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CONSEQUENCES OF UNREGULATED RELEASE OF RAW ACID MINE DRAINAGE INTO THE BULKLEY RIVER, BRITISH COLUMBIA

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INTRODUCTION

Approximately 800 000 m^3 of acid mine drainage (AMD) is generated per year at the Equity Silver Mine southeast of Houston. The property is located in the headwaters of the Bulkley River, which flows northwesterly approximately 215 km and enters the Skeena River at Hazelton. The acid generation problem and the company's response to it are reported by Patterson (1987, this proceedings). The company continues to recognize that treatment of the AMD will be necessary well beyond the time when the ore body is exhausted and actual mining is finished. The AMD could continue to flow from the waste rock dump and other facilities. Ministry projections are that the flow of AMD could continue for up to 150 000 years (Wilkes 1985). The present mean rate of flow is approximately 26 litres per second from the main acid sump, and 3.3 litres per second from the No. 1 Dam seepage pond, located in the Foxy Creek drainage.

These seem like insignificant amounts, but the concentration of heavy metals in the AMD is such that even these small flows would have devastating effects on the Bulkley River if for whatever reason it was allowed to flow untreated from the property for a prolonged period of time.

In order to develop an understanding of the consequences to the river of this possibility, bioassays were set up using raw acid mine drainage and acutal Bulkley River water taken at Quick, about 90 km downstream from the mine (Figure 1). The bioassays were run in October 1986 and February 1987. Both times we were looking for the concentration of AMD in river water in which 50% of the test fish would survive for 96 hours. This test is refered to as the 96 hour LC50, or the concentration lethal to 50% of the test fish over a 96 hour period. This is the acute toxicity threshold.

This paper reports the results of the bioassays and develops a picture of the magnitude of the consequences the AMD would have on the river. It is

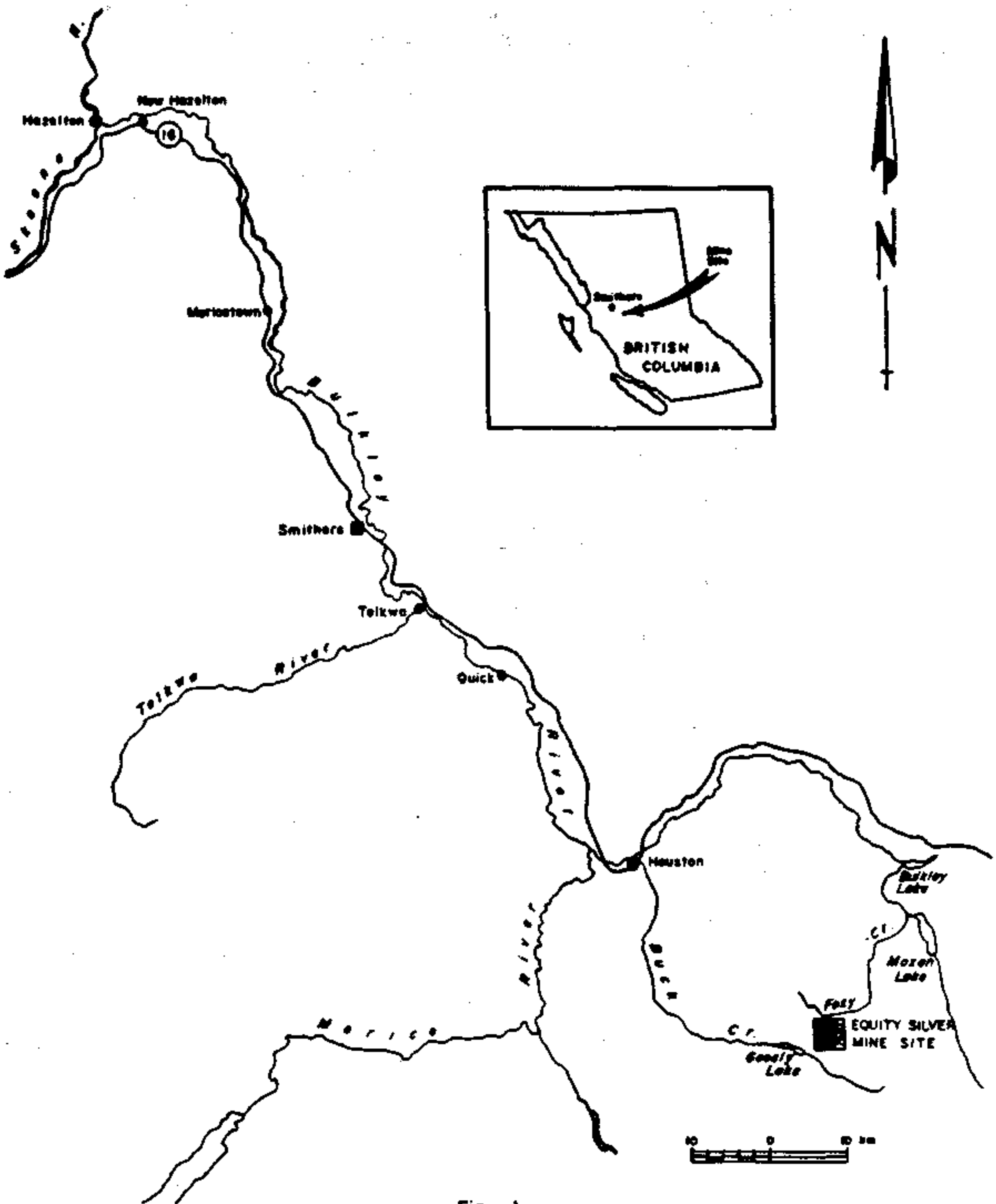


Fig. 1
LOCATION OF EQUITY SILVER MINE

confirmed that perpetual treatment of AMD at the minesite will be necessary to protect water quality and the sustainable economic benefits derived from the river.

This discussion should be useful for establishing that acid generation problems at mine sites can, and do, pose major environmental threats. While this is generally acknowledged by both government and industry, the spectre of what could lay ahead for the Bulkley is so horrendous it goes well beyond our usual notion of environmental impact.

THE BIOASSAYS

The bioassays were carried out according to standard methods (Bioassay Task Force, 1982) at the Federal Toxicity Laboratory in Vancouver, using juvenile rainbow trout as the test species.

The October 1986 set-up used samples collected several days earlier and sent by courier to Vancouver. In October the AMD was sampled from the main acid sump, which collects runoff from the waste rock dump, but also the plant site and south tail pit water. Chemical characteristics *of* the October AMD and river water used in the test are shown in Table 1.

TABLE 1 CHEMICAL CHARACTERISTICS OF AMD AND RIVER WATER OSED IN BIOASSAYS

	October 1986		February 1987	
	Bulkley at Quick (mg/l)	AMD (mg/l)	Vancouver tap water (mg/l)	AMD (mg/l)
pH	7.5	2.2	6	2.1
Diss Cu	<.001	63.8	<.005	527
Diss Zn	<.005	41.5	<.002	235
Diss As	<.001	9.5	<.05	174
Diss Fe	<.010	741	.092	7420
Diss Cd	<.010	.43	<.002	1.52
Diss Al	<.020	282	.17	1770
hardness	50.0		4.0	

The bioassay resulted in a 96 hr LC50 of .124% AMD in Bulkley River water. Therefore the AMD must be diluted by river water 806 times to achieve 50% survival of test fish (1 litre of AMD in 806 litres river water).

The February 1987 bioassay was set up using raw AMD from the ditch along the foot of the waste dump only. Unfortunately, Vancouver city tap water had to be used for the dilution water. Table 1 shows this AMD has much higher concentrations of dissolved metals. The bioassay resulted in a 96 hr LC50 of .0051%. This AMD must be diluted 19 608 times to achieve 50% survival of test fish. See Table 2.

TABLE 2 BIOASSAY RESULTS

AMD TYPE	MAIN ACID SUMP October 1986	WASTE ROCK DUMP DITCH February 1987
LC50	.124%	.0051%
mean flow	26 l/s	6 l/s
ppm Cu mg/l	.079	.027
ppm Zn	.051	.012
ppm As	.012	.009
dilution needed	1:806	1:19 608
Bulkley flow to achieve LC50	21 m^3/s	118 m^3/s

Based on the bioassay results, and known mean AMID flows, a river flow of 21 m^3/s would theoretically be needed in October to achieve the 96 hr LC50, and a river flow of 118 m^3/s would be needed to achieve it in February. Bearing in mind that winter low flows in the Bulkley consistenty drop below 20 m^3/s for periods of days or weeks, the river is at risk of becoming acutely toxic. Sub-lethal effects on fish and aquatic life in the river will occur well below the 96 hr LC50 concentration.

ASSUMPTIONS

Before going further here it is necessary to explain the assumptions used in forecasting the effects of the AMD on the river.

(1) I am assuming conditions under which AMD continuously and freely flows off the minesite for a period of years.

(2) I am assuming that both Goosly Lake and Bulkley Lake would eventually fill with dilute AMD and subsequently act as a continuous sources with minor fluctuations in concentration. The biological processes which sequester metals in the lakes would eventually stop. Because the lakes have storage, they would tend to dampen fluctuations in AMD flow and potency leaving the minesite.

(3) I am assuming there are 2 sources of AMD, one from the main acid sump, on the Buck Creek side, the other from the No. 1 Dam seepage pond on the Foxy Creek side.

(4) I am assuming a gradual increasing contamination of Buck and Foxy Creeks, followed in turn by the upper Bulkley River, and then the main Bulkley. The time frame for this creeping contamination is not known. Goosly Lake has a flushing rate of 0.9 years and this will have a bearing on how rapidly the AMD reaches an equilibrium concentration in the lake. Other factors will tend to slow the rate of contamination, such as the inherent resilience of the aquatic ecosystem.

DISCUSSION OF BIOASSAY RESULTS

Given these assumptions, several points need to be raised regarding the bioassay results:

(1) The AMD from the main sump is, on average, more potent than the material used for the bioassay in October (see Table 1). If AMD of average potency had been used, it is expected that the LC50 would have been lower, (i.e. less AMD required to achieve the same level of toxicity).

(2) The AMD from the waste rock dump ditch used in the February bioassay is extremely potent, containing 8x more copper, 10x more iron, 18x more arsenic and 6x more zinc than the October AMD sample, and was approximately 24x more toxic to fish. Dilution water used in February was Vancouver city tap water. This is 1.5 pH units lower than Bulkley River water, and has a hardness of 4 to 6 mg/l compared to 50 mg/l hardness in the river. Therefore we would expect the AMD to be somewhat less toxic in the river. New bioassays using the ditch AMD and actual river water will be set up in mid-April 1987 to evaluate this difference.

(3) Based on the October result, the 96 hr LC50 of the AMD at 0.124% calculates out to 0.079 mg/l copper, 0.051 mg/l zinc, and 0.012 mg/l arsenic (see Table 2). These concentrations would be expected to cause toxicity to the rainbow trout fry. Chinook and coho are more sensitive to copper (see review by Singleton and Travers, 1986). In *fact,* the copper 96 hr LC50 value calculated for the February AMD sample, 0.027 mg/l (Table 2) is closer to the expected LC50 for coho and chinook.

(4) Given the assumptions, when Bulkley River flows drop below the dilution required to achieve the 96 hr LC50, conditions in the river would be presumed to be acutely toxic to fish. Sublethal toxicity in aquatic organisms would occur at concentrations much lower than this. In fish, sublethal toxic effects can take the form of avoidance, affects on growth, detrimental changes in blood chemistry, failed spawning attempts and impaired metabolism (Singleton and

Travers, 1986). Early exposure to elevated copper levels in some juvenile salmonids prevents proper osmoregulation of sodium when they reach salt water. (Davis and Shand, 1978)

(5) The much higher toxicity of the February AMD sample is attributed to increased synergistic toxicities between metals at high concentrations and also the much higher proportion of arsenic.

FLOWS

Flow data show that, given the assumptions and bioassay results above, conditions do occur in the river which would cause acute toxicity to fish. The principle period of concern *is* the winter low flow condition between November 1 and March 31. River flows are lowest then, but flows of AMD remain elevated due to the heat generated by the waste rock dump. Table 3 shows mean monthly river flows in m^3/s for selected stations along the system. Table 4 shows the ratio of mean AMD flow to mean monthly river flow.

TABLE 3 MEAN MONTHLY FLOWS
(m^3/s)

	Bulkley above Buck Ck	Bulkley R. below Houston	Buck Ck at mouth	Bulkley R at Quick	Bulkley R at Hazelton[1]
Jan 86	.189*	.252*	0.063	16.9	23.2
Feb 86	.075*	.100*	.025	14.1	19.3
Mar 86	1.113*	1.484*	.371	23.6	32.3
Apr 86	7.76	10.3	2.54	46.7	64
May 86	32.3	48.6	16.3	179	245
Jun 86	46	66.9	20.9	499	683.6
Jul 86	7.09	9.32	2.23	251	343.9
Aug 86	.769	1.04	.271	132	180.8
Sep 86	.566	0.970	.404	73.5	100.0
Oct 86	2.53	3.81	1.28	69.0	94.5
Nov 86	2.887*	3.85*	.963	58.0	79.5
Dec 86	1.75*	2.30*	.575	34.0	46.6

Buck Drainage 580 km²
Upper Bulkley Drainage 2 380 km²

***calculated**

(1) The ratio of flow between Quick and Hazelton are estimated in Envirocon, 1981.

TABLE 4 DILUTION RATIOS
MEAN AMD FLOW TO KEAN MONTHLY DISCHARGE

	Bulkley above Buck	Buck at mouth	Bulkley at Quick	Bulkley at Hazelton
AMD flow (l/s)	3.3	26	29.3	29.3
1 9 8 6				
Jan	1:57	1:3	1:576	1:792
Feb	1:23	1:1	1:481	1:658
Mar	1:337	1:14	1:805	1:1102
Apr	1:2352	1:98	1:6109	1:2184
May	1:9788	1:627	1:17030	1:8362
Jun	1:13939	1:804	1:8566	1:23331
Jul	1:2148	1:86	1:4505	1:11737
Aug	1:233	1:10	1:2491	1:6171
Sep	1:172	1:16	1:2508	1:3413
Oct	1:766	1:49	1:2354	1:3225
Nov	1:887	1:37	1:1979	1:2696
Dec	1:530	1:22	1:1160	1:1590

TOXICITY ESTIMATION

Now that we know the dilutions available for mean flows for 1986, we can look at potential toxic effects in the river. We need to use mean metal content in the AMD as well. The October AMD sample was atypically low in metals and February was atypically high. Table 5 shows mean metals concentrations in the AMD from the acid sump for 1986, and from file records of No. 1 Dam seepage (Patterson, pers comm).

TABLE 5 MEAN CONCENTRATION OF METALS IN AMD

	AMD Main Sump (l/s)	No. 1 Dam Seepage (l/s)
flow	26	3.3
Cu mg/l	88	76
Zn mg/l	58	57
As mg/l	16	16.8
Fe mg/l	775	1346

The October 96 hr LC50 for copper was .079 mg/l. Assuming the same contribution to toxicity from the other metals/ and using the mean concentrations of metals, the following minimum dilutions would achieve the LC50 for copper in the Bulkley system:

Bulkley above Buck	Bulkley at Quick	Bulkley at Hazelton
1:962	1:1096	1:1096

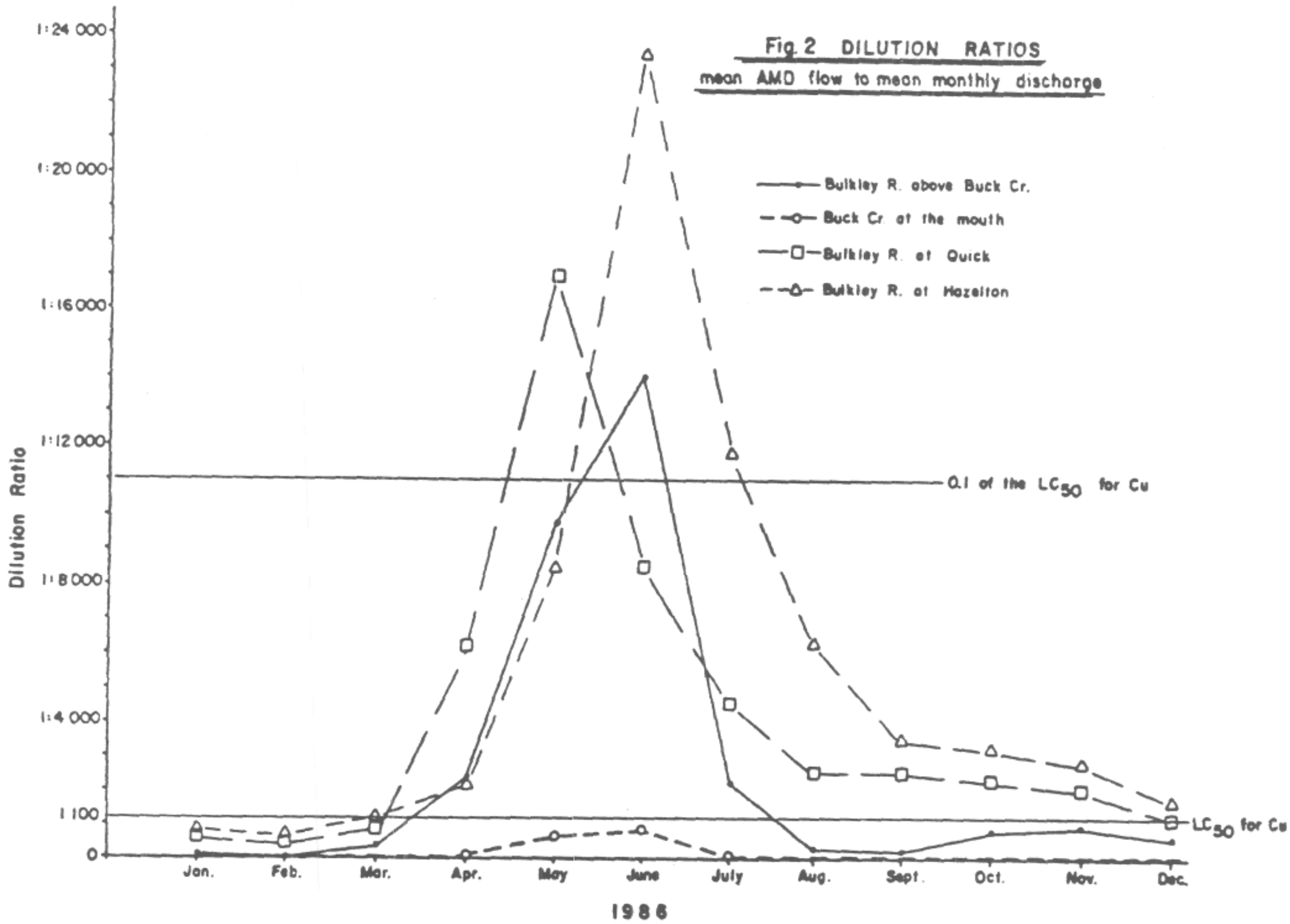
All ratios which are less than about 1:1100 would create conditions in the river toxic to fish. Based on Table 4, which is 1986 data, this includes every month in the upper Bulkley except April, May, June and July. The upper Bulkley would exceed objectives for drinking water (Reeder, 1979) for arsenic and copper for January, February, August and September.

Buck Creek would be toxic to fish all year. Copper, zinc and arsenic would exceed drinking water recommended maxima for most of the year, except May and June.

The Bulkley River at Ouick would exceed the 96 hr LC50 in January, February, March and would closely approach it in December. The Bulkley River at Hazelton would exceed the 96 hr LC50 in January, February and approach it in March.

Generally, in order to provide adequate protection to aquatic life, a contaminant level for copper of 0.1 of the 96 hr LC50 should be maintained (US EPA 1976). This amounts to .008 mg/l total copper in the river. This level should protect fish in the river against sublethal effects mentioned previously. Background concentrations of dissolved copper in the Bulkley River vary from less than .001 mg/l to .003 mg/l.

Figure 2 illustrates the dilution ratios in the river for four stations. The horizontal line at 1:1100 denotes the dilution ratio below which the river would be acutely toxic to fish, based on the October bioassay results. All stations in the river fall below the line during the critical late winter low flows. The horizontal line at 1:11000 denotes the dilution ratio which achieves 0.1 of the LC50 determined in October. Flows below the line are not adequate to provide protection to fish from sub-lethal effects of metal contamination. Figure 2 clearly shows that aquatic resources in the entire river would be under some threat for most of the year, and under an acute threat during low flow periods.



RESOURCES AT RISK IN THE BULKLEY RIVER

Now that we have established the potential extent of the contamination in the Bulkley River, it is necessary to outline the resource values at stake. This will add to our understanding of the magnitude and importance of the potential impact.

In the following discussion an attempt is made to put a dollar value on the fisheries benefits from the river. But it is simply not possible to quantify the value placed on the river by the residents of the valley. The river serves as the unifying thread and context for life in the valley, and a simple economic assessment cannot take this into account.

Water uses, hydrology and water quality in the Bulkley River basin was assessed in detail in 1985 (Nijman 1986). This assessment contains discussions of the major economic uses of the Bulkley, all of which are dependent on the maintenance of good water quality.

Fisheries

The main fish species using the river are resident rainbow and anadromous steelhead trout, pink, coho, sockeye and chinook salmon, cutthroat trout and Dolly Varden char, whitefish, and longnose dace.

For salmonid species, the river serves as a migration route, holding water, spawning ground, and rearing area.

Adult steelhead and resident trouts overwinter in the mainstem Bulkley and Morice Rivers. The upper Bulkley, Buck Creek and the Morice Rivers produce most of the steelhead fry, and older juvenile steelhead drop down to the main stem Bulkley below Houston prior to smelting (Envirocon, 1981). Salmonid species produced in the system contribute to the sport and commercial ocean salmon fishery on the north coast.

Valuing the fish resources is done using models developed by the Department of Fisheries and Oceans. The actual values are very rough estimates, which are subject to revision as the models are refined.

Table 6 shows approximate values of the three basic economic activities centred on fish. These are the sport fishery, native food fishery, and the Bulkley's contribution to the north coast commercial fishery. These are discussed in greater detail in Mullen (1987).

TABLE 6 ESTIMATED ECONOMIC VALUES
OF BULKLEY RIVER FISHERIES
(X $1000)

	Net	Gross	Present value discounted at 8% over 60 years
Sport Fishery	$1,300	$3,000	$20,845
Food Fishery	104	239	2,205
Commercial Fishery	131	301	3,340
Total	$1,535	$3,540	$26,400

Present values are reported in Mullen (1987). Net values are grossed by using a multiplier of 2.3. The food fishery is valued at the commercial opportunity cost. Indians fish along the Skeena and Bulkley Rivers. Hagwilget and Moricetown canyons are the key fishing locations on the Bulkley.

The potential exists for expansion of sport and commercial fisheries. Steelhead enhancement efforts are underway in the Bulkley system, and first adult returns are expected this year.

Recreation Values

The Bulkley and Morice Rivers are growing in importance for sport fishing, particularly for steelhead. In 1986 there were an estimated 19 400 angler days expended over a season lasting from about mid-July to November 31. Nine licenced fishing guides operate on the river, serving a clientele from all over the world, some of whom come to B.C. specifically to fish the Bulkley River. Mullen (1987) estimated the economic value of the sport fishery to be $1.2 million per annum. The river is also of local importance for canoeing and kayaking, swimming and as a setting for family recreation. A value has not been estimated for these uses.

Also, I have not included an estimate *of* the cost of seeking alternative drinking water supplies for *the* domestic water users along Buck Creek and the upper Bulkley River.

DISCUSSION

The consequences of long term, unregulated release of raw acid mine drainage into the Bulkley River, based on mean AMD flow into mean monthly river flows, would be as follows:

(1) The gradual poisoning and eventual loss of all fish in the upper Bulkley River, Buck Creek, and the mainstem Bulkley River. Resident fish in the Morice River would be unaffected. During peak flows in May, June, and July, it is possible Chinook and coho salmon could get through the diluted waters of the Bulkley to spawn in the Morice. But if juveniles *of* these species venture downstream to the mainstem Bulkley during winter low flow conditions they could be at risk.

It is expected that fish would be eliminated, at least seasonally, as far downstream as Hazelton, 215 river km from the minesite. It is not necessary to kill all fish outright. It is enough merely to create habitat conditions so severe it causes a steady decline through avoidance, poor recruitment or other chronic sublethal toxic effect.

(2) The loss of the economic benefits and employment which the commercial and sports fisheries represent. This is a sustainable value estimated to be in the range of $4.3 million per annum.

(3) Contamination of the system and subsequent loss of drinking water quality in Buck Creek and the upper Bulkley River.

(4) A public perception that the river is contaminated, with an attendant reduction in recreational uses.

These consequences are of such a magnitude that they cannot be permitted. This brings the discussion back to the treatment of the AMD at its source by Equity Silver Mines Ltd. The company presently spends about $1.1 million per year treating the drainage/ removing the metals down to discharge standards, and discharging the treated effluent under controlled conditions. In casting our sights forward, the costs associated with perpetual treatment and sludge disposal are very high. But these costs pale against the value of what would be forfeited by the alternative.

In the Equity Silver Mine case, the magnitude of this potential impact on the Bulkley River was never clearly visualized until now. But these impacts, and their related costs, plus the costs associated with preventing the impact for the forseeable future need to be accounted for in the planning and approval of mine developments.

The Ministry of Environment and Parks, in its role as a member of the mine development steering committee, is therefore understandably being extra careful and cautious in the evaluation of new raining proposals where this problem could recur.

March 1987

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