WATER QUALITY OF TRIBUTARIES TO DILLON RESERVOIR

Submitted to

Breckenridge, Copper Mountain, and Keystone Ski Areas

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by

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INTRODUCTION

A water quality study was conducted on the Blue River, Tenmile Creek, the Snake River and selected tributaries. Drainage from historical metal mining activity has been shown to have deleterious effects on the biological communities of streams in the Dillon Reservoir area (Britton 1979, Goettl 1970, Wentz 1974). The present study consisted of collection and analysis of water quality samples and stream bottom sediments. The purpose of the study was to determine the water quality of the study streams during spring 1985. This data will be compared to the concurrent benthic invertebrate collections and future fish sampling and used as a data base to finalize minimum stream flow recommendations for these streams.

SAMPLING LOCATIONS

Eighteen sampling stations were located on the Snake River, the Blue River, Tenmile Creek and selected tributaries above and below the ski areas (Fig. 1). Station locations are summarized in Table 1.

METHODS

Water quality samples were collected on 17 - 19 and 25 April 1985 along with benthic invertebrates. The samples consisted of "grab" samples collected at the mid-point of the stream, mid-depth. Samples were placed in plastic bottles and preserved according to U.S. EPA recommended methods (U.S. EPA 1982). Samples were delivered within 48 hours to Core Laboratories, Aurora, Colorado, for analysis.

Field measurements of flow, dissolved oxygen, pH, specific conductivity, and water temperature were taken when water quality samples were collected. Flow measurements were made using a Gurley pygmy flow meter and top-setting rod. Dissolved oxygen, pH, specific conductivity and water temperature measurements were made in the field using Beckman and Altex meters.

Stream bottom sediments were collected along a transect across the stream and composited into one sample. Sediment was also collected from pools and still water areas to collect fine sediments. The samples were collected with a plastic scoop and placed in plastic bags.

Water quality samples were analyzed by Core Laboratories in Aurora, Colorado. The samples were analyzed according to recognized methods (APHA 1980, U.S. EPA 1983). Water quality parameters measured included pH, conductivity, total dissolved solids (TDS), total suspended solids (TSS), hardness, nitrate, nitrite, orthophosphate, cadmium, copper, iron, lead, manganese, molybdenum and zinc.

Stream bottom sediments were analyzed by Core Laboratories. The samples were digested in acid and then analyzed with atomic absorption (U.S. EPA 1983). Total metal concentrations were determined for cadmium, copper, iron, lead, manganese, molybdenum and zinc.

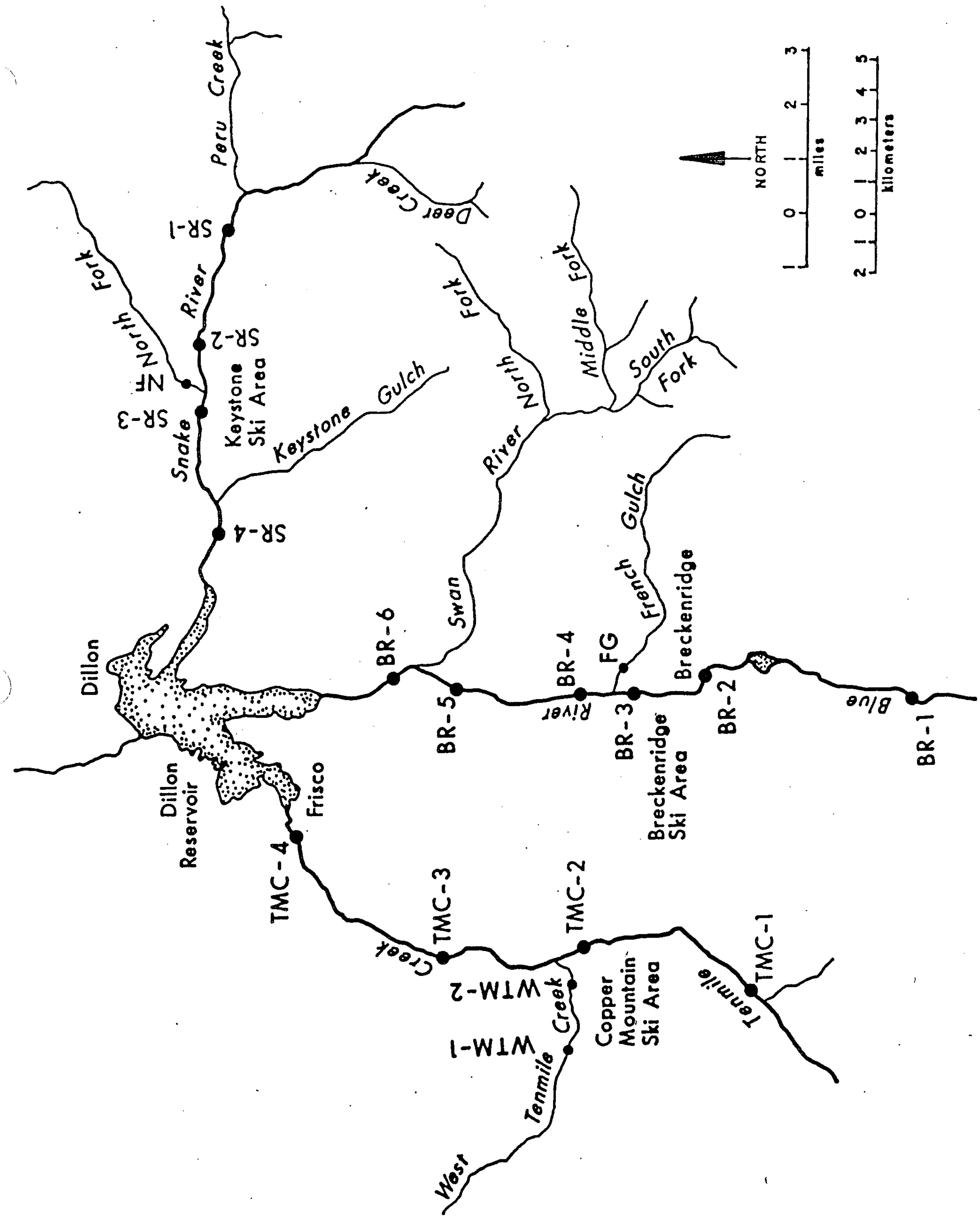

Figure 1: Station locations on tributary streams to Dillon Reservoir, Colorado, April 1985.

Table 1: Sampling locations for streams in Summit County near the Breckenridge, Copper Mountain, and Keystone Ski areas, Colorado, April 1985.

Station	Location	Elevation	Distance upstream of Dillon Reservoir
Blue River			
1	SW1/4 SW1/4 Sec 30 T7S R77W	3120 m (10235 ft)	21.09 km (13.11 mi)
2	NW1/4 SE1/4 Sec 6 T7S R77W	2958 m (9705 ft)	12.95 km (8.05 mi)
3	NW1/4 NW1/4 Sec 31 T6S R77W	2896 m (9500 ft)	9.75 km (6.06 mi)
4	SW1/4 NW1/4 Sec 30 T6S R77W	2871 m (9420 ft)	8.23 km (5.11 mi)
5	NE1/4 NW1/4 Sec 18 T6S R77W	2800 m (9195 ft)	4.27 km (2.65 mi)
6	NW1/4 NE1/4 Sec 7 T6S R77W	2780 m (9120 ft)	2.68 km (1.67 mi)
French Gulch			
	NE1/4 NW1/4 Sec 31 T6S R77W	2902 m (9520 ft)	0.37 km (0.23 mi)*
Tenmile Creek			
1	NW1/4 NW1/4 Sec 18 T7S R78W	3141 m (10305 ft)	19.02 km (11.82 mi)
2	SE1/4 SW1/4 Sec 29 T6S R78W	2978 m (9770 ft)	13.04 km (8.11 mi)
3	SW1/4 SW1/4 Sec 8 T6S R78W	2877 m (9440 ft)	6.98 km (4.37 mi)
4	SE1/4 NW1/4 Sec 34 T5S R78W	2780 m (9120 ft)	2.13 km (1.33 mi)
West Tenmile Cr.			
1	SW1/4 NE1/4 Sec 25 T6S R79W	3005 m (9860 ft)	2.80 km (1.74 mi)*
2	SW1/4 NE1/4 Sec 30 T6S R78W	2961 m (9715 ft)	1.37 km (0.85 mi)*
Snake River			
1	SW1/4 SE1/4 Sec 22 T5S R76W	2975 m (9760 ft)	12.71 km (7.90 mi)
2	NW1/4 NW1/4 Sec 20 T5S R76W	2860 m (9385 ft)	8.23 km (5.11 mi)
3	SW1/4 NW1/4 Sec 19 T5S R76W	2836 m (9305 ft)	6.40 km (3.98 mi)
4	NW1/4 SE1/4 Sec 22 T5S R77W	2774 m (9100 ft)	1.74 km (1.08 mi)
North Fork			
	NW1/4 NE1/4 Sec 19 T5S R76W	2858 m (9375 ft)	0.46 km (0.28 mi)*

* distance above their confluence with Blue River, Tenmile Creek and Snake River, respectively.

RESULTS AND DISCUSSION

The three drainage basins of interest have all been heavily impacted by past metal-mining activities. It is well documented that drainage from old mines and tailings piles can be harmful to aquatic organisms and humans. The mine drainage, if severe enough, can make waters unusable for recreational activities and domestic use (Boyles et al. 1974, Wentz 1974, Wildeman 1981).

Surface waters and aquatic organisms are impacted the most at the point where mine drainage enters the water. Effects decrease downstream as a result of natural buffering conditions of the stream, dilution, and metals precipitating out of solution (Hem 1970). The effects on water quality tend to show seasonal variations, dependent upon time, atmospheric precipitation, snowmelt runoff and other factors. A one-time "grab" sample can not be used to definitively classify a river system. However, combined with historical data and benthic invertebrate samples, the data can be used to gain a general understanding of current conditions.

Blue River and French Gulch

The Blue River and French Gulch were mined using a floating dredge from the late 1800's to 1940's. This type of mining disturbed large areas of the river and produced large spoils piles. More conventional types of mining have also been used in the French Gulch basin (Moran and Wentz 1974).

Results of the water quality samples and stream sediment sampling are presented in Tables 2 and 3. Overall water quality on the Blue River is good for domestic and aquatic use. Total dissolved solids (TDS) and nutrient levels are low, the water is classified as soft to moderately hard, and all pH values are greater than 7 (U.S. EPA 1976). There was an increase in TDS and zinc at Station 4, which is just downstream of French Gulch. However, concentrations decrease to background levels downstream.

Iron concentrations are a problem throughout the river. Concentrations consistently exceeded the 0.3 mg/l criteria for domestic use (U.S. EPA 1976). Iron is not toxic at these concentrations, but can affect the taste of the water and may stain laundry. Iron concentrations, also, approached the recommended criteria of 1.0 mg/l for aquatic life (U.S. EPA 1976). The concentrations that are present may affect some aquatic species (Moran and Wentz 1974).

Flows on the Blue River are quite variable. Much of the flow downstream of Station 2 is subsurface through the spoils as indicated by the reduced flows at Stations 3 and 4. Flows return to normal at Stations 5 and 6.

French Gulch had the poorest water quality. Field observation noted a thick coating of iron oxide on the stream bottom. Iron, manganese and zinc concentrations exceeded the recommended water quality criteria for domestic use and aquatic life (U.S. EPA 1976). The effects of French Gulch can be seen at Station 4, but are not apparent downstream at Stations 5 or 6.

Total metal concentrations in stream bottom sediments followed the same pattern as the water quality parameters. Stations 1 and 2 are upstream of the floating dredge mining and can be considered to have normal background concentrations. Metal concentrations are elevated at Stations 3 and 4 and return to near background levels at Stations 5 and 6. French Gulch discharges into the Blue River just below Station 3. Although Station 3 is upstream of French Gulch, the elevated concentrates may be caused by alluvial flow from French Gulch or discharges from old mines near Station 3.

French Gulch had the highest sediment metal concentrations, especially manganese and zinc (Table 3). Concentrations were much higher on French Gulch than they were on the Blue River. The apparent cause is drainage from the old mines in the hillsides along French Gulch.

Table 2: Selected physiochemical parameters for stations on the Blue River and French Gulch, Colorado, April, 1985 (all values mg/l unless noted).

	BLUE RIVER						FRENCH GULCH
Parameters	1	2	3	4	5	6	
Physical Parameters							
Flow (cfs)	14.6	39.6	17.0	3.8	37.7	82.4	4.9
Water Temperature (°C)	6.0	6.0	5.0	5.0	9.0	6.0	3.0
Dissolved Oxygen	10.4	10.2	11.9	8.5	9.7	13.5	10.3
pH (field)	N/A	8.5	N/A	N/A	7.2	8.5	8.3
pH (lab)	7.97	8.06	8.03	7.54	7.65	7.91	7.38
Conductivity (field) (umhos/cm @ 25°C)	107	147	139	202	140	151	270
Conductivity (lab) (umhos/cm @ 25°C)	141	178	163	229	156	168	288
Total Dissolved Solids	68	84	62	121	79	63	165
Total Suspended Solids	7	< 4	38	< 4	< 4	< 4	< 4
Chemical Parameters							
Hardness (as mg/l $CaCO_3$)	58.3	77.6	68.4	93.8	62.2	72.5	114
Nitrate	0.1	0.1	0.2	0.3	0.5	0.3	0.1
Nitrite	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Orthophosphate	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Cadmium (ug/l)	<1	<1	<1	3	1	1	5
Copper	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.92	0.47	1.91	0.36	0.53	0.19	1.44
Lead	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01
Manganese	0.04	0.02	0.07	<0.01	<0.01	<0.01	1.29
Molybdenum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.02	<0.01	0.08	0.97	0.13	0.07	4.8

Table 3: Total metal concentrations in stream bottom sediments for stations on the Blue River and French Gulch, Colorado, April 1985 (all values mg/kg).

Parameters	BLUE RIVER 1	2	3	4	5	6	FRENCH GULCH
Cadmium	<0.05	<0.05	0.65	7.5	2.75	1.50	17
Copper	13.5	14	39.5	66	27	18	78
Iron	15500	14000	23500	26500	19000	19000	26000
Lead	60	90	80	380	115	100	285
Manganese	750	750	750	1600	600	850	5200
Molybdenum	<5	<5	<5	<5	<5	<5	5
Zinc	125	100	235	1850	550	290	4350

Tenmile Creek and West Tenmile Creek

The headwaters of Tenmile Creek had extensive amounts of metal-mining activity in the past. Currently the Climax mine is producing molybdenum and disposing the tailings in the headwaters. During spring runoff, excess process water from the tailings is eventually discharged into Tenmile Creek (Moran and Wentz 1974).

Results of water quality sampling from Tenmile Creek and West Tenmile Creek are summarized in Tables 4 and 5. Water quality is poorest in upper Tenmile Creek. Stations 1 and 2 are immediately downstream of the mining activity and have the poorest water quality. TDS concentrations are high, metal concentrations are elevated and the water is classified as very hard. However, nutrient levels are low and all pH values were greater than 7. Manganese concentrations exceeded the recommended water quality criteria for domestic use and aquatic life (U.S. EPA 1976, Moran and Wentz 1974). Manganese, like iron, is not toxic to humans, but can cause objectionable tastes. Iron exceeded the criteria for domestic use. Zinc concentrations were also elevated and are toxic to certain species (U.S. EPA 1976, Moran and Wentz 1974). Molybdenum concentrations were high. However, there are no water quality criteria for molybdenum at the present time.

Concentrations of all parameters in Tenmile Creek decreases dramatically at Station 3 and continue to decrease at Station 4. The decrease is apparently a result of the confluence with West Tenmile Creek. On the date the samples were collected, West Tenmile Creek contributed approximately 35% of the flow to Tenmile Creek. Manganese concentrations still exceeded the criteria for domestic use and aquatic life at Stations 3 and 4, and iron exceeded the criteria for domestic use.

West Tenmile Creek discharges into Tenmile Creek near Wheeler Junction. West Tenmile Creek has had very limited amounts of mining activity in its basin. Most disturbances have been a result of road construction and resort development. There has been little recent disturbances and past disturbances have been stabilized. West Tenmile Creek has good water quality. TDS and nutrient levels are low, the water is soft, all pH values are greater than 7 and metal concentrations are low. Iron is the only metal to exceed the water quality criteria for domestic use.

Total metal concentrations in the sediment of Tenmile Creek followed the same pattern as the water quality parameters. Concentrations were highest at Stations 1 and 2, just below the mining activities (Table 5). Lead, molybdenum and zinc exhibited markedly higher values at these stations. Concentrations decreased at Stations 3 and 4. These stations are located below the confluence of West Tenmile Creek. The West Tenmile Creek basin has had a limited amount of mining activity and metal concentrations were quite low when compared to Tenmile Creek.

Table 4: Selected physiochemical parameters for stations on Tenmile Creek and West Tenmile Creek, Colorado, April 1985 (all values mg/l unless noted).

Parameters	TEN MILE CREEK				WEST TEN MILE CREEK	
	1	2	3	4	1	2
Physical Parameters						
Flow (cfs)	29.4	34.1	78.8	86.4	25.3	27.7
Water Temperature (°C)	7.0	9.0	8.0	7.0	6.0	6.0
Dissolved Oxygen (mg/l)	10.3	10.7	11.3	9.1	10.9	10.2
pH (field)	N/A	7.5	N/A	N/A	7.8	N/A
pH (lab)	7.56	7.79	7.94	7.92	8.05	8.11
Conductivity (field) (umhos/cm @ 25°C)	1340	1130	623	514	146	152
Conductivity (lab) (umhos/cm @ 25°C)	1530	1361	721	655	156	158
Total Dissolved Solids	1320	1150	540	467	109	139
Total Suspended Solids	< 4	< 4	9	< 4	6	< 4
Chemical Parameters						
Hardness (as mg/l $CaCO_3$)	717	617	305	272	67.4	67.6
Nitrate	0.5	0.5	0.3	0.4	0.9	0.1
Nitrite	0.19	0.15	0.06	0.05	<0.01	<0.01
Orthophosphate	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Cadmium (ug/l)	2	2	1	1	<1	<1
Copper	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.76	0.67	0.78	0.77	0.49	0.47
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	2.8	2.41	1.03	0.78	0.03	0.03
Molybdenum	2.0	1.7	0.71	0.61	<0.01	<0.01
Zinc	0.28	0.26	0.16	0.15	0.01	0.01

Table 5: Total metal concentrations in stream bottom sediments for stations on Tenmile Creek and West Tenmile Creek, Colorado, April 1985 (all values mg/kg).

Parameters	TENMILE CREEK 1	2	3	4	WEST TENMILE CREEK 1	2
Cadmium	4.85	5.45	1.75	2.8	<0.05	<0.05
Copper	130	144	40	48.5	12.5	12.5
Iron	23000	30500	20500	23500	8000	10500
Lead	260	325	60	95	20	15
Manganese	1250	2050	1050	1200	550	600
Molybdenum	225	210	50	60	<5	<5
Zinc	1250	1450	490	650	35	55

Snake River and North Fork of the Snake River

There has been a significant amount of mining activity in the headwaters of the Snake River and its tributaries, especially in the Peru Creek drainage. Water quality samples were collected from the Snake River and the North Fork of the Snake River to determine the impacts these historic mining operations on water quality. Results are presented in Tables 6 and 7.

Overall water quality is fair on the Snake River for domestic and aquatic use. TDS and nutrient levels are low, the water is classified soft, and all pH values were greater than 7. There are some problems with trace metals. Zinc exceeded the water quality criteria for aquatic life at Stations 1 and 2 (U.S. EPA 1976). Iron and manganese also exceeded the criteria for domestic use. Cadmium is present at all stations on the Snake River. However, it is present at low concentrations and did not present a problem during this sampling episode.

There is a marked decrease in the concentrations of all parameters at Stations 3 and 4. However, the concentrations of iron, manganese and zinc still exceed the water quality criteria. The decrease at these stations is an apparent result of the inflow from the North Fork of the Snake River.

The North Fork of the Snake River basin has had minimal mining activity. Its water quality is comparable to that found in West Tenmile Creek and the upper Blue River stations (Table 6). TDS and nutrient values are low, the water is soft, pH is greater than 7 and metal concentrations are low. There are no metal concentrations that exceeded the water quality criteria for domestic or aquatic life.

Total metal concentrations in the sediments of the Snake River follow a pattern similar to that for the sediment concentrations in Tenmile Creek. Stations 1 and 2, which are closest to historic mining activities, had elevated concentrations (e.g. copper and zinc). Concentrations decreased at Stations 3 and 4, which are below the confluence of the North Fork of the Snake River.

Although there is a decrease at Stations 3 and 4, concentrations are still above background levels. The North Fork of the Snake River has been relatively undisturbed by mining and had low sediment metal concentrations. These could be considered to be background levels.

Table 6: Selected physiochemical parameters for stations on the Snake River and the North Fork of the Snake River, Colorado, April 1985 (all values mg/l unless noted).

Parameters	SNAKE RIVER 1	2	3	4	NORTH FORK
Physical Parameters					
Flow (cfs)	18.7	23.3	22.1	45.9	14.7
Water Temperature (°C)	2.0	2.0	3.0	3.0	2.0
Dissolved Oxygen (mg/l)	12.9	13.5	12.9	11.8	13.1
pH (field)	7.5	NA	8.8	8.5	8.3
pH (lab)	7.16	7.36	7.36	7.57	7.79
Conductivity (field) (umhos/cm @ 25°C)	127	116	133	113	101
Conductivity (lab) (umhos/cm @ 25°C)	124	121	122	114	99
Total Dissolved Solids	67	69	43	46	46
Total Suspended Solids	< 4	< 4	< 4	6	< 4
Chemical Parameters					
Hardness (as mg/l $CaCO_3$)	44.4	44.8	45.7	43.6	36.8
Nitrate	0.2	0.2	0.3	0.2	0.3
Nitrite	<0.01	<0.01	<0.01	<0.01	<0.01
Orthophosphate	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium (ug/l)	2	2	1	1	<1
Copper	0.02	0.02	<0.01	0.01	<0.01
Iron	0.75	0.91	0.38	0.76	0.21
Lead	0.01	0.01	<0.01	<0.01	<0.01
Manganese	0.40	0.29	0.18	0.14	<0.01
Molybdenum	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.58	0.48	0.35	.23	<0.01

Table 7: Total metal concentrations in stream bottom sediments for stations on the Snake River and the North Fork of the Snake River, Colorado, April 1985 (all values mg/kg).

Parameters	SNAKE RIVER				NORTH FORK
	1	2	3	4	
Cadmium	6.5	5.5	3.55	1.95	<0.05
Copper	268	149	88	58	11
Iron	27500	18500	20000	19000	16500
Lead	750	455	250	140	25
Manganese	3950	3450	1950	1450	500
Molybdenum	5	5	<5	<5	<5
Zinc	1500	1200	850	550	70

CONCLUSIONS

Water quality in the project area is still being impacted from current and historic mining activity. The closer the monitoring stations are to the disturbance, the greater the observed impact. Streams that had minimal amounts of mining disturbance had few water quality problems.

Iron, manganese and zinc were the metals most prevalent in water quality samples. Manganese and zinc presented the greatest problem for aquatic life, whereas iron and manganese presented the greatest problem for domestic use. Table 8 presents a summary of all the streams and the parameters that exceeded the water quality criteria for aquatic life or domestic use. Although iron and manganese frequently exceed domestic use standards, neither one is toxic and are only aesthetically unpleasing.

Table 8 indicates that French Gulch and upper Tenmile Creek have the poorest water quality. French Gulch impacts the Blue River. However, after dilution, water quality criteria are not exceeded downstream. The same affect is noted in Tenmile Creek and the Snake River after their confluence with West Tenmile Creek and the North Fork, respectively.

Total metal concentrations in stream bottom sediments followed the same pattern as the water quality parameters. Metal concentrations were elevated near historic or current mining areas. Concentrations decreased downstream of the mining activities and there was a marked decrease in sediment metal concentrations below the confluence of major tributaries.

It should be noted that these conclusions are based on a one-time grab sample and are not representative of seasonal variations.

Table 8: Summary of streams and parameters exceeding known water quality criteria for domestic use (+) or aquatic life (*).

Stream/ Station		Fe	Mn	Zn
Blue River	Station 1	+		
	Station 2	+		
	Station 3	+	+	
	Station 4	+		*
	Station 5	+		
	Station 6			
	French Gulch	+ *	+ *	*
Tenmile Creek	Station 1	+	+ *	*
	Station 2	+	+ *	*
	Station 3	+	+ *	
	Station 4	+	+	
	West Tenmile Creek 1	+		
	2	+		
Snake River	Station 1	+	+	*
	Station 2	+	+	*
	Station 3	+	+	*
	Station 4	+	+	
	North Fork Snake River			

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