both sites, whereas inflowing Bessemer Creek water (sampled at Site 0700081) had a pH of 6.2. A difference in pH of this magnitude indicates either a recording or instrument error. Of the 267 pH measurements collected between 1980 and 1995 at Site 0400765, only one value (the minimum value of 6.2) fell below the criteria range protective of both drinking water and aquatic life of 6.5 to 8.5 and 6.5 to 9.0, respectively (McKean and Nagpal, 1991). The pH at Site 0400766 downstream of treated discharge inflows had a slightly broader range of pH, ranging from 6.1 to 8.5 with a mean of 7.2 (when the <1 value is ignored). Again, these downstream levels were generally within both aquatic life and drinking water criteria, with only 5 of 259 samples less than the lower limit of 6.5 set for both uses (ranging from 6.13 to 6.41). All low pH values occurred before 1983, and therefore before any discharge of treated drainage from the mine site occurred. On only two of these occasions were paired Bessemer Creek data available; the pH was similarly low in Bessemer Creek at these times (values of 4.4 and 5.38), which could explain slight reductions in pH from the background Site 0400765 at the site downstream of the Bessemer Creek inflow. It is possible that some undetected acid drainage was flowing to Bessemer Creek before collection and treatment of these drainages began. The impacts of inflowing Bessemer Creek water at least on the dates sampled appear to have been minor. As all recently measured values fall within the criteria ranges, it does not appear that pH is a concern at this site.

Levels of suspended solids increased from the ambient site to the site downstream of the Bessemer Creek inflow to Buck Creek. Values at the upstream site ranged from <0.5 to 26 mg/L at Site 0400765 with a mean of 3.9 mg/L and from <0.5 to 83 mg/L at Site 0400766 with a mean of 5.7 mg/L. For example, the maximum level recorded at downstream Site 0400766 (83 mg/L) was much higher than the concentration measured upstream at Site 0400765 (22 mg/L). This was probably due in the most part to the Bessemer Creek inflow, as a concentration of 388 mg/L was measured at Site 0700081 on this date. As it appears that effluent from the mine can have a significant effect on suspended solids concentrations, an objective is proposed for this characteristic at Site 0400766. The objective for suspended solides states that <u>the maximum incremental addition to background levels when the background concentration is ≤100 mg/L is 10 mg/L</u>.

Background alkalinity at Site 0400765 ranged from 20.9 to 106 mg/L, with a mean of 62.8 mg/L. There was a similar range of levels downstream at Site 0400766, from 20.3 to 104 mg/L, and a similar mean of 61.3 mg/L. Levels of alkalinity in Bessemer Creek water was also similar (mean of 53.3), and did not affect Buck Creek levels during discharge periods to a measurable degree. This contrasts to the Foxy Creek side of the Equity mine drainage, where alkalinity levels downstream of the discharge were noticeably higher, probably reflecting the addition of lime neutralized effluents. The levels of alkalinity measured at Sites 0400765 and 0400766 indicate that Buck Creek has low sensitivity to acidic inputs due to the buffering capacity from these relatively high alkalinity levels (Swain, 1987).

Cyanidation was removed from the metals extraction process and no cyanide data are available since 1989. All concentrations measured prior to this date were below the detection limit (0.005 mg/L).

Nitrate/nitrite values ranged from <0.02 to 0.54 mg/L, with a median of <0.02 mg/L at the upstream site, and from <0.02 mg/L to 1.78 mg/L with a mean of 0.20 mg/L at the downstream site. Aquatic life criteria for dissolved nitrate/nitrite levels are a maximum of 200 mg/L and a 30-day average of ≤40 mg/L, while the drinking water criterion is a maximum of 10 mg/L (Nordin and Pommen, 1986). As levels at both sites are well below these criteria, it does not appear that nitrogen levels are a concern in Buck Creek.

The aquatic life criteria for sulphate is a maximum of 100 mg/L dissolved sulphate (Nijman, 1993). Levels in Buck Creek Site 0400766 downstream of Bessemer Creek ranged from 7.5 to 211 mg/L, exceeding this criterion for dissolved sulphate in 2 of 24 samples with maximum concentrations of 200 and 211 mg/L. These values, as well as the 102 mg/L sulphate concentration measured in Bessemer Creek on May 8, 1984, are suspiciously high since treated acid mine drainage was not being discharged to Bessemer Creek on any of these occasions according to Equity Mines discharge (1985-1994). Levels measured at the three monitoring sites on the dates when the maximum values were recorded are as follows:

Date	0400765 Buck (Control-u/s)	0700081 Bessemer	0400766 Buck d/s
May 8, 1984	4.6 mg/L	102 mg/L	211 mg/L
August 26, 1991	2.8 mg/L	(NA)	200 mg/L

Since effluent was not being discharged when these large increases occurred, it is unclear what caused these high concentrations. In order to protect aquatic life from these anomalistically high values, an objective for dissolved sulphate concentrations in Buck Creek at Site 0400766 is therefore proposed: <u>the maximum dissolved sulphate concentration should not exceed 100 mg/L in any discrete sample.</u>

Background levels of dissolved aluminum measured at Site 0400765 ranged from <0.005 to 0.49 mg/L, with a mean of 0.09 mg/L. These concentrations are relatively high, exceeding the 0.05 mg/L 30-day average criterion in 89 of 219 samples (41%) and exceeding the 0.1 mg/L maximum criterion in 62 of the 219 samples (28%)(Butcher, 1988). Since Bessemer Creek had considerably higher dissolved aluminum levels than at the upstream Buck Creek site (mean concentration 0.13 mg/L, maximum concentration 2.53 mg/L), the Buck Creek site downstream of the inflow would be expected to have higher levels than at the ambient site. Levels at Site 0400766 do in fact have a higher maximum than at the background site (0.63 mg/L compared to 0.49 mg/L), but a lower mean of 0.06 mg/L. Only 66 of 180 samples collected at Site 0400766 exceeded the 0.05 mg/L 30-day average criterion (37%) and 40 of 180 exceeded the maximum criterion of 0.1 mg/L (22%). Levels of dissolved aluminum in Bessemer Creek during periods of treated acid mine drainage discharge are quite low, however, showing good historical control of aluminum levels by the permitee in the discharge from the treated mine drainage 'polishing pond'. These levels vary from 0.02-0.37 mg/L over the period of record, so changes in aluminum in Buck Creek from the addition of treated acid mine drainage would not be expected to be large when discharge is occurring. The highest levels of dissolved aluminum in Bessemer Creek of 1.53 and 2.53 mg/L actually occurred when there was no discharge of treated mine drainage according to the discharge records (April 9, 1984 and May 16, 1988). Since the mean concentration of dissolved aluminum measured downstream of the effluent discharge from

Bessemer Creek is actually lower than at the ambient site, and concentrations exceeding the criteria are due to high ambient levels, no objective is proposed for aluminum in Buck Creek.

The working drinking water criterion for antimony is 0.006 mg/L maximum total (Health and Welfare Canada, 1983). Levels of total antimony in Bessemer Creek ranged from <0.0002 to 0.32 mg/L, with a mean of 0.032 mg/L. It is notable that the higher levels of antimony measured in Bessemer Creek occurred outside the discharge periods of treated acid mine drainage. Levels of antimony in Buck Creek, however, were generally low, with median concentrations of <0.005 mg/L at both sites. The vast majority of samples had concentrations below detection limits (ranging from <0.0001 to <0.005 mg/L): 92% of samples at Site 0400765 and 77% of samples at the downstream site. Two exceptions to these low values were as follows:

(i) The 0.140 mg/L maximum dissolved antimony concentration occurred at the downstream Buck Creek site (0400766) on May 4, 1982, with a corresponding total antimony level of 0.001 mg/L. This anomaly is further suspect in that the concentration measured at the upstream site (0400765) was below detection (<0.001 mg/L) for both dissolved and total antimony, and concentrations in Bessemer Creek (Site 0700081) were also low (0.001 and 0.083 mg/L for dissolved and total antimony, respectively).

(ii) The maximum concentration of total antimony measured at the upstream site (0400765) of 0.050 mg/L (equal to the maximum criterion) was also suspicious since levels measured on the same date at both the Bessemer Creek (Site 0700081) and downstream site (0400766) were below the 0.001 mg/L detection limit.

Therefore, antimony concentrations do not appear to be a concern in Buck Creek and no objective is proposed.

Total arsenic levels at background Site 0400765 were generally near or below detection limits (which ranged from <0.001 to <0.25 mg/L). The high detection limit of 0.25 mg/L masked levels that might have exceeded the maximum aquatic life criterion of 0.050 mg/L total arsenic

(CCREM, 1987), but was only used for one sample. The highest value actually measured was 0.010 mg/L total arsenic, well below the criterion. A similar range of detection limits were used at Buck Creek Site 0400766, with a maximum measurement of 0.029 mg/L. All data were below the aquatic life criterion. Concentrations at the Bessemer Creek site were also generally low (though detection limits ranged up to 0.3 mg/L), but eight of 320 samples exceeded the 0.05 mg/L aquatic life criterion. The maximum concentration measured was 0.25 mg/L total arsenic. None of these exceedences occurred during treated mine drainage discharge periods, as recorded in the Equity Environmental Reports (1985-1994). Therefore, little impact is expected due to mine effluents, and therefore no objective is recommended for arsenic levels in Buck Creek.

Measurement of cadmium concentrations in Buck Creek to allow comparison with the aquatic life criterion were compromised by detection limits that were generally too high (0.5, 1.0 or 10 µg/L). The criterion for a mean hardness ≤60 mg/L at the lower Buck Creek site is 0.2 µg/L, and increases to 0.8 µg/L when total hardness is between 60 and 120 mg/L (quite often the case) (CCREM, 1987). Available data suggest that the aquatic life criterion was infrequently exceeded at this site. The highest measured concentration was 20 µg/L on Feb. 22, 1983, before treated mine drainage was discharged to Bessemer Creek. The concentration measured at the upstream Site 0400765 on this date was <1 µg/L, and the level at the Bessemer Creek Site 0700081 was 3 µg/L, which casts some doubt on the reliability of this maximum value. Similar high detection limits compromised the data at the Bessemer Creek Site 0700081, which ranged from below the various detection limits to a maximum of 86 µg/L. The second highest level at this site was 6.4 µg/L, measured during a period of no treated drainage discharge. Since cadmium concentrations are higher in the Bessemer Creek, presumably due to effluent discharges, and as levels occasionally exceed the aquatic life criterion, and objective is proposed for cadmium concentrations in Buck Creek. The objective states that concentrations of total cadmium should not exceed 0.2 µg/L when hardness is ≤60 mg/L, and should not exceed 0.8 µg/L when total hardness is between 60 and 120 mg/L.

Total copper levels at Site 0400766 downstream of treated discharges varied from less than the 0.001 mg/L detection limit to a maximum of 0.1 mg/L, with a mean level of 0.006 mg/L. Ambient copper levels at Site 0400765 were also relatively high, ranging from <0.001 to 0.083 mg/L with a mean of 0.005 mg/L, presumably due to copper mineralization in the watershed. These background levels frequently exceeded the aquatic life criterion, and may be exacerbated downstream by elevated copper levels in the treated or untreated mine effluent which flows through Bessemer Creek. The copper levels in Bessemer Creek measured at Site 0700081 had a maximum value of 7.71 mg/L total copper and 7.41 mg/L dissolved copper. Although these maximums appear very high, both occurred on March 28, 1982 when freshet flows carried almost 40 mg/L suspended solids. The mean total copper concentration in Bessemer Creek was 0.08 mg/L. The maximum total copper level at the downstream Buck Creek Site 0400766 of 0.1 mg/L far exceeded the maximum aquatic life criterion of 0.006 mg/L (based on the mean hardness of 40 mg/L). This elevated downstream level occurred when background levels were only 0.003 mg/L total copper and levels in Bessemer Creek (at Site 0700081) were very high at 0.28 mg/L. Although the maximum concentration at Site 0400766 occurred on September 6, 1983, before the discharge of treated mine drainages began, it presumably reflects seepage of untreated acid mine drainage to Bessemer Creek. Since there appear to be high levels of copper reaching Bessemer Creek due to mine effluents, an objective is set for the lower Buck Creek site. The objective states that concentrations of total copper measured on any one day at Site 0400766 should not exceed 110% of concentrations measured at Site 0400765 on the same day, and concentrations of total copper should not be significantly higher here than at the upstream ambient site using a 2-tailed t-test and a minimum of five samples collected in a 30-day period.

The criterion of 0.3 mg/L for total iron (CCREM, 1987) was frequently exceeded at all three sites, with a maximum of 3.01 mg/L at background Site 0400765 (mean = 0.71 mg/L), 5.87 mg/L at downstream Site 0400766 (mean = 0.94 mg/L), and 52.3 mg/L at Bessemer Creek Site 0700081 (mean = 1.2 mg/L). High total iron concentrations are frequently due to elevated levels of suspended sediments in high water flows, in which case the iron associated with this particulate matter is not harmful to aquatic organisms and therefore is not a concern. At the upper Buck Creek and Bessemer Creek sites, most of the levels exceeding 1 mg/L total iron were during the April to July freshet period. Therefore, iron concentrations are probably not a concern and no objective is proposed.

The median concentration of total lead at Site 0400766 was below detection limits (which ranged from <0.001 to <0.1 mg/L) and the maximum recorded value was 0.084 mg/L. The second-highest concentration was only 0.01 mg/L. If the average hardness level of about 40 mg/L is used, the water quality maximum criterion to protect aquatic life is 0.025 mg/L total lead. This criterion was exceeded only once, by the maximum value recorded at this site. Levels at the background Site 0400765 were lower, with the majority below detection limits (ranging from <0.001 to <0.1 mg/L) and a maximum recorded concentration of 0.011 mg/L. This value is well below the criterion of 0.025 mg/L at a mean hardness of about 40 mg/L. The median concentration measured at the Bessemer Creek site was below detection limits as well (which ranged from <0.001 to <0.1 mg/L). Therefore, lead concentrations do not appear to be a concern in Buck Creek.

Some data on mercury levels in water were collected from 1980 to 1983 at both background and downstream sites. Due to the many sources of mercury contamination as well as the problem of accurately measuring mercury levels in water (see Pommen, 1994), these data will not be discussed. Mercury in biological tissue is the key indicator of mercury contamination, and will be discussed in Section 8 of this report, Fish Tissue Monitoring.

Few samples were analyzed for manganese concentrations in Buck Creek. Presumably the levels measured during the pre-mining and early operational stages were too low to be of concern. The American Fisheries Society (1979) suggests a range of 0.1 to 1.0 mg/L total manganese (rather than a single number) to protect fresh water aquatic life due to limited and variable data. Levels of total manganese at Site 0400766 ranged from 0.04-0.38 mg/L with a mean of 0.14 mg/L, and five of eight samples fell within the criterion range. Background levels of manganese at Site 0400765 were lower, ranging from 0.02 to 0.23 mg/L total manganese with a mean of 0.1 mg/L. Increases to these background levels were apparent when samples were collected downstream on the same date, presumed due to manganese levels from Bessemer Creek. Maximum concentrations measured at Bessemer Creek Site 0700081 were 1.9 and 1.97 mg/L dissolved and total manganese, respectively. It does not appear that manganese concentrations in effluent raise levels in Bessemer Creek sufficiently to seriously affect concentrations in Buck Creek, so no objective is proposed.

Nickel levels in Buck Creek were below detection limits (ranging from <0.01 to <0.05 mg/L) for all samples. With a mean hardness concentration at Sites 0400765 and 0400766 of about 40 mg/L, the criterion for the protection of fresh water aquatic life is 0.025 mg/L (CCREM, 1987). The majority of samples were analyzed at the 0.05 mg/L detection limit, so values exceeding the criterion may have been masked. Nickel concentrations were detected in Bessemer Creek to a maximum of 0.14 mg/L for both dissolved and total nickel, but the majority of the samples collected at this site had concentrations below detectable limits. It does not appear that nickel concentrations are a concern in Buck Creek, and no objective is proposed.

Levels of total zinc at downstream Site 0400766 ranged from below the 0.003 mg/L detection limit to a maximum of 0.14 mg/L with a mean of 0.013 mg/L. The aquatic life criterion of 0.03 mg/L maximum total zinc (CCREM, 1987) was exceeded in 17 of 262 samples (6%). Table 7.2.2 shows that the maximum dissolved zinc concentration (0.38 mg/L) was higher than the maximum concentration of total zinc (0.14 mg/L). Both the maximum and second highest level of dissolved zinc (0.14 mg/L) appear to be anomalies since these values exceeded the total zinc levels measured at the same site at the same time. Removal of these values results in a maximum dissolved zinc level of 0.070 mg/L. Ambient levels at Site 0400765 were lower, ranging from <0.005 to 0.18 mg/L total zinc with a mean of 0.01 mg/L. Levels of total zinc at this site exceeded the 0.03 mg/L aquatic life criterion in 10 of 275 samples (4%). As expected, some of the elevated downstream levels are due to the influences of inflowing Bessemer Creek, with levels measured at Site 0700081 as high as 4.15 and 4.22 mg/L dissolved and total zinc, respectively. Interestingly enough, eight of nine occasions when total zinc exceeded 1 mg/L in Bessemer Creek occurred prior to the discharge of treated acid mine drainage in 1985. This presumably indicates the effects of untreated acid mine drainage on Bessemer Creek. Determining the impact of these nine instances of elevated total zinc levels in Bessemer Creek on downstream Buck Creek water quality is made difficult due to: i) the high detection limit on one occasion downstream in Buck Creek (0.03 mg/L), ii) the lack of downstream or background data for the same date (in three instances), and anomalous downstream levels lower than ambient concentrations (on two occasions). As the water quality criterion was seldom exceeded for zinc concentrations in Buck Creek, no objective is proposed.

7.2.3 Site 0700084 Goosly Lake at Center

As mentioned in Section 3, Goosly Lake supports a small recreational trout fishery, but more importantly flows into lower Buck Creek which is a major spawning and rearing area for salmon, steelhead and resident trout. The location of Goosly Lake is indicated on Figures 1 to 3. Lower Buck Creek is also used as a domestic water supply by residents of Buck Flats near Houston. The Ministry of Environment, Lands and Parks monitored Goosly Lake until 1993, with concerns that mining-induced impacts to Goosly Lake might affect downstream water quality. A report was written by Wilkes and McLean (1987) and updated by Remington (1989) in which the water quality and biology of Goosly Lake was assessed, and water quality objectives and a monitoring program were established. This report section will assess existing water quality data, summarized in Table 7.2.3.

The pH of Goosly Lake measured at Site 0700084 ranged from 6.5 to 7.7, with a mean of 7.2. All values fall within the range suitable for both drinking water (6.5 to 8.5) and for the protection of fresh water aquatic life (6.5 to 9.0) (McKean and Nagpal, 1991). Therefore, pH is not a concern.

Alkalinity in Goosly Lake ranged from 33.8 to 45.9 mg/L, with a mean of 38.4 mg/L. Alkalinity concentrations exceeding 20 mg/L, such as measured at this site, have a low sensitivity to acid inputs due to their buffering capacity (Swain, 1987).

Chlorophyll a concentrations ranged from 1.9 to 6.5 µg/L, with a mean level of 4.3 µg/L. These concentrations occasionally exceed the 1 to 3.5 µg/L range recommended as a summer average in lakes for the protection of fresh water aquatic life (Nordin, 1985). There is a clear relationship between phosphorus and algal biomass (mean growing season chlorophyll a concentrations), and phosphorus concentration provides the best indicator of actual or potential problems. The phosphorus criterion recommended to protect the various uses in BC lakes and the relevant ambient data for Goosly Lake are discussed below. The criteria are in terms of total phosphorus, measured at spring overturn for lakes with residence time of greater than 6 months; the residence time of Goosly Lake is 1.1 years (Wilkes and McLean, 1987).

(a) Recreation and Aesthetics: The BC criterion is a maximum of 10 μg/L total phosphorus measured at spring overturn, to ensure high water clarity by limiting algal growth (Nordin, 1985). The mean water column total phosphorus levels at spring overturn ranged from 20-30 μg/L, consistently exceeding this criterion over the period of record 1982 to 1991.

(b) Aquatic Life: A range of from 5-15 μg/L total phosphorus at spring overturn is the recommended BC criterion to protect aquatic life in lakes (Nordin, 1985). As described above, this criterion was consistently exceeded in the ambient data over the 1982 to 1991 period of record, ranging from 20-30 μg/L.

In order to protect both fresh water aquatic life and the recreation and aesthetics uses of Goosly Lake, an objective for total phosphorus is proposed. The objective states that the mean concentration of total phosphorus measured at spring overturn should not exceed 10 μg/L. This mean value, equal to the recreation and aesthetics criterion, should also protect aquatic life (which may have a more stringent criterion), since ambient levels are fairly high in Goosly Lake and aquatic life would be adapted to these levels.

Hardness levels in Goosly Lake ranged from 43.2 to 52.0 mg/L, with a mean of 46.0 mg/L between 1982 and 1984. These data show Goosly Lake water to be quite soft, with levels less than the 80 to 100 mg/L considered optimal for drinking water use (Health and Welfare Canada, 1989). As only five measurements were collected, the resulting lack of hardness data make the determination of some metals criteria (those dependent on hardness) difficult.

Ammonia levels in Goosly Lake at Site 0700084 were quite low, ranging from <0.005 to 0.035 mg/L, with a mean of 0.008 mg/L. Levels were less than both 30-day average and maximum BC criteria, as detailed in Nordin and Pommen (1986), and therefore ammonia-nitrogen concentrations are not considered to be a problem.

Total nitrate/nitrite concentrations ranged from <0.02 to 0.22 mg/L, with a mean of 0.07 mg/L. The thirty day average and maximum aquatic life criteria for nitrate are 40 mg/L and 200 mg/L, respectively, so concentrations were well below the criterion and therefore not of concern.

Sulphate is the primary ion of concern in cases of acid mine drainage. Typical untreated AMD from Equity has a sulphate content between 9 000 mg/L and 15 000 mg/L (Equity Silver Mines Limited Fact Sheet, 1992). After liming at the treatment plant, the sulphate level in the discharge to Bessemer Creek is significantly reduced, as evidenced by the 1987 measurement of 1582 mg/L by Remington (1989). Dissolved sulphate levels in Goosly Lake over the 1982-1991 period of record ranged from 8.8 to 63.1 mg/L, with a mean of 30.4 mg/L. These levels all fall below the working criterion of 100 mg/L maximum dissolved sulphate to protect aquatic life (Nijman, 1993). As observed by Wilkes and McLean (1987) and confirmed by Remington (1989), there has been an increasing trend in sulphate concentrations in Goosly Lake since the discharge of treated acid mine drainage began in 1985, with the first recorded increase actually following an acid spill on the Equity property in late 1981. The following table shows that the mean annual dissolved sulphate levels in Goosly Lake as measured at Site 0700084 have increased from 15.5 mg/L in 1982 to 60.3 mg/L in 1991.

	Year									
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
SO_4 mg/L	15.5	14.2	13.1	16.9	26.3	39.6	32.5	33.0	48.9	60.3

Although there were no discharges of treated AMD in either 1988 or 1991, the table above shows no consistent reductions in Goosly Lake levels in those two years. Since levels of sulphate have increased greatly over the period of record, an objective is proposed for the concentration of this ion in Goosly Lake. Wilkes and McLean (1987) previously recommended an objective of 30 mg/L in order to "draw attention to possible changes in the lake." The objective recommended in this report is the provincial criterion of 100 mg/L for total sulphate to protect aquatic life.

Levels of dissolved aluminum ranged from <0.02 to 0.12 mg/L, with a mean of 0.06 mg/L. All values were below the drinking water criterion of 0.2 mg/L maximum dissolved aluminum (Butcher, 1988). Only 5 of 46 sample concentrations marginally exceeded the 0.10 mg/L maximum dissolved aluminum aquatic life criterion, based on a pH ≥6.5 as found in Goosly Lake samples: these values ranged from 0.11-0.12 mg/L. Therefore, aluminum concentrations do not appear to be a concern in Goosly Lake and no objective is proposed.

Total arsenic levels were generally close to or below the 1 µg/L detection limit, with the exception of most pre-1984 data where levels were masked by a high detection limit of 25 µg/L. Excluding the high detection limit data, the maximum measured value was 7 µg/L, less than both the drinking water and aquatic life criteria of 25 µg/L (Health and Welfare Canada, 1989) and 50 µg/L (CCREM, 1987) total arsenic, respectively. Therefore, arsenic levels are of no concern.

Although none of the samples analyzed for cadmium had measurable concentrations, this data is compromised by high detection limits of between 5 and 10 µg/L which exceeds the maximum aquatic life criterion of 0.2 µg/L total cadmium when hardness is ≤60 mg/L (CCREM, 1987). Cadmium concentrations are probably not a concern in Goosly Lake however, and so no objective is recommended.

Similarly high detection limits for chromium of 5 and 10 µg/L makes a comparison of these data with aquatic life criteria difficult. Four of 56 samples had concentrations exceeding both detection limits and the 2 µg/L maximum for phyto/zooplankton (CCREM, 1987), ranging between 10 and 20 µg/L. All values were below or equal to the 20 µg/L maximum criterion forfish and the 50 μg/L criterion for the protection of drinking water (1987). Chromium concentrations are not considered a concern in Goosly Lake and no objective is proposed.

Levels of total copper ranged from less than the detection limit (which were between 1 and 10 μg/L) to a maximum of 20 μg/L, with a mean of 5 μg/L. Hardness data collected to 1984 from Goosly Lake show a maximum value of 52 mg/L (as $CaCO_3$), while hardness values calculated from concentrations of magnesium and calcium yield a range of values between 40.8 and 100.6 with a mean of 70.9 mg/L. At this mean hardness, the 30-day average criterion is 3 μg/L, and the maximum criterion is 8.6 μg/L (Singleton, 1987). The maximum criterion was exceeded by 11 of 66 values, but values were below ambient levels measured at Site 0400765. Therefore, no objective is proposed for total copper concentrations at this site.

Total iron concentrations measured at this site on Goosly Lake ranged from 0.06 to 4.42 mg/L, with a mean concentration of 0.37 mg/L. Although the range of data appears broad, the maximum value is probably an anomaly. It was sampled at a depth of 19 m on May 14, 1990, and the corresponding dissolved iron concentration was only 0.21 mg/L, which suggests that resuspension of sediments may be occurring. However, none of the other metals measured in this sample were similarly elevated. The second-highest value of total iron was 0.59 mg/L collected at a depth of 17 m with a corresponding concentration of 0.45 mg/L dissolved iron. Levels of dissolved iron at Goosly Lake Site 0700084 ranged from 0.01 to 0.58 mg/L, with a mean level of 0.17 mg/L. The majority of the samples had a concentration below the criterion of 0.3 mg/L maximum total iron for the protection of freshwater aquatic life (CCREM, 1987), and therefore iron concentrations are not considered a concern in Goosly Lake.

Levels of total lead ranged from less than the 1 μg/L detection limit (prior to 1985, the detection limit was <10 μg/L) to a maximum of 8 μg/L. These levels of total lead were less than the maximum aquatic life criteria (10 μg/L when hardness exceeds 30 mg/L $CaCO_3$), and the majority of values were below the 30-day average criterion of 5 μg/L at an average hardness of 70 mg/L. Therefore, it does not appear that lead concentrations are sufficiently elevated to require an objective.

A guideline ranging from 0.1 to 1.0 mg/L total manganese has been proposed for the protection of freshwater aquatic life (American Fisheries Society, 1979). Dissolved manganese as well as precipitates are the important forms, as levels of total manganese can be high due to the manganese content of suspended sediment. Levels of dissolved manganese at Goosly Lake Site 0700084 ranged from <0.01 to 1.65 mg/L, with a mean level of 0.16 mg/L. Eleven of 56 samples exceeded the lower limit of the range (0.1 mg/L), and two of the 56 samples exceeded the 1.0 mg/L criterion. The two highest concentrations of dissolved manganese were 1.65 and 1.46 mg/L, taken in September and October of 1989, respectively; and could be indicative of release from the sediments under low oxygen conditions. All the sample concentrations exceeding both the 0.1 and 1.0 mg/L criteria occurred in the deep sample, collected between 16 and 19m depth. No objective is recommended for manganese.

All the data for the remaining variables listed in Table 7.2.3 were below the relevant criteria and will not be discussed.

7.2.4 Buck Creek Sites below Goosly Lake: E207067 at Second Bridge and E207066 at Houston

The locations of these two sites on lower Buck Creek are indicated on Figure 1. The sites were sampled on four occasions in 1987, including three replicate samples on each of July 16 and September 16, and one sample on each of August 6 and October 19. The few data (Table 7.2.4) show levels of variables at these two downstream sites to be within the concentration range found in Goosly Lake, with the following exceptions:

i) pH: Sites E207067 and E207066 had higher maximum pH than in Goosly Lake; 8.1 and 8.5 in comparison to 7.7, respectively. These levels were still within both aquatic life and drinking water criteria.
ii) Alkalinity: Higher maximum alkalinity levels were documented at these sites (52.4 and 62.2 mg/L at sites E207067 and E207066, respectively), in comparison to the maximum

of 45.9 mg/L in Goosly Lake. These higher levels confer greater buffering capacity to acidic inputs.

iii) Sulphate: Levels of dissolved sulphate were lower at these sites than in Goosly Lake, with maximums of 7.4 and 5.1 mg/L at Sites E207067 and E207066, respectively, compared to the maximum concentration of 63.1 mg/L measured in Goosly Lake.

iv) Copper: One total copper concentration (0.03 mg/L at Site E207066) exceeded the 0.02 mg/L maximum recorded in Goosly Lake. This value is considerably higher than the 0.0075 mg/L maximum criterion recommended at the mean hardness of about 60 mg/L calculated for Site E207066, but lower than the maximum concentration of 0.08 mg/L maximum recorded at the Buck Creek ambient site (0400765).

v) Zinc: One of the sixteen samples collected at the two downstream sites had a total zinc concentration exceeding the maximum level of 0.02 mg/L measured in Goosly Lake; this was 0.06 mg/L at Site E207067. This was the only sample at any of the sites downstream from Site 0400766 to exceed the 0.03 mg/L maximum tentative total zinc aquatic life criterion set by the CCREM (1987), while samples from Buck Creek above Goosly Lake frequently exceeded this criterion.

7.2.5 Environment Canada Water Quality Data, Buck Creek System

Environment Canada conducted monitoring in the Buck Creek system between 1987 and 1990 to determine the impact of the Equity Silver mine's discharge on Goosly Lake. Their water quality monitoring data is discussed below.

(a) Godin (1988) measured water quality in the Buck Creek system in May and June of 1987 (Table 7.2.5.1). Data were collected at sites equivalent to Ministry of Environment Buck Creek Sites 0400765 and 0400766, Bessemer Creek Site 0700081, and Goosly Lake Site 0700084. In addition, another site was sampled in Goosly Lake 800 m below the inlet, as well as three additional Buck Creek sites: 500 m upstream of Site 0400766 (below Bessemer Creek), 100m downstream of Goosly Lake, and 12 km upstream of Houston (Buck Flats, between Ministry of Environment Sites E207066 and E207067, at the mouth of

Bob Creek: see Figure 1). All data were within the range of concentrations previously discussed for the Buck Creek system, including Goosly Lake, that were collected by both the permittee and the Ministry of Environment and summarized in Tables 7.2.1, 7.2.2, 7.2.3, and 7.2.4. Hardness data were not collected as part of this study, making calculations for the appropriate criteria for cadmium, copper and lead difficult.

(b) Godin (1992) conducted a comprehensive study in 1988, 1989 and 1990 for Environment Canada, again to determine the impact of the Equity silver mine discharges on Goosly Lake. According to the treated discharge records provided by the permittee (Equity Silver Mines Environmental Reports, 1985-1994), however, the Environment Canada samples collected in 1988 (June 22-23) and 1989 (June 30) occurred during periods of no treated water discharges; only the 1990 samples (June 15-17) were collected when treated acid mine drainage was being discharged to Buck Creek via Bessemer Creek. This would affect only the water quality data, and not the other aspects of the sampling program which included sediments and biota. The water quality data from the Buck Creek sites (equivalent to Ministry of Environment Sites 0400765 and 0400766), Bessemer Creek site (equivalent to MoE Site 0700081), and Goosly Lake site (located at MoE Site 0700084) as well as an additional site at the lake outlet, are summarized in Tables 7.2.5.2, 7.2.5.3, and 7.2.5.4 for data from the years 1988, 1989, and 1990, respectively. Some data collected at additional sites sampled during the study in locations other than the Ministry of Environment sites previously discussed have not been summarized for this report. As reported for the 1987 Environment Canada study, these data were within the range of concentrations measured for the MoE data collected in the Buck Creek/Goosly Lake system. Some of the variables at the sites downstream of Bessemer Creek showed increases over levels at the background Site 0400765, both when the treated discharges were occurring as well as when they were not. This suggests background levels of some variables in Bessemer Creek were higher than in Buck Creek, or possibly that untreated acid mine drainage was impacting Bessemer Creek. The 1988-1990 Environment Canada study also lacked hardness data for relevant criteria calculations for cadmium, copper and lead.

Of particular interest were the low detection limits used for some of the metals analyzed during these studies which resulted in more useful data for the following:

i) Cadmium was measured with a 0.1 µg/L detection limit for the June 20, 1987 sampling, and for all samples collected between 1988 and 1990, compared to the detection limit of 5 and 10 µg/L used for the MoE data. Environment Canada data for total cadmium from all Buck Creek and Goosly Lake sites were generally low, ranging from below the detection limit (<0.1 µg/L) to a maximum of 0.2 µg/L. These levels are below the water quality criterion for the protection of aquatic life, regardless of the hardness concentration (CCREM, 1987). These data were collected from both periods of treated mine drainage discharge and from non-discharge periods. Total cadmium data collected by Environment Canada from an intensive sampling program in Goosly Lake in May and June of 1988 (eight sites and three depths; data not tabulated for this report) had levels ranging from <0.1 to 2.8 µg/L, with a mean of 0.3 µg/L. Determining the relevant criterion for these data is difficult without hardness data, but 73% of these values were less than the criterion of 0.2 µg/L maximum for hardness of ≤60 mg/L, and 92% were less than the criterion of 0.8 µg/L maximum total cadmium with a hardness between 60 and 120 mg/L. Based on the few hardness data collected by the Ministry of Environment and the permittee tabulated in this report, concentrations of hardness can fall in either range.

ii) Copper was measured with a 0.5 µg/L detection limit for samples collected between 1987 and 1989 and a 5 µg/L detection limit in 1990. Levels of total copper at sites in Buck Creek above Goosly Lake ranged from 1.4 to 6.9 µg/L. Levels in Goosly Lake itself ranged from 2.9 to 9.4 µg/L. The higher maximum concentration in Goosly Lake may be simply due to the higher sampling frequency (63 values vs. 10 in Buck Creek).

Buck Creek and Goosly Lake waters were characterized by high dissolved organic content ("brown" water), and the binding of metals to organic substrates can in some cases reduce their toxicity (*e.g.*, copper). Environment Canada determined a copper-complexing capacity in the water from upper Buck Creek ranging from 28.6 to 47.9 μg/L in their 1989 study (Godin, 1992). They suggest that because of this high complexing capacity, levels in the Buck Creek system should pose no risk to the aquatic resources. While the maximum concentration of total copper measured by Environment Canada data was only 9.4 μg/L, the Ministry of Environment and permittee data discussed previously had a maximum concentration of 83 μg/L. However, only four samples exceeded the minimum complexing capacity of 28.6 μg/L calculated by Environment Canada. The complexing capacity data suggest copper levels identified by the Ministry of Environment and the permittee may not be a problem in the Buck Creek system. This complexing capacity, however, does not eliminate the need for monitoring for copper of the setting of an objective in waters draining the Equity property, where elevated levels have been documented. Although complexing capacity does render portions of copper unavailable to biota, levels in fish tissue higher than those found in pristine (uncontaminated) BC lakes have been documented in fish sampled from waters draining the Equity property (section 8. Fish Tissue Monitoring). A water quality objective provides a numerical reference point for monitoring permit restricted additions of copper to the aquatic environment.

iii) Lead was measured with a 0.5 μg/L detection limit in 1989 and 1990. Environment Canada data from these years showed low levels of total lead in the Buck Creek system, including Goosly Lake. Levels ranged from below the 0.5 μg/L detection limit to 9.5 μg/L, with 70% of values below detection. The maximum concentration measured by Environment Canada is equal to the criterion maximum permitted for a relatively low hardness level of 20 mg/L, historically often exceeded in the Buck Creek system (i.e., the criterion for Buck Creek would be higher than 9.5 μg/L). These data support the conclusion that lead levels in the Buck Creek system are no cause for concern.

8. FISH TISSUE MONITORING

The following discusses muscle tissue mercury levels in Rainbow trout and Peamouth chub from Goosly Lake collected in 1990, followed by a historical review of muscle tissue metals levels in Rainbow trout from Goosly Lake and Buck and Foxy Creeks between 1982 and 1994. Values are compared with concentrations in Rainbow trout from pristine (uncontaminated) lakes in British Columbia (Rieberger, 1992).

8.1 Mercury in Fish Muscle Tissue, Goosly Lake

Environment Canada collected Rainbow trout and Peamouth chub from Goosly Lake in 1990 for analysis of muscle mercury concentrations (Godin, 1992). Although the data haven't been tabulated in this report, all samples of two to four year old Rainbow trout had wet weight mercury levels less than the 0.5 µg/g maximum acceptable level for human consumption (Nagpal, 1989), ranging from 0.051 to 0.134 µg/g. Peamouth chub (all three year old) had higher muscle mercury levels (generally between 0.021 and 0.464 µg/g), and one sample (0.505 µg/g) approximated the maximum acceptable level. It was suggested that diet contributed to the difference between species, with trout feeding on insects whereas chub feed on zooplankton. Mercury levels in the recreationally important Rainbow trout were not a concern for human consumption.

Other fish tissue samples were collected in 1988 as part of the same study but analyzed for mercury concentrations as dry weight. These samples had a mean muscle mercury content of 0.36 µg/L for Rainbow trout, and 1.68 µg/L for Peamouth chub. Conversion of the 0.5 µg/g wet weight mercury criterion to dry weight, using an assumed 80% moisture content of fish, yields a 0.9 µg/L dry weight mercury criterion equivalent. Concentrations of all Rainbow trout samples were below this criterion, while concentrations in the Peamouth chub muscle tissue exceeded the dry weight mercury criterion in 9 of 11 samples. As mentioned above, the higher muscle mercury content of Peamouth chub versus Rainbow trout is most likely diet related.

8.2 Other Metals in Fish Muscle Tissue

8.2.1 Goosly Lake

Concentrations of various metals were measured in fish collected from Goosly Lake between 1982 and 1994 as part of various studies, and data are summarized in Table 8.2.1. Mean dry weight concentrations are compared with mean levels from British Columbia pristine lakes (converted from wet weights, assuming an 80% moisture content) (Rieberger, 1992). Samples were not compared to the water quality criteria for fish tissue due to the difficulty in comparing dry weight concentrations to the wet weight criterion. Mean muscle levels in Rainbow trout from Goosly Lake appeared slightly higher than in the same species from pristine lakes, most notably for aluminum (up to 5.6 µg/g vs. 2.2 µg/g in pristine lakes), copper (up to 1.9 µg/g vs. 0.7 µg/g) mercury (0.363 vs. 0.16 µg/g) and zinc (maximum of 33.5 vs. 7.7 µg/g). Comparisons are made slightly more difficult by the fact that maximum values are compared to mean values, as well as the high standard deviations of the BC pristine lakes data. Concentrations of metals in Rainbow trout liver tissues showed elevated levels in comparison to pristine lakes data for cadmium (up to 14.8 vs. 0.56 µg/g), copper (up to 257 vs. 92 µg/g) and zinc (up to 172 vs. 51.8 µg/g). Differences between the Goosly Lake and pristine lake fish were more evident in the livers than in muscle tissue.

8.2.2 Buck and Foxy Creeks

The permittees metals data from Rainbow trout muscle sampled from Buck and Foxy Creeks (1982-1994) are summarized in Table 8.2.2.1. Of the parameters analyzed, only mean copper and zinc tissue levels in both creeks exceeded the mean levels for BC pristine lakes; in 42 of 44 samples for copper, and in all 44 samples for zinc. The standard deviations for the BC pristine lakes means was quite large relative to the standard deviations for the Buck and Foxy Creek samples, however.

The permittees metals data from Rainbow trout liver from Buck and Foxy Creeks (1982 - 1994) are summarized in Table 8.2.2.2. Of the parameters analyzed, arsenic (in Buck Creek only), and cadmium, copper and zinc (in both Buck and Foxy Creeks) exceeded the mean level for BC pristine lakes. The cadmium, copper and zinc levels were clearly higher than in pristine lakes, even when taking into account the high standard deviations for the pristine (uncontaminated) lakes. The standard deviations for the Buck and Foxy Creek samples were not reported.

9. SEDIMENT MONITORING

Sediment data have been collected at various times by the permittee, the Ministry of Environment, Lands and Parks, and Environment Canada. These data are not reviewed in this report. Some of these data can be found on the Ministry's SEAM database, as well as in a number of Environment Canada reports (e.g.: Godin, 1988 and 1992). Water quality objectives set in this report have been based on water quality data and fish tissue concentrations.

10. FUTURE MONITORING RECOMMENDATIONS

The following tables summarize the recommended future monitoring schedule in both the Foxy and Buck Creek drainages, complete with the frequency and types of analyses which should occur to minimize the potential for impacts from mining effluents.

a) Foxy Creek Drainage:

Site #	Location	Frequency	Date	N	Parameter
0400763 0400764	Foxy Cr. u/s discharge Foxy Cr. d/s discharge	5 times in 30 days (water)	Mar 1-Nov. 30 when effluent discharged	10	pH, NFR, Sulphate(D), Total Metals (include Ca/Mg), Total Cu (LL), Total Cd (LL), Total Pb (LL), Dissolved Al
0700108	Foxy Cr. below falls	5 times in 30 days (water)	Mar 1-Nov. 30 when effluent discharged	5	pH, Sulphate(D), Total Metals (include Ca/Mg), Total Cu (LL), Total Cd (LL), Total Pb (LL)
		5 fish muscle (once)	Mar 1-Nov. 30 when effluent discharged	5	Hg fish Pb fish (LL)

Note: (LL)= low limit analysis

b) Buck Creek Drainage:

Site #	Location	Frequency	Date	N	Parameter
0400765 0400766 0700081	Buck Cr. u/s Bessemer Buck Cr. d/s Bessemer Bessemer Cr. @ siltcheck	5 times in 30 days (water)	Mar 1-Nov. 30 when effluent discharged	15	pH, NFR, Sulphate(D), Total Metals (incl. Ca/Mg), Total Cu (LL), Total Cd (LL), Total Pb (LL), Dissolved Al
0700084	Goosly Lake @ Center	5 times in 30 days (water) once @ surface, mid-depth & near-bottom	Mar 1-Nov. 30 when effluent discharged once @ spring overturn	5 3	pH, NFR, Sulphate(D), Total Metals (incl. Ca/Mg), Total Cu (LL), Total Cd (LL), Total Pb (LL), Dissolved Al Total P
----	Goosly Lake (general)	5 fish muscle (once)	(open)	5	Hg fish Pb fish (LL)

Note: (LL) = low limit analysis

REFERENCES CITED

Acid Rock Drainage Technical Guide. Prepared for the British Columbia Acid Mine Drainage Task Force by Steffen Robertson and Kirsten (B.C.), in association with Norecol Environmental Consultants and Gormely Process Engineering. 1989.

American Fisheries Society. 1979. A Review of the EPA Red Book: Quality Criteria for Water, April 1979.

Aziz, M., Environmental Coordinator for Equity Silver Mines. Personal Communication to R. Nijman re: Regional Creek Flows. September 18, 1992.

Bailey, L. 1983. Fisheries Input to the Water Quality Section of the Skeena-Nass Strategic Plan. Memorandum to P. Warrington, Water Management Branch, March 17, 1983.

Beak Consultants Ltd., 1976. Sam Goosly Project, Stage II. Detailed Assessment, Prepared for Equity Mining Corporation, Vancouver, B.C.

Bustard and Associates, 1984. Assessment of Benthic Invertebrates and Juvenile Fish Populations in Foxy and Buck Creeks, September 1984.

Butcher, G.A. 1988. Water Quality Criteria for Aluminum. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

Canadian Council of Resource and Environment Ministers, March 1987. Canadian Water Quality Guidelines.

Clark, M. 1994 (Feb. 4, 1994). Manager, Ducks Unlimited (Prince George), Personal Communication, Waterfowl Use in Bulkley River Headwaters.

Envirocon Ltd., 1981. Kemano Completion. Hydroelectric Development. Environmental Impact Assessment. Vol. 4. Fish Resources Studies. Morice Systems. Prepared for: Alcan Smelters and Chemicals Ltd., Kitimat, B.C.

Environment Canada, 1991. Historical Streamflow Summary British Columbia to 1990. Minister of Supply and Services Canada 1992, Cat. No. En 36-418/1990-7.

Equity Silver Mines Environmental Reports, 1985-1995. A series of reports published annually by Equity Silver Mines Ltd.

Equity Silver Mines Limited Fact Sheet, a handout at the B.C.'s Sixteenth Annual Mine Reclamation Symposium: Mine Reclamation From Exploration to Decommissioning. 1992.

Godin, Benoit. 1988. Water Quality and Sediment Analysis for the Buck Creek System Adjacent to the Equity Silver Mine Near Houston, B.C., May 21 and June 19-20, 1987. Environment Canada Regional Program Report: 88-01, September 1988.

Godin, Benoit. 1992. Water Quality and Sediment Analysis, Equity Silver Mines, Data from 1988, 1989, and 1990 Surveys. Environment Canada Regional Program Report: 92-02, March 1992.

Halam, R.L., R. H. Kussat, and M. Jones, 1975. Environmental Impact Information of the Proposed Equity Mining Capital Ltd. Development near Houston, B.C. Environmental Protection Service Manuscript Report No. 75-1.

Hatfield Consultants Ltd. 1983. A Review of Probable Effects of Equity Silver Mines Ltd. Effluent on Fish Resources of the Buck Creek System in Central British Columbia.

Health and Welfare Canada. 1989. Guidelines for Canadian Drinking Water Quality. Fourth Edition. Supply and Services Canada, Ottawa, Ontario.

Health and Welfare Canada. Federal Provincial Subcommittee on Drinking Water. April 1993 Meeting.

International Joint Commission. Great Lakes Scientific Advisory Board. 1987 Report to the Aquatic Ecosystem Objectives Committee.

Ker Priestman and Associates Ltd. 1983. Hydrology Study for Equity Silver Mines Ltd.

Le, H.T. 1983. Technical Assessment for Amendment Application, PE 373. Waste Management Branch, April 28, 1983.

McKean, C.J.P. and N.K. Nagpal. 1991. Ambient Water Quality for pH. Water Quality Branch, Water Management Division, Ministry of Environment, Lands and Parks, Victoria, B.C.

Nagpal, N.K. 1987. Water Quality Criteria For Lead. Ministry of Environment and Parks, Water Management Branch, Resource Quality Section, Victoria, B.C.

Nagpal, N.K. L.W. Pommen and L.G. Swain. 1995. Approved and Working Criteria for Water Quality - 1995. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks., Victoria, B.C.

National Academy of Sciences. 1972. Water Quality Criteria 1972, Washington, D.C., 1972.

Nijman, R. 1986. Skeena-Nass Area, Bulkley River Basin Water Quality Assessment and Objectives. Water Management Branch, British Columbia Ministry of Environment, Victoria, B.C.

Nijman, R.A. 1993. Queen Charlotte Islands, Yakoun River and Tributaries, Water Quality Assessment and Objectives. Ministry of Environment, Water Management Division, Water Quality Branch, Victoria, B.C.

Nordin, R.N. 1985. Water Quality Criteria for Nutrients and Algae. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

Nordin, R.N. and L.W. Pommen. 1986. Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia). Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

Norecol Environmental Consultants, 1984. Assessment of Fish and Benthic Invertebrate Populations in Streams Draining the Equity Silver Mine Near Houston, B.C. Prepared for: Equity Silver Mines Ltd.

Obedkoff, W. 1983. Water Management Branch, Personal Communication, Low Flow Estimates for the Bulkley River.

Osborne, V. and B. Hallam. 1982. Summary of Environmental Information for the Equity Silver Mine. Environmental Protection Service.

Pommen, L.W. 1994. Mercury Monitoring Issues (Mark II). Water Quality Branch, Environmental Protection Department, BC Environment. Presented at the Environmental Protection Impact Biologists' Meeting February 21-22, 1994, Victoria, B.C.

Remington, Dawn. 1989. Memorandum Re: Goosly Lake Update. Environmental Section, Waste Management Branch, Ministry of Environment. February 20, 1989.

Rhebergen, Frank. 1986. Resume for permit amendment application assessment, PE-4475, application dated July 18, 1986. Frank Rhebergen, October 17, 1986

Rieberger, K. 1992. Metal Concentrations in Fish Tissue from Uncontaminated B.C. Lakes. Water Quality Branch, Ministry of Environment, Lands and Parks.

Singleton, H.J. 1985. Water Quality Criteria for Particulate Matter. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

Singleton, H.J. 1986. Water Quality Criteria For Cyanide. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

Singleton, H.J. 1987. Water Quality Criteria for Copper. Resource Quality Section, Water Management Branch, Ministry of Environment and Parks, Victoria, B.C.

Swain, L.G. 1985. Personal Communication. Resource Quality Section, Water Management Branch, Ministry of Environment, Victoria, B.C.

Tredger, C.D. 1981. Assessment of Steelhead Enhancement Opportunities in the Morice River System. Progress in 1980. Fish and Wildlife Branch, Ministry of Environment, Victoria, B.C.

Tredger, C.D. 1982. Upper Bulkley River reconnaissance with reference to juvenile steelhead carrying capacity. Unpublished Masters Thesis, Fish and Wildlife Branch, Ministry of Environment, Victoria, B.C.

Tredger, C.D. 1983. Assessment of Steelhead Enhancement Opportunities in the Morice River System. Progress in 1981. Fish and Wildlife Branch, Ministry of Environment, Victoria, B.C.

Tredger, C.D. and G. Caw, 1974. Lake survey data, Bulkley Lake. Fish and Game Department, Province of British Columbia.

Water Management Branch, Ministry of Environment, 1986. Principles for Preparing Water Quality Objectives in British Columbia.

Water Use Inventory-Bulkley River to 1983. Summary from Waste Management Branch, Ministry of Environment, Smithers.

Wilkes, B. and T. Roberts. 1987. Protecting the Bulkley River System from Acid Mine Drainage Produced at the Equity Silver Mine -- An Overview and Strategy Proposal (unpublished report). Waste Management Branch, Ministry of Environment and Parks, August 1987.

Wilkes, B. D. and D.B. McLean. 1987. The Effect of Equity Silver Mine on Goosly Lake. Waste Management Branch, Ministry of Environment and Parks. Environmental Section Report 87-01.

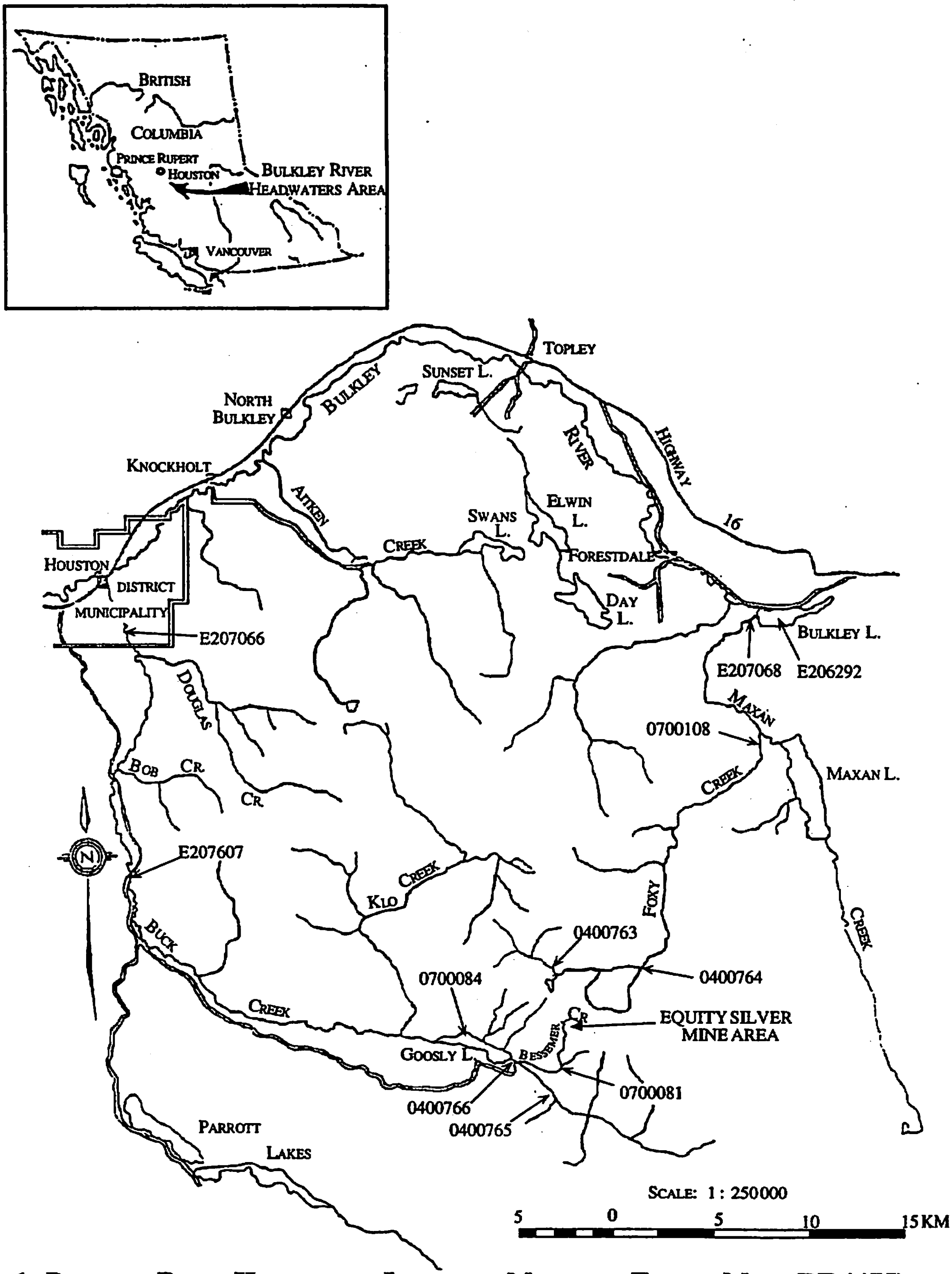

Figure 1: Bulkley River Headwater Location Map with Equity Mine (PE 4475) and Receiving Water Monitorng Sites

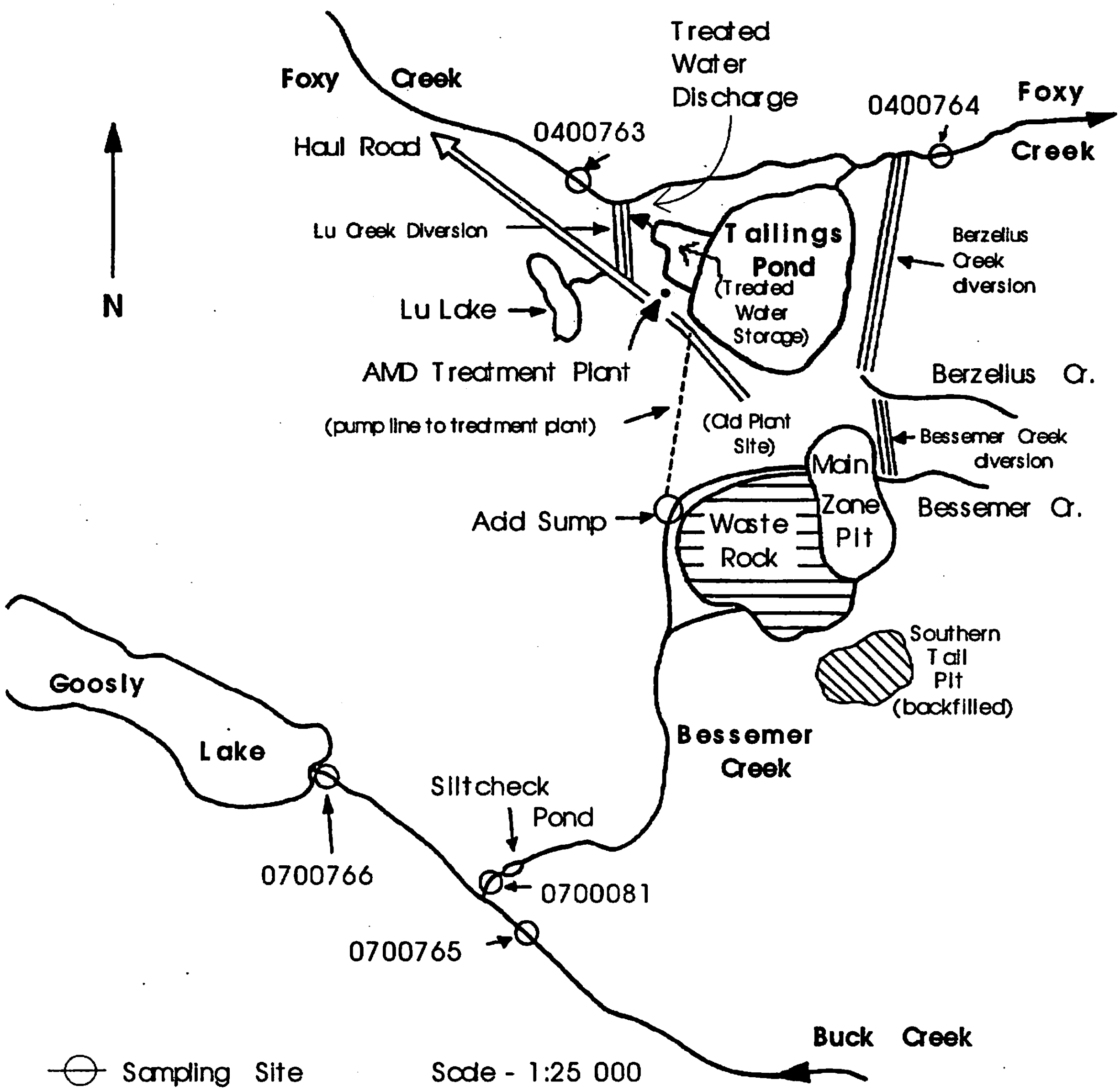

FIGURE 2: MAP OF THE EQUITY MINE (PE 4475) SITE, PRE-RECLAMATION

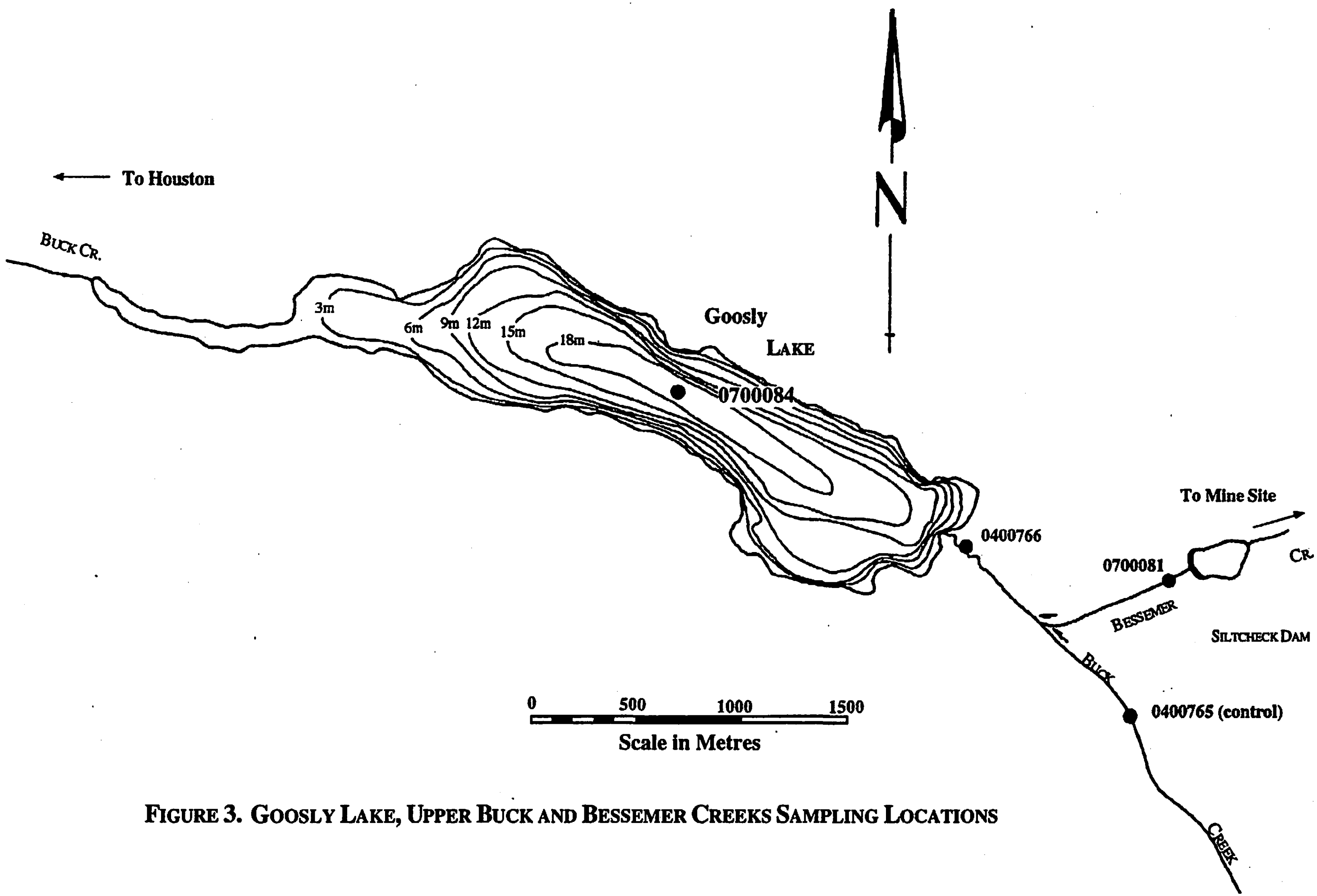

FIGURE 3. GOOSLY LAKE, UPPER BUCK AND BESSEMER CREEKS SAMPLING LOCATIONS

Table 4.2.1. Range of Theoretical Annual Loadings from Treated Water Discharges (Diversion Pond) to Buck and Foxy Creeks

	Discharge	Range of Loadings (kg/y) at Permitted Levels (dissolved fraction, mg/L)							
	Flow (m^3)	Cu(0.010)*	As(0.05)	Al(0.50)	Cd(0.01)	Fe(0.30)	Sb(0.05)	Zn(0.20)	NO_3NO_2(20)
Foxy Creek									
min	25 000 -	0.3-	-	-	-	-	-	-	-
max	1 611 900	16.1	-	-	-	-	-	-	-
Buck Creek									
min	78 400 -	0.8-	3.9-	39.2-	0.8-	23.5-	3.9-	15.7-	1570-
max	804 900	8	40.2	402.5	8	241.5	40.2	161	16100

*Calculation of copper loading based on minimum of the permitted concentration (0.010-0.050 mg/L).

Loading calculations for variables other than copper in Foxy Creek have not been calculated because only copper levels are regulated under permit

Table 4.2.2. Annual Loadings from Diversion Pond (Treated Water Discharges) to Foxy and Buck Creeks

	Treated	Suspended Solids		SO_4		NO_3		CN (T)		Al (D)*		As (T)*	
Foxy Creek	**Discharge (m^3)**	DP	Loading	DP	Loading	DP	Loading	DP	Loading	DP	Loading	DP	Loading
(Oct-Dec) 1983	25 000	6.7	168	1080	27000	3.14	79			0.173	4	0.0048	0.12
(Apr-Dec) 1984	1 611 900	7.5	12 090	1896	3100000	4.08	6577	0.006	9.7	0.188	303	0.0027	4.35
(May-July) 1985	256 500	10.6	2 719	1886	480000	3.63	931			0.120	31	0.0022	0.56
(May-Nov) 1986	323 400	7.3	2 361	1629	530000			0.005	1.6	0.068	22	0.0013	0.42
(May-July) 1987	252 700	8.4	2 123	1663	420000	1.00	253	0.005	1.3	0.090	23	0.0011	0.28
(May-Oct) 1988	524 100	25.6	13 417	1507	790000	0.55	288			0.277	145		
(July-Sept) 1989	32 800	8	462	1517	50000	0.15	5			0.056	2		
(Apr-June) 1990	267 950	10.1	2 706	1667	450000	1.14	306			0.046	12		
(Apr-May) 1992	272 440	7.4	2 016	2038	560000	0.35	95			0.081	22		
(May) 1993	257 825												
Buck Creek													
(May-Nov) 1985	634 000	10.6	6 720	1886	1200000	3.63	2301			0.120	76	0.0022	1.39
(May-Nov) 1986	468 600	7.3	3 416	1629	760000			0.005	2.3	0.068	32	0.0013	0.61
(Apr-July) 1987	268 200	8.4	2 253	1663	450000	1.00	268	0.005	1.3	0.090	24	0.0011	0.30
(July-July) 1989	78 400	8	627	1517	120000	0.15	12			0.056	4		
(Apr-July)1990	804 900	10.1	8 129	1677	1300000	1.14	918			0.046	37		
(Apr-June) 1992	442 455	7.4	3 274	2038	900000	0.35	155			0.081	36		
(Apr-June) 1993	367 205												

Note: Loadings are reported in kg. and calculated from the average concentration of the variable in treated water discharged from the diversion pond multiplied by the annual flow. Some data were not available.
DP: diversion pond yearly average concentration (mg/L)
* Form of metal reported is the same as Provincial Working Criteria

...continued

Table 4.2.2. (continued) Annual Loadings from Diversion Pond (Treated Water Discharges) to Foxy and Buck Creeks

	Treated	Cd (T)*		Cu (T)*		Fe (T)*		Sb (T)*		Zn (T)*	
Foxy Creek (cont)	**Discharge (m^3)**	DP	Loading	DP	Loading	DP	Loading	DP	Loading	DP	Loading
(Oct-Dec) 1983	25 000	0.0031	0.08	0.183	4.6	0.838	21	0.0010	0.03	0.343	9
(Apr-Dec) 1984	**1 611 900**	0.0011	**1.77**	0.038	**61.3**	0.528	**851**	0.0015	**2.42**	0.063	**102**
(May-July) 1985	256 500	0.0033	0.85	0.067	17.2	0.203	52	0.0035	0.90	0.135	35
(May-Nov) 1986	323 400	0.0007	0.23	0.025	8.1	0.330	107	0.0030	0.97	0.045	15
(May-July) 1987	252 700	0.0008	0.20	0.041	10.4	0.337	95	0.0011	0.28	0.103	26
(May-Oct) 1988	524 100			0.043	22.5	0.400	210			0.165	87
(July-Sept) 1989	32 800	0.0040	0.13	0.029		0.137				0.166	5
(Apr-June) 1990	267 950			0.023	6.2					0.240	64
(Apr-May) 1992	272 440			0.017	4.6					0.049	13
(May) 1993	257 825										
Buck Creek (cont)											
(May-Nov) 1985	634 000	0.0033	2.09	0.067	42.5	0.203	129	0.0035	2.22	0.135	86
(May-Nov) 1986	468 600	0.0007	0.33	0.025	11.7	0.330	154	0.0030	1.40	0.045	21
(Apr-July) 1987	268 200	0.0008	0.22	0.041	11.0	0.377	101	0.0011	0.30	0.103	28
(July) 1989	78 400	0.0040	0.31	0.029	2.3	0.137	11			0.166	13
(April-July)1990	**804 900**			0.023	**18.5**					0.240	**193**
(Apr-June) 1992	442 455			0.017	7.5			0.0035	1.55	0.049	22
(Apr-June) 1993	367 205										

Note: Loadings are reported in kg. and calculated from the average concentration of the variable in treated water discharged from the diversion pond multiplied by the annual flow. Some data were not available.
DP: diversion pond yearly average concentration (mg/L)
* Form of metal reported is the same as Provincial Working Criteria

Table 7.1.1. Water Quality Summary for Foxy Creek Sites 0400763 (Upper Foxy) and 0400764 (Lower Foxy): 1980-1995

	0400763 u/s Diversion					0400764 d/s Diversion				
Variable	**n**	**Min**	**Max**	**Mean**	**SD**	**n**	**Min**	**Max**	**Mean**	**SD**
pH	182	5.6	8.1	7.1	0.39	208	<1	8.1	7.3	0.5
Susp. Solids (mg/L)	73	<0.5	28	4	5.7	199	<0.5	133	5.8	15
Conductance (µs/cm)	9	35	145	85	38	15	34	762	320	214
Alkalinity (mg $CaCO_3$/L)	68	8.6	32.4	22.9	6.2	69	14.2	257	42	29
Cyanide, T (mg/L)	1	0.006	0.006	0.01	-	6	0.005	0.038	0.01	0.01
WAD (mg/L)	1	<0.005	<0.005	<0.005	-	170	<0.005	0.12	0.009	0.01
Hardness, T (mg/L)	47	5.8	44	21.9	8	81	<0.1	113	27	20
NO_2/NO_3 (mg/L)	1	0.05	0.05	0.05	-	6	<0.02	4.6	1.1	1.7
Sulphate, D (mg/L)	6	1.5	<5	3.4	1.8	11	<5	310	122	99
T (mg/L)	109	<1	20.5	2.6	2.8	114	<1	267	38	44
Metals										
Aluminum, D (mg/L)	152	0.012	0.449	0.14	0.08	161	<0.005	0.49	.09	.09
T (mg/L)	133	0.023	5.31	0.43	0.69	142	0.016	10	0.4	1.0
Arsenic, D (mg/L)	58	<0.0001	<0.25	med<0.001		73	<0.0003	<0.25	med <0.0003	
T (mg/L)	51	<0.0001	0.019	med<0.001	0	65	<0.0006	0.11	med <0.0006	
Barium, D (mg/L)	4	<0.01	0.04	0.02	0.02	10	<0.01	<0.01	<0.01	-
Cadmium, D (mg/L)	13	<0.0002	<0.01	0.003	0.004	121	<0.0002	<0.01	0.001	0.002
T (mg/L)	30	<0.0002	<0.01	med <0.01	0	103	<0.0002	<0.01	0.001	0.002
Chromium, D (mg/L)	4	<0.01	<0.01	<0.01	-	10	<0.01	<0.01	<0.01	-
T (mg/L)	3	<0.01	<0.01	<0.01	-	9	<0.01	<0.01	<0.01	-
Copper, D (mg/L)	186	<0.001	0.036	0.003	0.004	193	<0.001	0.18	0.006	0.02
T (mg/L)	182	<0.001	0.1	0.006	0.015	188	<0.001	0.27	0.01	0.03
Iron, D (mg/L)	63	<0.03	7.2	0.26	0.9	145	<0.01	1.41	0.13	0.2
T (mg/L)	60	0.07	2.5	0.48	0.49	86	0.03	2.78	0.4	0.5
Mercury, T (µgL)	39	<0.05	<2	med <2		38	<0.05	0.9	0.1	0.2
Manganese, D (mg/L)	4	<0.01	0.05	0.02	0.02	10	<0.01	0.12	0.04	0.03
T (mg/L)	3	0.01	0.08	0.04	0.04	9	<0.01	0.12	0.05	0.04
Nickel, D (mg/L)	4	<0.05	<0.05	<0.05	-	10	<0.01	<0.05	<0.05	-
T (mg/L)	4	<0.01	<0.05	med <0.05		10	<0.01	<0.05	<0.05	-
Lead, D (mg/L)	47	<0.001	<0.1	med <0.001		54	<0.001	<0.1	med <0.001	
T (mg/L)	42	<0.001	<0.1	med <0.001		49	<0.001	<0.1	med <0.001	
Antimony, D (mg/L)	61	<0.0001	0.026	med <0.0001		69	<0.0001	<0.005	med <0.0001	
T (mg/L)	55	<0.0001	0.034	med <0.0001		62	<0.0001	<0.01	med <0.0001	
Zinc, D (mg/L)	187	<0.001	0.039	0.001	0.007	196	<0.002	0.38	0.01	0.03
T (mg/L)	183	<0.004	0.16	0.004	0.01	190	<0.003	0.43	0.02	0.04

Note: Samples collected by both Equity Silver and the Ministry of Environment, Lands and Parks.

Table 7.1.2. Water Quality Summary for Site 0700108 Foxy Creek: 1982-1995

Variable	n	Min	Max	Mean	SD
pH	73	6.8	7.9	7.3	0.2
Suspended Solids (mg/L)	28	<1	74	5	14
Conductance (µs/cm)	8	175	249	212	35
Alkalinity, T (mg CaC03/L)	17	21.8	60.6	45.6	11
Hardness, T (mg/L)	4	10.4	45.8	30.5	15.7
NO_2/NO_3 (mg/L)	4	<0.02	<0.02	<0.02	-
Sulphate, D (mg/L)	7	36.3	80.6	58.4	21.8
T (mg/L)	44	3	81	14.0	11
Metals					
Aluminum, D (mg/L)	77	0.005	0.59	0.10	0.1
T (mg/L)	58	0.01	3.48	0.30	0.5
Arsenic, D (mg/L)	11	<0.001	0.001	med <0.001	
T (mg/L)	12	<0.001	0.002	med <0.001	
Barium, D (mg/L)	8	0.02	0.03	0.02	0.005
Cadmium, D (mg/L)	13	<0.0002	<0.0005	med <0.0005	
T (mg/L)	13	<0.0002	<0.0005	med <0.0005	
Chromium, D (mg/L)	8	<0.01	<0.01	<0.01	-
T (mg/L)	8	<0.01	<0.01	<0.01	-
Copper, D (mg/L)	78	<0.001	0.006	0.002	0.001
T (mg/L)	78	<0.001	0.02	0.003	0.003
Iron, D (mg/L)	13	0.01	0.1	0.03	0.02
T (mg/L)	13	0.03	2.65	0.29	0.71
Manganese, D (mg/L)	8	<0.01	<0.01	<0.01	-
T (mg/L)	8	<0.01	0.02	0.01	0.004
Nickel, D (mg/L)	9	<0.05	<0.05	<0.05	-
T (mg/L)	9	<0.05	<0.05	<0.05	-
Lead, D (mg/L)	8	<0.1	<0.1	<0.1	-
T (mg/L)	8	<0.1	<0.1	<0.1	-
Zinc, D (mg/L)	75	<0.005	0.014	0.005	0.001
T (mg/L)	77	<0.005	0.03	0.007	0.005

Note: Samples collected by both Equity Silver and the Ministry of Environment, Lands, and Parks.

Table 7.1.3. Water Quality Data Summary for Maxan Creek Site E207068 at Bulkley Lake (1987)

Variable	n	Min	Max	Mean	SD
pH	4	7.6	7.8	7.8	0.1
Suspended Solids (mg/L)	8	<1	17	3	6
Conductance (µs/cm)	8	173	197	186	11
Alkalinity, T (mg CaC03/L)	4	48.4	57.8	51	4.6
NO_2/NO_3 (mg/L)	4	<0.02	<0.02	<0.02	-
Sulphate, D (mg/L)	7	30.4	45.6	38.5	7.6
Metals (mg/L):					
Aluminum, D	8	0.05	0.14	0.09	0.03
T	1	0.13	0.13	0.13	-
Arsenic, D	8	<0.001	<0.001	<0.001	-
T	8	<0.001	<0.001	<0.001	-
Barium, D	8	0.01	0.02	0.02	0.01
Cadmium, D	8	<0.0005	<0.0005	<0.0005	-
T	8	<0.0005	0.006	med <0.0005	
Cobalt, D	8	<0.1	<0.1	<0.1	-
T	8	<0.1	<0.1	<0.1	-
Chromium, D	8	<0.01	<0.01	<0.01	-
T	8	<0.01	<0.01	<0.01	-
Copper, D	8	0.001	0.001	0.001	0
T	8	0.001	0.008	0.004	0.002
Iron, D	8	0.03	0.06	0.05	0.01
T	8	0.05	0.42	0.18	0.11
Manganese, D	8	0.01	0.01	0.01	0
T	8	0.01	0.04	0.02	0.01
Nickel, D	8	<0.05	<0.05	<0.05	-
T	8	<0.05	<0.05	<0.05	-
Lead, D	8	<0.1	<0.1	<0.1	-
T	8	<0.1	<0.1	<0.1	-
Zinc, D	8	<0.005	<0.005	<0.005	-
T	8	<0.005	<0.005	<0.005	-

Note: samples collected by the Ministry of Environment

Table 7.1.4. Water Quality Data Summary for Bulkley Lake Site E206292 at Lake Center (1985-1987)

Variable	n	Min	Max	Mean	SD
pH	10	7	8.8	7.4	0.5
Suspended Solids (mg/L)	10	<1	13	5.8	4.5
Conductance (µs/cm)	12	104	196	124	30
Turbidity (NTU)	4	2.6	4.8	3.8	1
Alkalinity, T (mg CaC03/L)	10	30.4	48.5	38.2	5
Carbon, Inorganic, T (mg/L)	6	7	14	11	3
Organic, T (mg/L)	6	19	27	22	3
Chlorophyll a (µg/L)	4	7	12.7	10	2.6
Ammonia D (mg/L)	10	<0.005	0.407	0.093	0.12
NO_2/NO_3 (mg/L)	10	<0.02	0.09	0.03	0.02
Phosphorus, ortho-D (mg/L)	6	0.004	0.099	0.031	0.034
Sulphate, D (mg/L)	12	8.6	56.6	19.9	14.7
Metals (mg/L):					
Aluminum, D	12	<0.02	0.09	0.05	0.02
T	8	<0.02	0.57	0.23	0.19
Arsenic, D	12	<0.001	0.006	0.002	0.001
T	12	<0.001	0.008	0.002	0.002
Barium, D	12	<0.01	0.03	0.02	0.01
Cadmium, D	12	<0.0005	<0.0005	<0.0005	-
T	12	<0.0005	0.0007	med <0.0005	
Cobalt, D	12	<0.1	<0.1	<0.1	-
T	12	<0.1	<0.1	<0.1	-
Chromium, D	12	<0.01	<0.01	<0.01	-
T	12	<0.01	<0.01	<0.01	-
Copper, D	12	<0.001	0.003	0.002	0.001
T	12	<0.001	0.005	0.003	0.001
Iron, D	12	0.044	0.97	0.25	0.25
T	12	0.08	2.8	0.8	0.8
Manganese, D	12	<0.01	2.07	0.57	0.73
T	12	0.02	2.33	0.65	0.83
Nickel, D	12	<0.05	<0.05	<0.05	-
T	12	<0.05	<0.05	<0.05	-
Lead, D	12	<0.001	<0.1	0.018	0.038
T	12	0.001	<0.1	0.019	0.038
Vanadium, D	12	<0.01	<0.01	0.01	0
T	12	<0.01	<0.01	0.01	0
Zinc, D	11	<0.005	0.006	med<0.005	
T	12	<0.005	0.03	med<0.005	

Note: samples collected by the Ministry of Environment

Table 7.2.1. Water Quality Data Summary for Bessemer Creek Site 0700081 (at Siltcheck)

Variable	n	Min	Max	Mean	SD
pH	664	3.44	9.46	7.41	0.58
Suspended Solids (mg/L)	653	<0.5	745	16.2	47
Conductance (µs/cm)	45	170	1690	814	418
Turbidity (NTU)	2	0.9	1.8	1.4	0.6
Alkalinity, T (mg CaC03/L)	132	15.9	119	53.3	25
Cyanide, WAD (mg/L)	55	<0.005	0.045	0.01	0.007
Hardness, T (mg/L)	103	1	146	59.3	32.2
NO_2/NO_3 (mg/L)	103	0.1	25	6.0	5.8
Sulphate, D (mg/L)	33	29.7	960	400.4	258
Metals (mg/L):					
Aluminum, D	300	0.011	2.53	0.13	0.22
T	219	<0.02	28.3	1.26	3.10
Antimony, D	414	<0.0002	0.32	0.03	0.04
T	404	<0.0002	0.32	0.03	0.04
Arsenic, D	333	<0.0001	<0.3	0.007	0.037
T	320	<0.0001	<0.3	0.011	0.040
Barium, D	32	0.02	0.2	0.06	0.03
Boron, D	32	<0.008	0.02	med <0.008	
Cadmium, D	266	<0.0002	0.015	0.002	0.003
T	374	<0.0002	0.086	0.002	0.005
Chromium, D	32	<0.002	<0.01	med <0.01	
T	30	<0.002	0.05	med <0.01	
Cobalt, D	32	<0.003	<0.1	med <0.1	
T	30	<0.003	<0.1	med <0.1	
Copper, D	678	0.00084	7.4	0.051	0.33
T	674	0.002	7.71	0.078	0.36
Iron, D	420	<0.008	8.08	0.118	0.42
T	399	<0.02	52.3	1.20	3.8
Lead, D	75	<0.001	<0.1	med <0.001	
T	71	<0.001	0.12	med <0.001	
Mercury, T (µgL)	40	<0.05	<0.5	med <0.5	
Manganese, D	32	<0.01	1.9	0.31	0.38
T	30	<0.01	1.97	0.34	0.41
Molybdenum, D	32	<0.004	0.02	med <0.01	
T	30	<0.004	0.04	med <0.01	
Nickel, D	32	<0.007	0.14	med <0.05	
T	30	<0.008	0.14	med <0.05	
Sulphate, S	253	34	2660	482	296
Zinc, D	676	<0.005	4.15	0.081	0.23
T	671	<0.005	4.22	0.107	0.26

Table 7.2.2. Water Quality Data for Buck Creek Sites 0400765 (Above Bessemer Creek) and 0400766 (at Bulkley Lake), 1980-1995

	0400765 Buck Ck U/S Bessemer					0400766 Buck Ck at Goosly Lake				
Variable	**n**	**Min**	**Max**	**Mean**	**SD**	**n**	**Min**	**Max**	**Mean**	**SD**
pH	267	<1	8	7.3	0.5	259	<1	8.5	7.2	0.5
Susp.Solids (mg/L)	236	<0.5	26	3.9	4.2	225	<0.5	83	5.7	7.8
Conductance (µs/cm)	46	53	190	142	41	40	83	539	209	90
Turbidity (NTU)	1	2.3	2.3	2.3	0	4	2.2	4.5	3.5	1
Alkalinity (mg $CaCO_3$/L)	77	20.9	106	62.8	22.9	78	20.3	104	61.3	23
Cyanide, WAD (mg/L)	22	<0.005	<0.005	<0.005	-	(no data; only CN total)				
Hardness, T (mg/L)	94	<0.1	109	40.9	33.4	100	<0.1	275	40.4	43.8
NO_2/NO_3 (mg/L)	89	<0.02	0.54	med <0.02		63	<0.02	1.78	0.2	0.32
Sulphate, D (mg/L)	29	2.4	7.2	4.5	1	24	7.5	211	44.4	52.8
Metals (mg/L):										
Aluminum, D	219	<0.005	0.49	0.09	0.1	208	<0.005	0.63	0.06	0.08
T	191	<0.01	3.36	0.23	0.36	174	<0.01	3.15	0.22	0.35
Antimony, D	167	<0.0001	<0.005	med <0.005		119	<0.0001	0.14	med <0.005	
T	157	<0.0001	0.05	med <0.005		110	<0.0001	0.012	med <0.005	
Arsenic, D	140	0.0006	<2	med <0.001		102	0.0006	<0.25	med <0.001	
T	128	0.0006	<0.25	med <0.001		96	0.0007	<0.25	med <0.001	
Barium, D	17	0.02	0.06	0.03	0.01	10	0.02	0.07	0.03	0.02
Boron, D	17	<0.01	<0.01	<0.01	-	10	<0.01	<0.01	<0.01	-
Cadmium, D	161	<0.0002	<0.01	med <0.0005		143	0.0001	<0.01	0.0008	0.002
T	183	<0.0002	<0.01	med <0.0005		177	<0.0002	<0.01	med <0.0005	
Chromium, D	17	<0.01	<0.01	<0.01	-	10	<0.01	<0.01	<0.01	-
T	14	<0.01	<0.01	<0.01	-	8	<0.01	0.01	med <0.01	
Cobalt, D	17	<0.1	<0.1	<0.1	-	10	<0.1	<0.1	<0.1	-
T	14	<0.1	<0.1	<0.1	-	8	<0.1	<0.1	<0.1	-
Copper, D	281	<0.001	0.34	0.004	0.02	265	<0.001	0.48	0.006	0.029
T	272	<0.001	0.083	0.005	0.008	261	<0.001	0.1	0.006	0.008
Iron, D	231	<0.005	4.96	0.45	0.45	218	<0.005	5.26	0.44	0.48
T	227	<0.005	3.01	0.7	0.62	218	<0.005	5.87	0.94	0.98
Lead, D	84	<0.001	<0.1	med <0.001		73	<0.001	<0.1	med <0.001	
T	77	<0.001	<0.1	med <0.001		69	<0.001	<0.1	med <0.001	
Mercury, T (µgL)	59	<0.05	0.7	med <0.05		56	<0.05	<0.5	med <0.05	
Manganese, D	17	0.01	0.22	0.07	0.05	10	0.03	0.35	0.11	0.1
T	14	0.02	0.23	0.1	0.07	8	0.04	0.38	0.14	0.11
Molybdenum, D	17	<0.01	<0.01	<0.01	-	10	<0.01	<0.01	<0.01	-
T	14	<0.01	<0.01	<0.01	-	8	<0.01	<0.01	<0.01	-
Nickel, D	18	<0.01	<0.05	<0.05	-	11	<0.01	<0.05	med <0.05	
T	16	<0.01	<0.05	<0.05	-	10	<0.01	<0.05	med <0.05	
Sulphate, S	89	<0.5	7	1.6	1.5	93	<0.5	282	27.8	38.6
Zinc, D	281	<0.001	0.19	0.007	0.01	263	0.003	0.38	0.010	0.026
T	275	<0.005	0.18	0.01	0.01	262	0.003	0.14	0.013	0.017

Note: samples collected by both the Ministry of Environment, Lands and Parks and the Permittee

Table 7.2.3. Water Quality Data Summary for Goosly Lake 0700084 (1982-1991)

Variable	n	Min	Max	Mean	SD
pH	51	6.5	7.7	7.2	0.3
Suspended Solids (mg/L)	53	<1	20	2.9	2.8
Conductance (µs/cm)	51	88	198	136	27
Turbidity (NTU)	47	0.5	14	2.3	2.1
Alkalinity, T (mg CaC03/L)	41	33.8	45.9	38.4	2.9
Carbon, Inorganic, T (mg/L)	16	8	12	10.1	1.3
Organic (mg/L)	8	10	13	11.8	0.9
Chlorophyll a (µg/L)	20	1.9	34.9	9.5	8.1
Hardness, T (mg/L)	5	43.2	52	46	3.8
Ammonia-N, D (mg/L)	39	<0.005	0.035	0.008	0.006
NO_3/NO_2 (mg/L)	49	<0.02	0.22	0.07	0.06
Kjeldahl-N (mg/L)	42	0.25	0.46	0.35	0.05
Phosphate, Ortho-D (mg/L)	47	<0.003	0.022	0.005	0.005
Phosphorus, D	24	0.007	0.025	0.013	0.004
T	57	0.006	0.054	0.024	0.009
Sulphate, D (mg/L)	57	8.8	63.1	30.4	16.1
Metals (mg/L):					
Aluminum, D	46	<0.02	0.12	0.06	0.03
T	41	<0.02	1.98	0.16	0.3
Arsenic, D	56	<0.001	<0.25	med <0.001	
T	56	<0.001	<0.25	med <0.001	
Barium, D	56	0.01	0.05	0.03	0.01
T	10	0.03	0.07	0.04	0.01
Boron, D	56	<0.01	0.01	med <0.01	
Cadmium, D	60	<0.0005	<0.01	med <0.0005	
T	60	<0.0005	<0.01	med <0.0005	
Chromium, D	56	<0.005	0.02	0.009	0.002
T	56	<0.005	0.02	0.009	0.002
Cobalt, D	56	<0.1	<0.1	<0.1	-
T	56	<0.1	<0.1	<0.1	-
Copper, D	65	<0.001	<0.01	0.004	0.003
T	66	<0.001	0.02	0.005	0.003
Iron, D	56	0.01	0.58	0.17	0.1
T	56	0.06	4.42	0.37	0.57
Lead, D	65	<0.001	<0.1	med <0.001	
T	67	<0.001	<0.1	med <0.001	
Manganese, D	55	<0.01	1.65	0.16	0.34
T	56	<0.01	1.79	0.21	0.36
Molybdenum, D	56	<0.01	0.01	med <0.01	
T	56	<0.01	0.03	med <0.01	
Nickel, D	56	<0.05	<0.05	<0.05	-
T	56	<0.05	0.07	med <0.05	
Zinc, D	62	<0.005	0.02	0.01	<0.01
T	66	<0.005	0.02	0.01	<0.01

Note: Sampled by the Ministry of Environment, Lands and Parks

Table 7.2.4. Water Quality Data Summary for Buck Creek Sites E207067 and E207066, 1987

	E207067 (Buck Creek at 2nd Bridge)					E207066 (Buck Creek at Houston)				
Variable	**n**	**Min**	**Max**	**Mean**	**SD**	**n**	**Min**	**Max**	**Mean**	**SD**
pH	7	7.7	8.1	8	0.2	4	8	8.5	8.4	0.3
Suspended Solids (mg/L)	8	1	2	1.5	0.5	8	<1	2	1.1	0.4
Conductance (µs/cm)	8	100	120	107	6	8	124	133	126	3
Alkalinity, T (mg $CaCO_3$/L)	7	47.6	52.4	49.3	1.6	4	58.9	62.2	60	1.5
NO2/NO3 (mg/L)	7	<0.02	<0.02	0.02	0	4	<0.02	<0.02	0.02	0
Sulphate, D (mg/L)	8	2.1	7.4	3.6	1.6	8	3.4	5.1	4.1	0.7
Metals (mg/L):										
Aluminum, D	8	<0.02	0.06	0.04	0.02	7	0.05	0.08	0.06	0.01
T	1	0.11	0.11	0.11	0	2	0.18	0.23	0.21	
Arsenic, D	8	<0.001	0.002	0.001	0.001	8	<0.001	0.002	0.001	0.001
T	8	<0.001	0.002	0.001	0.001	8	<0.001	0.002	0.001	0.001
Barium, D	8	<0.01	<0.01	<0.01	-	8	<0.01	0.03	0.01	0.01
Boron, D	8	<0.01	<0.01	<0.01	-	8	<0.01	0.03	0.01	0.01
Cadmium, D	8	<0.0005	<0.0005	<0.0005	-	8	<0.0005	<0.0005	<0.0005	-
T	8	<0.0005	<0.0005	<0.0005	-	8	<0.0005	<0.0005	<0.0005	-
Chromium, D	8	<0.1	<0.1	<0.1	-	8	<0.01	<0.01	<0.01	-
T	8	<0.1	<0.1	<0.1	-	8	<0.01	0.02	med <0.01	
Cobalt, D	8	<0.1	<0.1	<0.1	-	8	<0.1	<0.1	<0.1	-
T	8	<0.1	<0.1	<0.1	-	8	<0.1	<0.1	<0.1	-
Copper, D	8	<0.001	0.002	0.001	<0.001	8	<0.001	0.002	0.001	0.001
T	8	0.001	0.007	0.003	0.002	8	0.001	0.03	0.01	0.01
Iron, D	8	0.07	0.25	0.2	0.03	8	0.01	0.07	0.04	0.02
T	8	0.26	0.33	0.3	0.03	8	0.08	0.22	0.13	0.04
Lead, D	8	<0.1	<0.1	0.1	0	8	<0.1	<0.1	<0.1	-
T	8	<0.1	<0.1	0.1	0	8	<0.1	<0.1	<0.1	-
Manganese, D	8	<0.01	0.03	0.02	0.01	8	<0.01	<0.01	<0.01	-
T	8	0.02	0.03	0.03	0.01	8	<0.01	<0.01	<0.01	-
Molybdenum, D	8	<0.01	<0.01	<0.01	-	8	<0.01	<0.01	<0.01	-
T	8	<0.01	<0.01	<0.01	-	8	<0.01	<0.01	<0.01	-
Nickel, D	8	<0.05	<0.05	<0.05	-	8	<0.05	<0.05	<0.05	-
T	8	<0.05	<0.05	<0.05	-	8	<0.05	<0.05	<0.05	-
Vanadium, D	8	<0.01	<0.01	<0.01	-	8	<0.01	<0.01	<0.01	-
T	8	<0.01	0.02	0.01	<0.01	8	<0.01	0.02	med <0.01	
Zinc, D	8	<0.005	0.005	med <0.005		8	<0.005	<0.005	<0.005	-
T	8	<0.005	0.06	med <0.005		8	<0.005	<0.005	<0.005	-

Note: Sampled by the Ministry of Environment, Lands and Parks

Table 7.2.6.1. Environment Canada Water Quality Data for the Buck Creek System, 1987

Site	Date 1987	Depth (m)	Alkalinity (mg/L)	pH	NH_3-N (mg/L)	NO_2-N (mg/L)	(NO_2/NO_3) (mg/L)	Diss Solids (mg/L)	SO_4(D) (mg/L)	Temp. (°C)
Buck Creek 1	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd
(400765)	20-Jun	0	42.3	6.9	0.047	<0.005	<0.005	<5	5	nd
Bessemer Creek 2	21-May	0	24.5	7.2	nd	0.01	2.58	12	780	4.3
(0700081)		1	24	7.5	nd	<0.005	0.491	25	450	5.3
	20-Jun	0	47.4	7.4	0.067	<0.005	1.14	7	200	nd
Buck Creek 3	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd
(500m u/s Buck 4)	20-Jun	0	42.3	7	0.043	<0.005	0.061	<5	nd	nd
Buck Creek 4	21-May	0	26	7.2	nd	<0.005	0.063	<5	38	2.3
(400766)	20-Jun	0	43.3	6.9	0.045	<0.005	0.013	<5.3	31	nd
Goosly Lake 5	21-May	1	35.9	7.3	nd	<0.005	0.009	<5	39	7.5
(800m below inlet)		17	35.9	7.4	nd	<0.005	0.042	6	35	5.8
	20-Jun	1	32	7.6	0.054	<0.005	<0.005	<5	30	nd
		17	32	6.5	0.059	<0.005	0.03	<5	29	nd
Goosly Lake 6	21-May	1	35.4	7.3	nd	<0.005	0.025	6	34	7.5
(700084)		17	35.4	7.4	nd	<0.005	0.045	<5	44	5.7
	20-Jun	1	30.9	7	0.055	<0.005	<0.005	<5	34	nd
		17	32	6.7	0.047	<0.005	0.037	7	37	nd
Buck Creek 7	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd
(100m d/s Goosly)	20-Jun	0	31.3	7	0.05	<0.005	nd	<5	33	nd
Buck Creek 8	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd
12 km u/s Houston	20-Jun	0	33	7.1	0.052	<0.005	<0.005	<5.3	11	nd

Site numbers in brackets are the equivalent Ministry of Environment site
* contamination suspected
nd = no data

... continued

Table 7.2.6.1 (1987 continued)

Site	Date	Depth	Al (mg/L)		Cd (mg/L)		Cr (mg/L)		Cu (mg/L)		Fe (mg/L)		Mn (mg/L)		P (mg/L)	
	1987	(m)	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
1	20-Jun	0	0.17	0.05	<0.001	<0.001	<0.005	<0.005	0.0022	0.0009	0.507	0.33	0.036	0.029	0.07	<0.05
Bessemer	21-May	0	0.09	0.07	0.003	0.002	<0.005	<0.005	0.028	0.019	0.687	0.048	0.445	0.409	0.15	0.11
2		1	2.09	0.11	0.003	<0.002	<0.005	<0.005	0.041	0.02	1.52	0.082	0.223	0.193	0.15	0.09
	20-Jun	0	0.55	0.11	0.0007	0.0005	<0.005	<0.005	0.017	0.023	0.557	0.075	0.125	0.122	0.1	<0.05
Buck	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	20-Jun	0	0.16	<0.005	<0.0001	<0.0001	<0.006	<0.005	0.0024	0.0015	0.647	0.416	0.074	0.069	0.08	0.09
Buck	21-May	0	0.4	0.13	<0.002	<0.002	<0.005	<0.005	0.0035	0.0032	0.522	0.245	0.038	0.031	0.07	0.07
4	20-Jun	0	0.15	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.0031	0.0014	0.96	0.614	0.09	0.085	0.08	<0.05
Goosly	21-May	1	0.21	0.06	<0.002	<0.002	<0.005	<0.005	0.0037	0.003	0.317	0.136	0.099	0.065	0.05	0.06
5		17	0.28	0.08	<0.002	<0.002	<0.005	<0.005	0.0066	0.0041	0.374	0.147	0.105	0.069	<0.05	0.06
	20-Jun	1	0.08	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.0069	0.0084	0.265	0.124	0.022	0.002	0.08	<0.05
		17	0.98	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.004	0.0025	1.72	0.184	0.307	0.174	0.2	0.07
Goosly	21-May	1	0.24	<0.05	<0.002	<0.002	<0.005	<0.005	0.004	0.0031	0.399	0.033	0.096	0.061	<0.05	<0.05
6		17	0.27	<0.05	<0.002	<0.002	<0.005	<0.005	0.004	0.0032	0.448	0.149	0.113	0.087	<0.05	<0.05
	20-Jun	1	<0.0	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.0032	0.0028	0.194	0.107	0.016	0.001	<0.05	<0.05
		17	0.19	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.0031	0.0018	0.496	0.18	0.267	0.196	0.09	<0.05
Buck	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
7	20-Jun	0	0.06	<0.05	<0.0001	<0.0001	<0.005	<0.005	0.003	0.0023	0.226	0.124	0.031	0.01	<0.05	<0.05
Buck	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
8	20-Jun	0	0.3	<0.05	<0.0001	<0.0002*	<0.041	<0.005	0.003	0.0037*	0.53	0.179	0.124	0.018	0.12	<0.07

Table 7.2.6.1 (1987 continued)

Site	Date	Depth	Pb (mg/L)		Sn (mg/L)		Sr (mg/L)		Ti (mg/L)		Zn (mg/L)	
	1987	(m)	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck 1	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	20-Jun	0	0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	<0.002	<0.003*
Bessemer 2	21-May	0	0.03	<0.02	<0.01	<0.01	2.39	2.19	0.021	<0.002	0.124	0.096
		1	0.04	<0.02	<0.01	<0.01	1.41	1.28	0.66	<0.002	0.068	0.04
	20-Jun	0	<0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	0.038	0.033
Buck 3	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	20-Jun	0	0.04	<0.02	<0.01	<0.01	nd	nd	nd	nd	0.004	0.003
Buck 4	21-May	0	<0.02	<0.02	<0.01	<0.01	0.196	0.191	0.012	<0.002	0.004	0.004
	20-Jun	0	<0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	<0.002	<0.002
Goosly 5	21-May	1	<0.02	<0.02	<0.01	<0.01	0.224	0.209	0.006	<0.002	0.007	0.004
		17	<0.02	<0.02	<0.01	<0.01	0.23	0.203	0.009	0.002	0.017	0.01
	20-Jun	1	<0.02	<0.02	0.06	<0.01	nd	nd	nd	nd	<0.002	<0.002
		17	<0.02	0.02	0.05	0.02	nd	nd	nd	nd	0.007	<0.002
Goosly 6	21-May	1	<0.02	<0.02	<0.01	<0.01	0.234	0.218	0.009	<0.002	0.003	0.004
		17	<0.02	<0.02	<0.01	<0.01	0.225	0.218	0.008	<0.002	0.007	0.005
	20-Jun	1	<0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	<0.002	<0.002
		17	<0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	0.01	0.008
Buck 7	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	20-Jun	0	<0.02	<0.02	<0.01	<0.01	nd	nd	nd	nd	<0.002	<0.002
Buck 8	21-May	0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	20-Jun	0	<0.02	<0.02	0.05	<0.01	nd	nd	nd	nd	<0.005	<0.003

* contamination suspected
nd = no data

Table 7.2.6.2. Environment Canada Water Quality Data Summary for the Buck Creek System, June 22-23,1988

Site	Depth	Alk	pH	NFR	S04	Ag (mg/L)		Al (mg/L)		As (mg/L)		Ba (mg/L)		Cd (mg/L)		Co (mg/L)	
	m	mg/L		mg/L	mg/L	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck Cr 1 400765*	0	39.8/ 0.3	7.9/ 0.1	<5/ 0	5/ 1	<0.01/ 0	<0.01/ 0	0.18/ 0.02	<0.05/ 0	<0.05/ 0	<0.05/ 0	0.024/ 0.002	0.022/ 0	0.0002/ 0	<0.0001/ 0	<0.005/ 0	<0.005/ 0
Bessemer Cr 2 700081*	0	61	8.1	<5	250	<0.01	<0.01	0.62	0.07	<0.05	0.06	0.056	0.049	0.0028	0.0008	<0.005/	<0.005/
Buck Cr 3 400766*	0	41.8/ 0.3	8.0/ 0	<5/ 0	37/ 0	<0.01/ 0	<0.01/ 0	0.16/ 0.02	<0.05/ 0	<0.05/ 0	<0.05/ 0	0.028/ 0.001	0.028/ 0.001	0.0002/ 0	0.0001/ 0	<0.005/ 0	<0.005/ 0
Goosly Lk 12 700084*	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	8	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	16	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Buck Cr 13 (d/s Goosly)	0	35.0/ 0	8.0/ 0.1	<5/ 0	29/ 1	<0.01/ 0	<0.01/ 0	0.09/ 0.01	<0.05/ 0	<0.05/ 0	<0.05/ 0	0.025/ 0.001	0.024/ 0.001	0.0001/ 0	<0.0001/ 0	<0.005/ 0	<0.005/ 0

Site	Depth	Cr (mg/L)		Cu (mg/L)		Fe (mg/L)		Mn (mg/L)		Mo (mg/L)		Ni (mg/L)		Pb (mg/L)		Sb (mg/L)	
	m	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck 1 4007658*	0	<0.005/ 0	<0.005/ 0	0.0014/ 0.0004	<0.005/ 0	0.428/ 0.02	0.259/ 0.005	0.026/ 0.002	0.018/ 0.001	<0.01/ 0	<0.01/ 0	<0.02/ 0	<0.02/ 0	<0.005/ 0	<0.005/ 0	<0.05/ 0	<0.05/ 0
Bessemer 2 700081*	0	<0.005	<0.005	0.038	0.028	0.449	0.02	0.223	0.189	<0.01	<0.01	<0.02	<0.02	<0.005	<0.005	0.07	<0.05
Buck 3 400766*	0	<0.005/ 0	<0.005/ 0	0.0043/ 0.0002	0.0032/ 0.0001	0.449/ 0.008	0.296/ 0.003	0.055/ 0.002	0.048/ 0.001	<0.01/ 0	<0.01/ 0	<0.02/ 0	<0.02/ 0	<0.005/ 0	<0.005/ 0	<0.05/ 0	<0.05/ 0
Goosly 12 700084*	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	8	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	16	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Buck 13 (d/s Goosly)	0	<0.005/ 0	<0.005/ 0	0.0038/ 0.0003	0.0028/ 0.0006	0.190/ 0.014	0.095/ 0.001	0.022/ 0.002	0.003/ 0.001	<0.01/ 0	<0.01/ 0	<0.02/ 0	<0.02/ 0	<0.005/ 0	<0.005/ 0	<0.05/ 0	<0.05/ 0

*equivalent Ministry of ELP site
nd = no data

Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

... continued

Table 7.2.6.2 (continued)

Site (continued)	Depth m	Si (mg/L) Tot	Si (mg/L) Dis	Sn (mg/L) Tot	Sn (mg/L) Dis	Sr (mg/L) Tot	Sr (mg/L) Dis	Ti (mg/L) Tot	Ti (mg/L) Dis	Zn (mg/L) Tot	Zn (mg/L) Dis
Buck 1 4007658*	0	5.51/ 0.29	5.09/ 0.06	<0.05/ 0	<0.05/ 0	0.111/ 0.008	0.111/ 0.002	0.006/ 0.001	<0.002/ 0	<0.002/ 0	<0.002/ 0
Bessemer 2 700081*	0	5.58	4.51	0.07	<0.05	4.14	4.01	0.002	0.051	0.051	0.04
Buck 3 400766*	0	5.42/ 0.12	5.26/ 0.04	<0.05/ 0	<0.05/ 0	0.497/ 0.019	0.533/ 0.001	<0.002/ 0	<0.002/ 0	<0.002/ 0	<0.002/ 0
Goosly 12 700084*	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	8	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	16	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Buck 13 (d/s Goosly)	0	<0.005/ 0	<0.005/ 0	<0.05/ 0	<0.05/ 0	0.259/ 0.004	0.272/ 0.002	0.003/ 0	<0.002/ 0	<0.002/ 0	<0.002/ 0

*equivalent Ministry of ELP site
nd = no data

Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

Table 7.2.6.3. Environment Canada Water Quality Data for the Buck Creek System, June 30, 1989

Site	Depth	Alk	pH	NFR	S04	Ag (mg/L)		Al (mg/L)		As (mg/L)		Ba (mg/L)		Cd (mg/L)		Co (mg/L)	
	m	mg/L		mg/L	mg/L	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck Cr 1	0	63.1/	8.1/	12/	5/	<0.01/	<0.01/	0.13/	<0.05/	<0.05/	<0.05/	0.028/	0.025/	0.0001/	<0.0001/	<0.005/	<0.005/
400765*		26.9	0	8	1	0	0	0.07	0	0	0	0.003	0	0	0	0	0
Bessemer Cr 2	0	74.2/	8.3/	23/	400/	<0.01/	<0.01/	1.81/	0.15/	<0.05/	0.06/	0.071/	0.060/	0.0014/	0.0014/	0.011/	<0.005/
700081*		0.8	0	1	26	0	0	0.17	0	0	0	0.001	0.001	0.0001	0.0001	0.002	0
Buck Cr 3	0	55.3/	8.2/	30/	84/	<0.01/	<0.01/	0.52/	<0.05/	<0.05/	<0.05/	0.048/	0.028/	<0.0001/	<0.0001/	0.006/	<0.005/
400766*		0	0	17	6	0	0	0.4	0	0	0	0.006	0.02	0	0	0.001	0
Goosly 12	1	36.9	8	<5	27	<0.01	<0.01	0.1	<0.05	<0.05	<0.05/	0.028	0.028	<0.0001	<0.0001	<0.005	<0.005
700084*	3	34.9	8	<5	29	<0.01	<0.01	0.05	<0.05	<0.05	<0.05/	0.025	0.026	<0.0001	<0.0001	<0.005	<0.005
	8	36.9	8.1	<5	28	<0.01	<0.01	<0.05	<0.05	0.06	<0.05/	0.025	0.025	<0.0001	<0.0001	0.008	<0.005
	16	41.7	8.1	<5	29	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05/	0.025	0.025	<0.0001	<0.0001	<0.005	<0.005
Buck Cr 13	0	35.9/	8/	<5/	26/	<0.01/	<0.01/	0.11.	<0.05/	<0.05/	<0.05/	0.026/	0.025/	0.0001/	<0.0001/	<0.005/	<0.005/
(d/s Goosly)		0	0	0	2	0	0	0.04	0	0	0	0.001	0.001	0	0	0	0

Site	Depth	Cr (mg/L)		Cu (mg/L)		Fe (mg/L)		Mn (mg/L)		Mo (mg/L)		Ni (mg/L)		Pb (mg/L)		Sb (mg/L)	
	m	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck 1	0	0.007/	<0.005/	0.0039/	0.0008/	0.468/	0.290/	0.033/	0.026/	<0.01/	<0.01/	<0.02/	<0.02/	0.0006/	<0.0005/	<0.05/	<0.05/
4007658*		0	0	0.0046	0.0002	0.046	0.011	0.001	0	0	0	0	0	0	0	0	0
Bessemer 2	0	0.006/	<0.005/	0.092/	0.045/	1.123/	0.033/	0.483/	0.504/	<0.01/	<0.01/	0.03/	<0.02/	0.0006/	<0.0005/	0.06/	0.06/
700081*		0	0	0.006	0.005	0.057	0.001	0.004	0.003	0	0	0	0	0	0	0.01	0.01
Buck 3	0	<0.005/	<0.005/	0.0060/	0.0045/	1.050/	0.360/	0.115/	0.094/	<0.01/	<0.01/	<0.02/	<0.02/	0.0006/	<0.0005/	<0.05/	<0.05/
400766*		0	0	0.0012	0.0003	0.391	0.031	0.018	0.001	0	0	0	0	0	0	0	0
Goosly 12	1	<0.005	<0.005	0.0049	0.005	0.31	0.149	0.067	0.006	<0.01	<0.01	<0.02	<0.02	0.0006	<0.005	<0.05	<0.05
700084*	3	<0.005	<0.005	0.0073	0.005	0.205	0.109	0.02	0.003	<0.01	<0.01	<0.02	<0.02	0.0006	<0.005	<0.05	<0.05
	8	0.005	<0.005	0.0044	0.005	0.138	0.09	0.013	0.002	<0.01	<0.01	<0.02	<0.02	0.0006	<0.005	<0.05	<0.05
	16	<0.005	<0.005	0.0088	0.004	0.144	0.091	0.011	0.002	<0.01	<0.01	<0.02	<0.02	0.0006	<0.005	<0.05	<0.05
Buck 13	0	<0.005/	<0.005/	0.0029/	0.0047/	0.254/	0.144	0.051/	0.025/	<0.01/	<0.01/	<0.02/	<0.02/	0.0006/	<0.0005/	<0.05/	<0.05/
(d/s Goosly)		0	0	0.0012	0.001	0.035	0.016	0.002	0.002	0	0	0	0	0	0	0	0

*equivalent Ministry of ELP site
nd = no data
Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

Table 7.2.6.3 (continued)

Site (continued)	Depth m	Si (mg/L) Tot	Si (mg/L) Dis	Sn (mg/L) Tot	Sn (mg/L) Dis	Sr (mg/L) Tot	Sr (mg/L) Dis	Ti (mg/L) Tot	Ti (mg/L) Dis	Zn (mg/L) Tot	Zn (mg/L) Dis
Buck 1 4007658*	0	4.95/ 0.14	4.61/ 0.04	<0.05/ 0	<0.05/ 0	0.132/ 0.003	0.136/ 0.001	nd	nd	0.015/ 0.001	<0.002/ 0
Bessemer 2 700081*	0	6.45/ 0.23	4.37/ 0.03	<0.05/ 0	<0.05/ 0	6.477/ 0.093	7.097/ 0.075	nd	nd	0.097/ 0.003	0.039/ 0.002
Buck 3 400766*	0	5.82/ 0.82	5.12/ 0.83	<0.05/ 0	<0.05/ 0	1.267/ 0.031	0.9/ 0.702	nd	nd	0.019/ 0.001	<0.002/ 0
Goosly 12 700084*	1	4.57	4	<0.05	<0.05	0.305	0.314	nd	nd	0.033	0.016
	3	4.17	3.69	<0.05	<0.05	0.304	0.311	nd	nd	0.022	0.004
	8	3.6	3.2	<0.05	<0.05	0.328	0.331	nd	nd	0.017	0.005
	16	3.56	3.27	<0.05	<0.05	0.327	0.337	nd	nd	0.021	0.004
Buck 13 (d/s Goosly)	0	2.92/ 0.15	2.61/ 0.05	<0.05/ 0	<0.05/ 0	0.302/ 0.002	0.315/ 0.005	nd	nd	0.011/ 0.001	<0.002/ 0

*equivalent Ministry of ELP site
nd = no data

Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

Table 7.2.6.4. Environment Canada Water Quality Data for the Buck Creek System, June 15-17, 1990

Site	Depth	Alk	pH	NFR	S04	Ag (mg/L)		Al (mg/L)		As (mg/L)		Ba (mg/L)		Cd (mg/L)		Co (mg/L)	
	m	mg/L		mg/L	mg/L	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck 1	0	41/	7.7/	10/	4.2/	<0.01/	<0.01/	0.56/	0.09/	<0.05/	<0.05/	0.033/	0.026/	<0.0001/	<0.0001/	<0.005/	<0.005/
400765*		0	0	1	0.2	0	0	0.02	0.02	0	0	0.001	0	0	0	0	0
Bessemer 2	0	52	7.8	<5	897	<0.01	<0.01	0.43	0.08	<0.05	<0.05	0.055	0.047	0.0014	0.0014	<0.005	<0.005
700081*																	
Buck 3	0	44/	7.7/	<5/	149/	<0.01/	<0.01/	0.42/	0.07/	<0.05/	<0.05/	0.042/	0.037/	0.0002/	0.0002/	<0.005/	<0.005/
400766*		0	0	0	7.6	0	0	0.05	0.01	0	0	0.001	0.001	0	0	0	0
Goosly 12	0	37	7.7	<5	64.3	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.03	0.027	0.0002	<0.0001	<0.005	<0.005
700084*	10	37	7.6	<5	56.4	<0.01	<0.01	0.14	<0.05	<0.05	<0.05	0.034	0.028	0.0002	<0.0001	<0.005	<0.005
	19	38	7.5	29	54.4	<0.01	<0.01	0.92	<0.05	<0.05	<0.05	0.051	0.037	<0.0001	<0.0001	<0.005	<0.005
Buck Cr 13	0	37/	7.7/	6/	57.9/	<0.01/	<0.01/	0.16/	<0.05/	<0.05/	<0.05/	0.031/	0.027/	<0.0001/	<0.0001/	<0.005/	<0.005/
(d/s Goosly)		1	0	0	3	0	0	0.01	0	0	0	0.001	0	0	0	0	0

Site	Depth	Cr (mg/L)		Cu (mg/L)		Fe (mg/L)		Mn (mg/L)		Mo (mg/L)		Ni (mg/L)		Pb (mg/L)		Sb (mg/L)	
	m	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis	Tot	Dis
Buck 1	0	0.007/	<0.005/	<0.005/	<0.005/	0.665/	0.274/	0.036/	0.023/	<0.01/	<0.01/	<0.02/	<0.02/	0.0027/	<0.0005/	<0.05/	<0.05/
4007658*		0	0	0	0	0.013	0.015	0.001	0.002	0	0	0	0	0.0003	0	0	0
Bessemer 2	0	0.011	<0.005	0.028	0.017	0.345	0.035	0.241	0.224	<0.01	<0.01	<0.02	<0.02	0.0041	<0.0005/	<0.05	<0.05
700081*																	
Buck 3	0	0.009/	0.009/	0.009/	<0.005/	0.772/	0.351/	0.116/	0.1/	<0.01/	<0.01/	<0.02/	<0.02/	0.0036/	0.0011/	<0.05/	<0.05/
400766*		0.002	0	0.001	0	0.047	0.004	0.004	0.001	0	0	0	0	0.0007	0.0005	0	0
Goosly 12	0	0.011	<0.005	0.007	<0.005	0.214	0.108	0.028	0.002	<0.01	<0.01	<0.02	<0.02	0.0056	0.0014	<0.05	<0.05
700084*	10	0.008	<0.005	0.006	<0.005	0.269	0.131	0.04	0.003	<0.01	<0.01	<0.02	<0.02	0.0021	0.0007	<0.05	<0.05
	19	0.01	<0.005	0.007	<0.005	1.62	0.223	0.203	0.121	<0.01	<0.01	<0.02	<0.02	0.0095	0.0008	<0.05	<0.05
Buck 13	0	<0.005/	<0.005/	<0.005/	<0.005/	0.264/	0.116/	0.046/	0.011/	<0.01/	<0.01/	<0.02/	<0.02/	0.0027/	0.0011/	<0.05/	<0.05/
(d/s Goosly)		0	0	0	0	0.011	0.002	0.001	0.001	0	0	0	0	0.0015	0.0001	0	0

*equivalent Ministry of ELP site

Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

... continued

Table 7.2.6.4. (continued)

Site (continued)	Depth m	Si (mg/L) Tot	Si (mg/L) Dis	Sn (mg/L) Tot	Sn (mg/L) Dis	Sr (mg/L) Tot	Sr (mg/L) Dis	Ti (mg/L) Tot	Ti (mg/L) Dis	Zn (mg/L) Tot	Zn (mg/L) Dis
Buck 1 4007658*	0	7.32/ 0.04	6.21/ 0.02	<0.05/ 0	<0.05/ 0	0.128/ 0.001	0.125/ 0.001	0.008/ 0.001	<0.002/ 0	<0.002 / 0	<0.002/ 0
Bessemer 2 700081*	0	4.16	3.52	<0.05	<0.05	4.16	4.06	<0.002	<0.002	0.071	0.048
Buck 3 400766*	0	6.72/ 0.19	5.88/ 0.04	<0.05/ 0	<0.05/ 0	0.895/ 0.008	0.879/ 0.007	<0.002/ 0	<0.002/ 0	0.010/ 0.007	0.003/ 0.001
Goosly 12 700084*	0	5.03	4.75	<0.05	<0.05	0.468	0.459	<0.002	<0.002	<0.002	<0.002
	10	5.19	4.93	<0.05	<0.05	0.447	0.443	<0.002	<0.002	<0.002	<0.002
	19	7.88	5.32	<0.05	<0.05	0.45	0.434	0.015	<0.002	0.007	<0.002
Buck 13 (d/s Goosly)	0	5.08/ 0.02	4.63/ 0.02	<0.05/ 0	<0.05/ 0	0.449/ 0.005	0.443/ 0.004	<0.002/ 0	<0.002/ 0	<0.002 / 0	<0.002/ 0

*equivalent Ministry of ELP site

Note: Sites 1, 3 and 13 data are the means of 3 replicates, followed by the standard deviations (mean concentration/SD)

Table 8.2.1. Mean Metal Concentrations in Goosly Lake Fish, 1982-1994

Tissue	Species	Sample Date	Ref.#	Tissue Metal Concentrations (in µg/g dry weights)												
				Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg	Mn
muscle	i) Rainbow trout	82/10/14	1	5.6	<25	nd	1300	<1	nd	nd	1.6	34.5	nd	nd	nd	nd
		83/05/04	1	<2	<25	nd	800	<1	nd	nd	<1	<1	nd	nd	nd	nd
		85/05/28	1	3	<0.1	nd	1300	<1	nd	nd	1.9	29.5	nd	nd	nd	nd
		88/06/17	2	<4	<4	<0.12	1013	<0.12	<0.4	<0.4	1.9	18.3	0.363	19600	1290	0.8
		94/10/04	3	nd	nd	nd	nd	<0.05	nd	nd	1.2	nd	nd	nd	nd	nd
		BC Pristine Lks/ (...SD)	4	**2.2/** 2.8	**0.27/** 0.94	**0.43/** 0.13	**680/** 1075	**0.41/** 0.05	nd	nd	**0.7/** 0.52	**13.5/** 14	**0.16/** 0.09	nd	nd	**0.49/** 0.23
	ii) Peamouth chub	88/06/17	2	<4	<4	2.1	2610	0.057	<0.4	<0.4	2.6	31.8	1.68	17100	1270	1.6
	iii) Largescale sucker	94/10/04	3	nd	nd	nd	nd	<0.05	nd	nd	1	nd	nd	nd	nd	nd
liver	Rainbow trout	82/10/14	1	nd	nd	nd	nd	14.8	nd	nd	257	nd	nd	nd	nd	nd
		90/06/17	2	<8	<8	<0.2	600	0.7	4.1	<0.8	247	1069	0.26	11300	770	6
		BC Pristine Lks/ (...SD)	4	**3.9/** 4.8	**0.32/** 1.13	**0.58/** 0.4	**148/** 147	**0.56/** 0.4	nd	nd	**92/** 84.2	**572/** 383	**0.2/** 0.2	nd	nd	**2.83/** 2.14

(continued)

Tissue	Species	Sample Date	Ref.#	Tissue Metal Concentrations (in µg/g dry weights)												
				Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
muscle	i) Rainbow trout	82/10/14	1	nd	nd	nd	nd	<11	nd	nd	nd	nd	2.9	nd	nd	33.2
		83/05/04	1	nd	nd	nd	nd	<10	nd	nd	nd	nd	1	nd	nd	16
		85/05/28	1	nd	nd	nd	nd	<11	nd	nd	nd	nd	2	nd	nd	33.5
		88/06/17	2	<0.8	1870	<2	11400	0.63	<4	<4	<4	<4	3.6	<0.2	<0.8	31
		94/10/04	3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	30.2
		BC Pristine Lks/ (...SD)	4	nd	nd	**2.2/** 0.7	**4363/** 808	**0.74/** 0.094	nd	nd	nd	nd	nd	nd	nd	**7.7/** 2.4
	ii) Peamouth chub	88/06/17	2	<0.8	1980	<2	10200	0.24	<4	<4	<5	<4	12.6	<0.2	<0.8	60.6
	iii) Largescale sucker	94/10/04	3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	35.5
liver	Rainbow trout	82/10/14	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	141
		90/06/17	2	<2	3760	<3	12900	<0.1	<7	20	12	<7	3	<0.3	<2	172
		BC Pristine Lks/ (...SD)	4	nd	nd	**2.9/** 1.9	**5492/** 1660	**1.3/** 3.4	nd	nd	nd	nd	nd	nd	nd	**51.8/** 30.2

*Reference No

1: Wilkes (1987)
2: Godin (1992)
3: Equity Environmental Report (1994)
4: Reiberger (1992): converted from wet weights

nd = no data

Table 8.2.2.1. Mean Metal Concentrations in Rainbow Trout Muscle from Buck and Foxy Creeks, 1982-1994

Sample Site	Date	As		Cu		Cd		Pb		Sb		Zn	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Buck Cr 400765	Jun-82	0.10	0.01	2.65	0.86	0.10	0.00	0.14	0.08	0.10	0.00	64.10	16.70
	Aug-82	0.10	0.04	2.08	0.18	0.10	0.00	0.29	0.18	0.10	0.00	32.80	3.70
	Aug-83	0.10	0.20	1.78	0.30	0.03	0.01	0.23	0.13	0.01	0.00	36.90	12.20
	Sep-84	0.28	0.00	0.70	0.17	0.12	0.06	0.10	0.00	0.05	0.00	27.10	3.00
	Sep-85	0.05	0.02	2.38	0.61	0.08	0.02	0.10	0.00	0.05	0.00	33.10	3.70
	Sep-86	0.05	0.00	1.74	0.32	0.05	0.00	0.05	0.00	0.05	0.00	32.84	2.56
	Sep-87	0.05	0.00	1.80	0.17	0.05	0.00	0.05	0.00	0.05	0.00	30.28	2.90
	Sep-88	0.05	0.00	1.81	0.41	0.05	0.00	0.09	0.04	0.05	0.00	24.17	2.43
	Sep-89	0.05	0.00	0.78	0.60	0.05	0.00	0.06	0.00	0.05	0.00	25.51	1.54
	Sep-90	0.13	0.05	2.93	0.47	0.09	0.04	0.05	0.00	0.05	0.00	45.48	4.98
	Sep-91	0.05	0.00	2.17	0.34	0.09	0.03	0.09	0.03	0.05	0.00	30.70	2.16
	Sep-93	0.17	0.08	3.16	0.57	0.11	0.06	0.05	0.00	0.01	0.00	54.38	5.87
Buck Cr 400766	Jun-82	0.11	0.02	2.20	0.57	0.10	0.00	0.35	0.46	0.10	0.00	73.70	26.80
	Aug-82	0.11	0.02	2.18	0.39	0.10	0.00	0.28	0.22	0.10	0.00	38.40	7.00
	Aug-83	0.10	0.02	1.42	0.23	0.03	0.01	0.18	0.12	0.01	0.01	60.30	13.10
	Sep-84	0.05	0.00	0.55	0.09	0.05	0.01	0.10	0.00	0.05	0.00	26.80	5.40
	Sep-85	0.05	0.00	1.58	0.50	0.08	0.05	0.07	0.04	0.05	0.00	33.10	8.60
	Sep-86	0.05	0.00	2.16	0.16	0.05	0.00	0.07	0.02	0.05	0.00	30.29	1.59
	Sep-87	0.07	0.05	1.84	0.26	0.05	0.00	0.05	0.00	0.05	0.00	33.01	4.65
	Sep-88	0.05	0.00	1.79	0.24	0.06	0.01	0.07	0.01	0.05	0.00	25.31	2.98
	Sep-89	0.05	0.00	1.33	0.47	0.05	0.00	0.05	0.00	0.05	0.00	24.20	2.38
	Sep-90	0.10	0.04	2.85	0.28	0.10	0.04	0.05	0.00	0.05	0.00	46.27	3.94
	Sep-91	0.06	0.01	2.12	0.21	0.06	0.02	0.15	0.05	0.05	0.00	29.42	1.37
	Sep-93	0.17	0.08	2.38	0.67	0.11	0.05	0.05	0.00	0.10	0.00	53.01	7.67
Buck Cr 700086	Jul-82	0.12	0.05	2.08	0.86	0.10	0.00	0.27	0.18	0.10	0.00	34.00	7.10
	Aug-82	0.11	0.02	2.20	0.79	0.10	0.00	0.17	0.18	0.10	0.00	31.20	3.80
	Sep-87	0.05	0.00	2.10	0.18	0.05	0.00	0.05	0.00	0.05	0.00	30.10	3.00
	Sep-88	0.05	0.00	1.42	0.15	0.06	0.01	0.06	0.01	0.05	0.00	26.03	3.71
	Sep-89	0.05	0.00	1.67	0.42	0.05	0.00	0.05	0.00	0.05	0.00	29.67	3.55
	Sep-90	0.05	0.00	2.90	0.24	0.09	0.05	0.05	0.00	0.05	0.00	49.50	6.22
	Sep-91	0.05	0.01	2.03	0.15	0.05	0.00	0.13	0.04	0.05	0.00	26.74	2.99
	Aug-93	0.12	0.06	2.35	1.01	0.05	0.01	0.05	0.03	0.10	0.00	50.40	18.77
Foxy Cr 700108	Jul-82	0.10	0.00	1.84	0.32	0.10	0.00	0.37	0.48	0.10	0.00	32.10	2.60
	Aug-82	0.10	0.00	2.57	0.53	0.10	0.00	0.13	0.07	0.10	0.00	32.20	6.40
	Sep-84	0.06	0.03	0.72	0.26	0.05	0.01	0.12	0.06	0.05	0.00	27.00	3.30
	Sep-85	0.06	0.02	2.20	0.31	0.05	0.01	0.14	0.10	0.05	0.00	23.50	2.90
	Sep-86	0.06	0.00	1.63	0.21	0.05	0.00	0.05	0.00	0.05	0.00	25.87	4.78
	Sep-87	0.05	0.00	1.60	0.15	0.05	0.00	0.05	0.00	0.05	0.00	25.70	3.15
	Sep-88	0.05	0.00	1.54	0.21	0.05	0.01	0.08	0.02	0.05	0.00	19.90	3.08
	Sep-89	0.05	0.00	1.69	0.41	0.05	0.00	0.05	0.00	0.05	0.00	25.62	2.52
	Sep-90	0.05	0.00	2.58	0.33	0.05	0.00	0.05	0.00	0.05	0.00	41.10	3.98
	Sep-91	0.05	0.00	1.86	0.19	0.05	0.00	0.07	0.02	0.05	0.00	24.67	3.42
	Aug-93	0.16	0.00	2.73	0.49	0.03	0.00	0.05	0.00	0.10	0.00	53.58	6.63
	Oct-94	nd		1.70	0.20	0.05	0.00	nd		nd		35.10	5.80
BC Pristine Lakes		**0.27**	0.94	**0.70**	0.52	**0.41**	0.01	**0.74**	0.94	nd		**7.70**	2.40

Note: All concentrations in µg/g dry weights
Permitee data (Equity Silver)

* from Reiberger (1992); converted from wet weights
nd = no data

Table 8.2.2.2. Mean Metal Concentrations in Rainbow Trout Liver from Buck and Foxy Creeks, 1982-1994

Site Number	Year	Mean Metal Concentration, µg/g Dry Weight					
		As	Cd	Cu	Pb	Sb	Zn
i) Buck Creek:							
400765	1987	<0.05	<0.05	343	<0.05	<0.05	219.3
	1988	<0.05	0.55	121	0.25	<0.05	180
	1989	nd	nd	nd	nd	nd	nd
	1991	0.05	1.55	234	0.45	0.05	187
	1993	<0.4	1	99	<0.2	<0.4	275
400766	1987	<0.05	<0.05	166	<0.05	<0.05	267.5
	1988	<0.05	0.5	208	0.25	<0.05	211.5
	1989	1.7	1.45	281	<0.05	<0.05	164.5
	1991	0.43	1.38	249.5	0.38	0.05	152.5
	1993	<0.1	0.6	368	<0.05	<0.1	434.5
(Below Goosly)	1987	<0.05	<0.05	53.3	<0.05	<0.05	205.3
	1988	<0.05	0.3	86.5	<0.05	<0.05	180
	1989	<0.1	0.55	56.5	<0.05	<0.1	259.5
	1991	0.05	0.45	77	0.35	0.05	158.5
	1993	0.7	0.57	72.5	<0.05	<0.05	392
ii) Foxy Creek:							
700108	1987	<0.05	<0.05	162.5	<0.05	<0.05	212.8
	1988	<0.05	<0.05	64	<0.05	<0.05	144
	1989	<0.05	0.55	208.5	<0.05	<0.05	264.5
	1991	0.06	0.7	248.3	0.5	0.05	144.5
	1993	<0.20	0.8	114.5	<0.2	<0.2	305
B.C. Pristine Lakes * / Stnd. Deviation		0.32 / 1.13	0.56 / 0.4	92.0 / 84.2	1.3 / 3.4	nd	51.8 / 30.2

Permittee data (Equity Silver)
nd = no data
* from Reiberger, 1992; data converted from wet weights