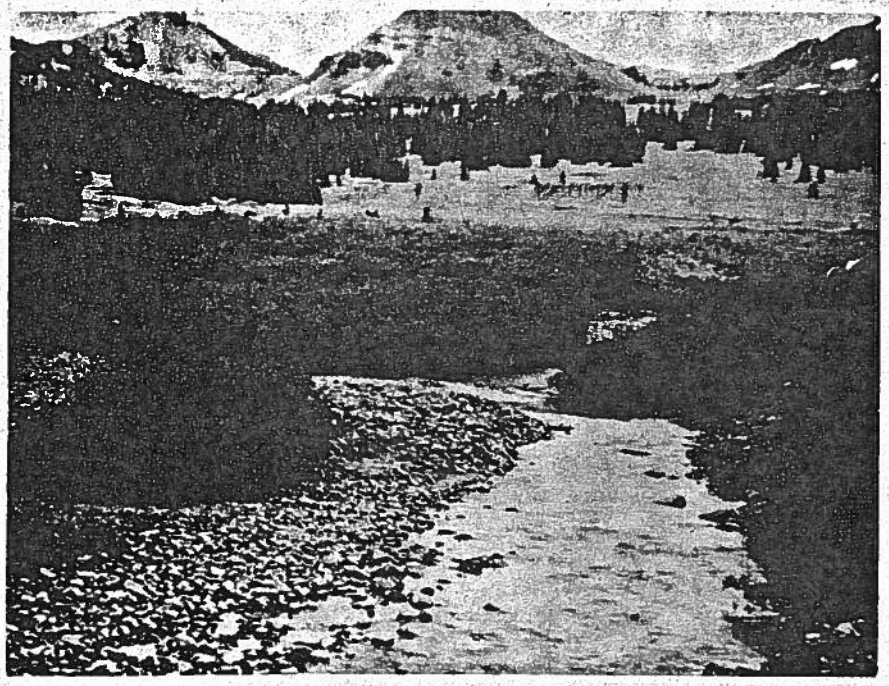
FINAL REPORT

Biological Study

Acid-Mine Control-Feasibility Study

Cooke City, Montana



Submitted to:

The Montana Department of Natural
Resources and Conservation

Submitted by:

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Report Period: May - October, 1975

ABSTRACT

Investigations of the upper Stillwater, Clarks Fork of the Yellowstone, and Soda Butte drainages were conducted from May through October, 1975, to determine the existing degraded biological conditions of these streams (resulting from acid-mine wastes), and to help determine the extent of reclamation necessary to restore a viable fisheries to the streams. The major problems in the upper Stillwater are dissolved aluminum, copper, and iron; although the toxic effects of these metals is sharply reduced as near as 3.0 km below the McLaren Mine, the bottom substrate of the stream is "cemented" with precipitated metals for up to 9.0 km below the mine. The lack of suitable pH (or the lack of buffering) is the major problem in the upper Clarks Fork; in the Clarks Fork proper, as far as 6.5 km below the Glengary Mine, pH values in the 5.0 to 6.0 range were common throughout the study period. Dissolved iron is the greatest problem in Soda Butte Creek; values greater than 10.0 mg/l were recorded at Station 322, which is immediately below the McLaren Mill tailings. Reclamation efforts should be directed to (1) reduce the metal loading in the upper Stillwater by 90%, (2) raise and stabilize the pH in the upper Clarks Fork to levels near 7.0, and (3) reduce the dissolved iron concentrations immediately below the McLaren Mill to concentrations less than 0.2 mg/l.

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ACKNOWLEDGEMENTS

The authors wish to express their appreciation to all of the other members of the Cooke City study team - members of the Montana Department of Natural Resources and Conservation and the Montana Bureau of Mines and Geology - for their help and suggestions throughout the planning and implementation of this study; particularly helpful were John Soneregger, Larry Wegglin and Al Brubacker. Many permanent and summer residents of Cooke City were always there to help in times of emergency, which, alas, happened all too often - "Jack" and "Berty" Williams, Suzie Thomas, and Darrell Crabb immediately come to mind. Sandy O'Dell did an excellent job typing and drafting this manuscript.

I. RECOMMENDATIONS:

A. Stillwater - McLaren Mine Area

It is fortunate that two relatively alkaline streams converge with Daisy Creek to form the Stillwater River. At Station 128, the pH of the stream is immediately raised to levels which are very near to being acceptable for a biological community. However, the total metal load (originating at the McLaren Mine) is very high, even though the dissolved values are sharply reduced at this station. If we look at reclamation only from a fisheries point of view, all efforts should be made to substantially reduce the aluminum, copper, and iron levels in the Upper Stillwater beginning at least 6.0 km below Station 128. Based on the very slow recovery of benthic insects at Station 128, and the unsuitable appearance of the bottom for some distance below this station, it would seem that a 90% reduction in total load of these three metals would not be out of line.

B. Clarks Fork - Glengary Mine Area

Heavy metals are much less of a problem in this area, compared to either the Stillwater or Soda Butte Drainages. The pH and/or lack of alkalinity appears to be the major problem affecting the aquatic community. If we only consider the Clarks Fork proper as ever having a native trout population, then reclamation efforts should be directed towards increasing the pH of the Clarks Fork below Lady of the Lake Creek to levels characteristic of this tributary, which is very near 7.0.

C. Soda Butte - McLaren Mill Area

The principal water quality problem affecting the biological community in Soda Butte Creek is dissolved iron. To significantly reduce the degraded conditions between Station 322 and 325, and to enhance the biological community

below Station 325, the dissolved iron concentration at Station 322 should not exceed 0.2 mg/l at any time.

II. DISCUSSION AND CONCLUSIONS:

A. Stillwater - McLaren Mine Area

The buffering action of the middle and west headwater feeder streams is instrumental in increasing the pH and lowering the dissolved metal concentrations in the 0.5 km section of the Stillwater immediately before Station 128. Because of this improvement in water quality, Yellowstone Cutthroat trout are able to survive at this station for at least three days. The precipitated metals, however, literally concrete the stream bottom, which allows very little suitable physical habitat for benthic insects. Also, without chronic bioassay data (which would be nearly impossible to obtain in this isolated area) using both insects and fish, it is difficult to say what the long term effects of the metal concentrations at Station 128 might have on these organisms.

It should be noted that a very steep stream gradient exists roughly 2.5 km below Station 128. This presents a formidable physical barrier to the upstream migration of fish. This barrier, along with the deep snow pack, severe cold and low stream flows, which occur every winter in the vacinity of the sampling stations, has very likely prevented the existence of a native trout population in the upper 9.0 km section of the Stillwater. The furthest natural, upstream point for the native trout population in the river is probably near the confluence of Goose Creek, which enters the Stillwater roughly 6.0 km below Station 128.

B. Clarks Fork - Glengary Mine

The dissolved metal concentrations, which at the mine adit were much lower than in the Stillwater, were even further reduced by Station 209. The

trout survived the bioassay at this station without any noticable behavioral changes. The bottom substrate was quite untarnished, with the benthic population less drastically reduced over the control than was noted in the Stillwater Stations (compared to their control station). As was true of the Stillwater drainage, a rapid increase in stream gradient, roughly 1.0 km below Station 209, presented a likely barrier to fish migration.

C. Soda Butte - McLaren Mill

The benthic insect, in-situ-bioassay, and fish shocking data revealed that the biological community of Soda Butte Creek is significantly degraded only above Station 325. Although no fish were collected at this station, it was quite noticable that the streambed within the community of Silver Gate had been extensively altered. Most of the undercut banks, logs, and other physical habitat for fish had been removed. Area residents claim that fish are caught during certain times of the year above the town, in areas which have not been physically altered by man.

Soda Butte Creek is much more alkaline than either of the other two streams which were studied for this report. Even at Station 322, the pH was consistantly near 7.0. Iron was by far the most concentrated dissolved heavy metal. In the in-situ bioassays, a total of 90% of the test fish were killed in dissolved-iron concentrations ranging from 3.0 to 6.0 mg/l. No fish mortality occurred in the flow-through bioassay, where the dissolved iron concentration ranged from 0.3 to 0.7 mg/l. A standard method for establishing safe concentrations of dissolved metals from bioassay data is to multiply the 96 hour median tolerance limit by 0.1. The median tolerance limit is that concentration at which 50% of the test organisms survive. Using the two extreme bioassay results, we can closely estimate that 50% of the fish would have survived at an average of the two test concentrations, a value of roughly 2.0 mg/l. Multiplying this value by 0.1 we get 0.2 mg/l, the safe concentration for long term exposure of juvenile

cutthroat trout.

III. INTRODUCTION:

During the summer of 1975, the Montana Department of Fish and Game (MDFG) conducted a biological study on three acid-mine impacted streams in the Cooke City, Montana, area. The biological study was a portion of the total Cooke City Acid Mine Drainage Feasibility Study, in which the Montana Department of Natural Resourc and Conservation (DNRC) was the lead investigative agency and the Montana Bureau of Mines and Geology (MBMG) was the principal contractor for site hydrologic and water quality determinations. The purpose of the biological portion of the study was to lend support to the two aforementioned agencies in their ongoing efforts to select a technique or techniques to reduce and treat the acid-mine seepage, which originate at three abandoned hard rock mine sites. Specifically, this portion of the study was designed (1) to determine the existing degraded conditions of the biological communities in the three impacted streams below the acid-mine sites, and (2) to attempt to define what components of the wastes are responsible for this degradation This information could then be used to estimate how effective (e.g. percent removal of heavy metals, etc.) any abatement technique must be to restore a viable fishery to the streams.

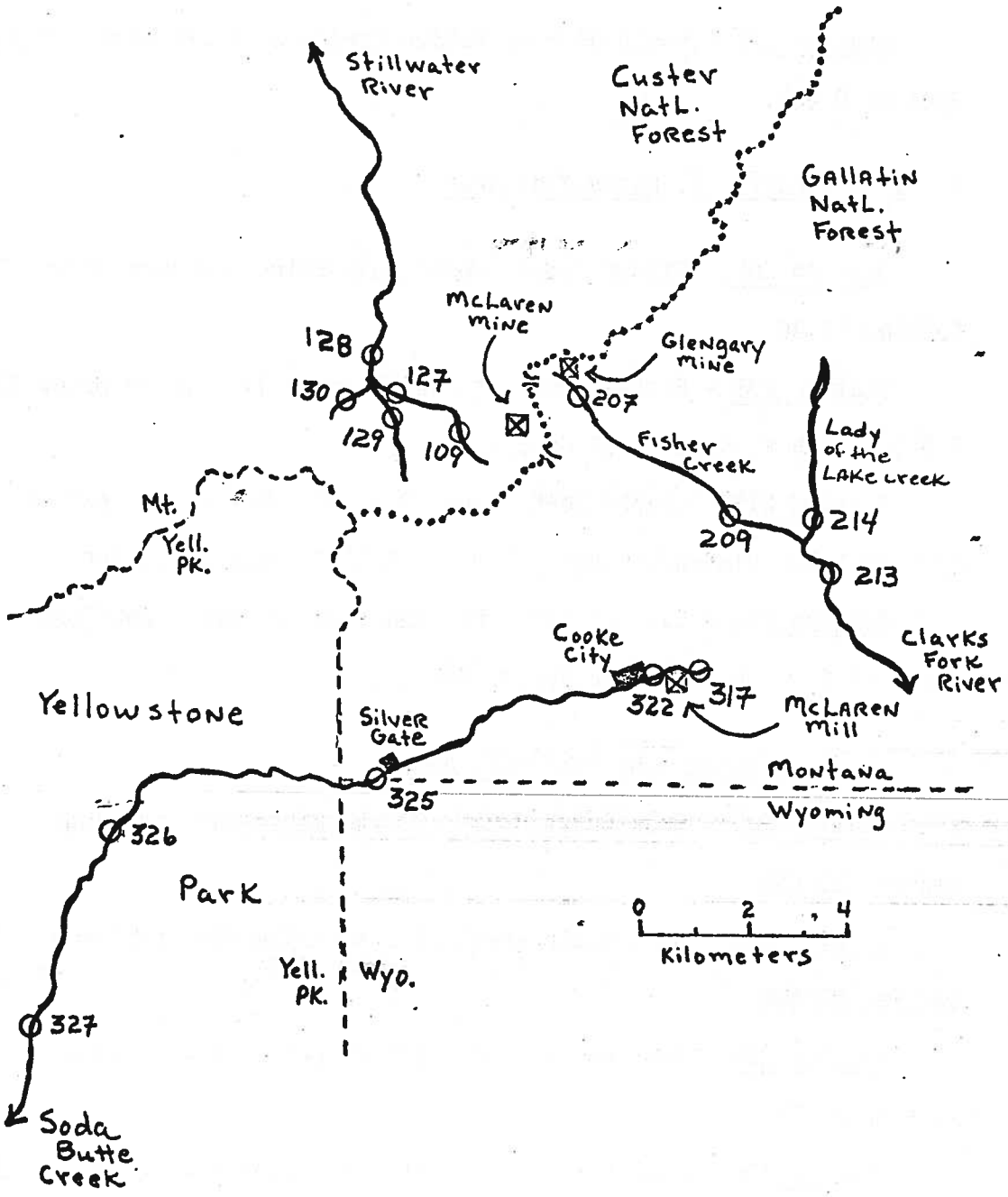
The field portion of the study was conducted from May 19 through September 30, 1975. In this report, reference is made to fourteen sampling stations. The station were sampled for water quality and/or biological data on a monthly or bimonthly schedule, depending upon need and accessibility. Ten of these stations were sampled exclusively by the MDFG, while the other four were principally water quality stations, which were normally sampled by the MBMG. The sampling locations, with their EPA station numbers are shown on Figure 1. Their specific locations (by drainage) are:

A. Stillwater - McLaren Mine Area

Station 109 - Daisy Creek (East feeder stream of the Stillwater's headwaters) immediately below McLaren Mine. T 9 S - R 14 E, Section 10 DDC.

FIGURE 1.

COOKE CITY ACID MINE STUDY AREA
Water Quality and Biological Sampling Stations----0



Station 127 - Daisy Creek, 3.0 KM below McLaren Mine. T 9 S - R 14 E, Section 9 BAC.

Station 128 - Headwaters of the Stillwater River 0.5 KM below the confluence of the three feeder streams (3.5 KM below McLaren Mine). T 9 S - R 14 E, Section 4 CCA.

Station 129 - Mouth of Middle feeder stream of Stillwater. T 9 S - R 14 E, Section 9 BDB.

Station 130 - Mouth of West feeder stream of Stillwater. T 9 S - R 14 E, Section 9 BDB.

B. Clarks Fork - Glengary Mine Area

Station 207 - Fisher Creek immediately below Glengary Mine. T 9 S - R 14 E, Section 11 ACD.

Station 209 - Fisher Creek at Old Whites Mill, 4.0 KM below Glengary Mine. T 9 S - R 15 E, Section 18 CCA.

Station 213 - Clarks Fork River, 0.75 KM below confluence with Fisher Creek (6.5 KM below Glengary Mine). T 9 S - R 15 E, Section 20 ACC.

Station 214 - Lady of the Lake Creek, 0.2 KM above confluence with Clarks Fork. T 9 S - R 15 E, Section 17 CAD.

C. Soda Butte - McLaren Mill Area

Station 317 - Soda Butte Creek, 0.1 KM above mill tailings. T 9 S - R 14 E, Section 25 ADB.

Station 322 - Soda Butte Creek, 0.2 KM below mill tailings. T 9 S - R 14 E, Section 25 ACB.

Station 325 - Soda Butte Creek, 5.9 KM below mill tailings. T 9 S - R 14 E, Section 22 ACD.

Station 326 - Soda Butte Creek, 15.5 KM below mill tailings. T 58 N - R 13 E, Section 21 BBC (Wyo. Coordinates).

Station 327 - Soda Butte Creek, 21.4 KM below mill tailings. T 57 N - R 13 E, Section 6 DBC (Wyo. Coordinates).

III. METHODS AND MATERIALS

A. Chemical Sampling:

1. Basic chemical parameters and heavy metal analyses.

Water samples for laboratory analyses were periodically collected in polyethelene bottles at all stations. Four sample bottles were collected at each station - one 1000 ml bottle, filtered (in the field) through a 0.45 micron filter; one 1000 ml bottle, unfiltered ("as is"); one 1000 ml bottle unfiltered, but acidified with 10 ml of concentrated nitric acid; and one 250 ml bottle filtered through the 0.45 micron filter and acidified with 2.5 ml of concentrated nitric acid. The bottles were refrigerated to 4^{o} C and sent to the MBMG chemistry laboratory in Butte, where they were analyzed for the following constituents:

Basic parameters - calcium, magnesium, sodium, potassium, manganese, silica, bicarbonate, carbonate, chloride sulfate, nitrate, ph, specific conductance, hardness, and total alkalinity.

Heavy metals (dissolved and total) - aluminum, cadmium, copper, iron, zinc, and lead.

2. Field physicochemical determinations

Field measurements for dissolved oxygen, specific conductance, and temperature were also made concurrently with the water sampling. Dissolved oxygen was measured with a YSI model 57 meter. Specific conductance was determined with a YSI model 33 Salinity-Conductivity-Temperature meter. Stream temperatures were also made with this meter or with a hand-held field thermometer.

3. Stream sediment analyses

In late September, stream bottom gravels were collected at nine of the sampling stations. The gravels were returned to the laboratory, where they were dried, and filtered through a -200 M sieve. Heavy metal determinations for

aluminum, cadmium, copper, lead, iron, and zinc were then made on this fraction of the sample.

B. Biological Studies

1. Benthic Insects

Aquatic larval insects were collected from the bottom gravels by using a Surber Sampler. One square foot of creek bottom was sampled at each station on each water chemistry collection date. The insects were preserved in the field with 70% ethyl alcohol and were returned to the laboratory, where they were enumerated and separated into basic taxinomic groups (Orders). In this report the orders of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Tricoptera) are considered to be "sensative" to changes in water quality, while the rest of the orders (true flies, beetles, etc.) are considered to be "tolerant" to such changes. This admittedly is a fairly general categorization, but it is widely used, particularly when taxinomic keys for an area, or the long working hours required for further taxinomic breakdown are not available to the researcher. A healthy stream section would therefore contain a large number of insects, a high percentage of which would be pollution "sensative". Any reduction in total numbers or in the percentage of sensative organisms from a control station would indicate stream degradation.

2. Fish Shocking

The presence or absence of fish was determined at each station by shocking a 75 to 300 foot stream segment. A small, battery operated backpack fish shocker, capable of producing up to 425 volts, was used. While this is a fairly reliable method for attracting fish, other factors such as the electrical conductivity of the water, or simply the lack of suitable physical habitat, may bias the information.

3. Bioassays

A bioassay is an evaluation of the toxicity of a pollutant in which living organisms (in this case fish) provide the scale. Fish are exposed to

a waste, or a diluted fraction of a waste, and their ability to survive is noted. All fish used in this study were small (3-6 cm) Yellowstone Cutthroat (Salmo clarki). The fish were transported from the MDFG Yellowstone River Trout hatchery at Big Timber, Montana, to Cooke City, where they were acclimated for at least 15 days in flow-through aquaria. Miller Creek, which provides the drinking water for some residents of Cooke City, was used for this acclimation.

a. In-Situ (caged fish) bioassays

For this portion of the bioassays, ten fish were placed in 50 x 30 x 30 cm fiberglass mesh bags, supported by metal frames. The tests were conducted for on 72 hour period at six stations, and for two 96 hour periods at three stations.

b. Flow-through (aquaria) bioassays

A small camper trailer, equipped with eight 38 liter aquaria and eight liquid proportional metering pumps (Matheson Scientific No. 56542), was used for this portion of the bioassays. The bioassay unit was located at station 322, which is below the McLaren mill tailings, near Miller Creek. This system automatically combined acid-mine water from Soda Butte Creek with dilution water from Miller Creek into present proportions. The following proportions of Soda Butte Creek water were used - 100%, 69%, 47%, 32%, 22%, 15%, 10%, 0%. The pumps were set to deliver 200 ml of the above proportions per ~~hour~~ minute. Standpipe drains maintained a volume of 30 liters in each aquarium, which allowed the test solutions to be turned over approximately 10 times per day. Water quality samples taken from the aquaria indicated that the pumps maintained the above dilutions within ± 2.0%. Two flow-through bioassays were conducted for 96 hours per test.

4. Fish tissue analyses

Fish from all bioassays were removed at the end of four days, frozen, and taken to the laboratory for heavy metal analyses. Since the fish were so small, several from each station were pooled prior to analyses. The fish were

also skinned, which allowed each sample to be divided into two subsamples - (1) tissue and bones, and (2) heads, internal organs, and skin.

IV. RESULTS:

Because individual abatement techniques will have to be applied at each of the three impacted areas, the results of the biological study will be presented in three different sections (e.g. Stillwater, Clarks Fork, and Soda Butte drainages).

A. Stillwater - McLaren Mine Area

1. Chemical Sampling

a. Basic chemical parameters

Water chemistry and biological samples were collected in the headwater area of the Stillwater River on four dates from August 5 through September 15, 1975. This area was not accessible by four-wheel vehicles before early August, which was unfortunate, since the peak runoff from the McLaren Mine area was in mid July. The six week MDFG sampling period therefore spanned the stream stages of high flow recession and low-flow high stream temperatures.

With the exception of two parameters, the concentrations of the basic chemical constiuents increased with time (decreasing flow), and decreased with distance downstream from the mine. As was expected, total alkalinity and pH did not conform to this pattern. Total alkalinity clearly increased both with time and with distance from the mine. The pH values demonstrated a similar, yet less precisely delineated pattern. These data are presented in Table 1.

b. Heavy Metals

Of the three impacted areas which were studied for this report, the stream below the McLaren Mine (Daisy Creek) consistantly contained the highest concentrations of heavy metals. At Station 109, the dissolved values for copper, iron, and particularly aluminum, were always much higher than concentrations reported in the literature to be toxic to trout (greater than 2.0 mg/l). The dissolved concentrations of the other three metals - cadmium, lead, and zinc, were much lower, with only zinc appearing at values greater than 0.01 mg/l. By

Table 1. Basic water quality concentrations (mg/l) and flows from the Daisy Creek/Stillwater stations.

	Calcium Date				Total Alkalinity Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	41.00	49.00	62.00	69.40	0.00	0.00	0.00	0.00
127	31.00	40.00	50.00	56.00	4.00	0.00	0.00	0.00
128	20.00	25.00	28.00	29.00	46.00	47.00	48.00	49.00
129				21.23				87.00

	Magnesium Date				Conductivity (umhos) Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	12.30	15.90	19.90	23.20	782.00	1027.00	1227.00	1211.00
127	8.00	1.60	12.70	16.60	249.00	360.10	430.80	490.30
128	4.80	5.50	6.80	7.20	154.00	181.50	209.70	221.10
129				4.66				146.00

	Sulfate Date				pH Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	304.10	375.60	510.00	569.20	2.70	3.19	3.42	3.44
127	110.00	160.00	206.00	223.00	5.68	4.43	4.41	3.84
128	28.00	37.00	51.00	57.00	6.13	5.63	6.23	6.10
129				5.00				7.76

	Silica (SiO_2) Date				Flow (m^3/sec) Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	19.50	24.00	31.20	32.20	0.033	0.012	0.009	0.005
127	10.10	12.50	13.90	14.40	0.226	0.085	0.057	0.042
128	5.60	5.60	5.60	5.50	0.359	0.283	0.198	0.142
129				3.50				0.050

Station 127, 3.0 km below the mine, these concentrations were reduced, without any consistant pattern, to values 2 to 100 times less than those found at Station 109. Below Station 127 and before Station 128, the other two feeder streams of the Stillwater converge with Daisy Creek to form the headwaters of the river. In this 0.5 km section of the stream, most of the heavy metals are rapidly precipitated, and by Station 128, no dissolved concentrations were ever found at values above 0.1 mg/l (Table 2). This removal of dissolved metals is no doubt prompted by the relatively high buffering capacity of the middle and west feeder streams, which have never been influenced by mining activity. The only water sample collected from the middle feeder stream contained a total alkalinity concentration of 87 mg/l, nearly twenty times the highest concentration found at Station 127. Also, throughout the study period, the flow of both the middle and west feeder streams were roughly equal to Daisy Creek, which added a considerable amount of alkaline dilution to the upper river system.

c. Stream sediment analyses

The results of the heavy metal determinations for the fine (-200 mesh) gravels from the Stillwater drainage are presented in Table 3.

TABLE 3. Heavy metal analyses of stream gravels. (All concentrations are in ug/g).

STATION	ALUMINUM	CADMIUM	COPPER	IRON	LEAD	ZINC
127	77,140	2.2	2,640	93,300	173	260
128	87,490	7.6	11,450	84,450	116	1,280
129	73,190	1.5	83	40,250	66	129

Significantly higher concentrations of precipitated metals were found at Station 128 compared to the control station (129), or the station above the confluence of the other two feeder streams (Station 127). Two exceptions were iron and lead, which were slightly more concentrated at Station 127 than at Station 128.

2. Biological Studies

a. Benthic Insects

TABLE 2. Heavy metal concentrations (mg/l) from the Daisy Creek/Stillwater stations. Total concentrations are in parenthesis below each coresponding dissolved concentration.

	Aluminum Date				Lead Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	17.00 (17.01)	23.50 (24.40)	30.00 (30.00)	37.40 (37.40)	0.007 (0.007)	---- (---)	0.009 (-----)	0.011 (-----)
127	0.15 (4.97)	3.76 (7.00)	5.89 (9.18)	6.80 (10.07)	0.005 (0.005)	0.003 (0.004)	0.006 (0.008)	0.005 (0.008)
128	0.11 (1.20)	0.07 (1.59)	0.08 (1.84)	0.09 (2.00)	0.006 (0.006)	0.003 (0.005)	<0.002 (0.005)	<0.002 (0.004)
129				0.05 (0.05)				0.003 (0.004)

	Copper Date				Cadmium Date			
STA	3/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	7.50 (7.50)	---- (----)	11.60 (-----)	12.70 (-----)	0.009 (0.009)	----- (-----)	0.002 (-----)	0.005 (-----)
127	1.83 (2.11)	3.13 (3.24)	3.79 (3.79)	4.02 (4.02)	0.001 (0.002)	0.003 (0.003)	0.002 (0.003)	0.003 (0.004)
128	0.04 (0.46)	0.05 (0.68)	0.07 (0.67)	0.40 (0.71)	<0.001 (<0.001)	<0.001 (0.001)	<0.001 (<0.001)	<0.001 (<0.001)
129				0.001 (0.003)				<0.001 (<0.001)

	Iron Date				Zinc Date			
STA	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
109	1.71 (30.60)	2.43 (37.80)	5.10 (43.40)	6.60 (37.60)	0.710 (0.710)	---- (----)	0.002 (-----)	0.004 (-----)
127	0.57 (5.00)	1.06 (7.50)	1.30 (7.86)	1.06 (9.23)	0.250 (0.250)	0.360 (0.360)	0.511 (0.511)	0.559 (0.559)
128	0.00 (1.44)	0.01 (1.67)	0.01 (1.44)	0.01 (1.86)	0.010 (0.060)	0.028 (0.070)	0.040 (0.092)	0.026 (0.088)
129				0.01 (0.16)				<0.001 (0.005)

The total of benthic insects was severely reduced at Station 127, with only two insects being found on four sampling dates, for an average of 0.5 organisms per square foot. At Station 128, the number of benthics had not recovered nearly as dramatically as the improvement in water quality might hint, since the average number had only increased to 3.75 organisms per square foot. These values are very low compared to the control Station (129), which contained an average value of 118 organisms per square foot. Station 129 had a clean, fine gravel bottom, while the former two stations had a "cemented", heavy metal appearance. Due to the poor showing of the benthic population at Station 127, no bottom samples were collected at the even more degraded area of Station 109.

b. Fish Shocking

On September 17, 1975, stream segments ranging from 100 to 300 feet were shocked in the vacinity of Stations 127, 128, and 129. No fish were found. In addition to checking these normal sampling stations for the presence of fish, several more pool and riffle areas were shocked on the mainstem of the Stillwater as far as 1.3 km below Station 128. No fish were found even in stream sections with excellent physical habitat. The electrical conductivity of the water was apparently conducive to shocking, since numerous insects were stunned and floated to the surface in the vacinity of the control station.

c. Bioassays

One 72 hour in-situ bioassay was conducted from September 15 through September 18, 1975. Cages were placed at Stations 127, 128, and 129. At Station 127, all ten fish were dead after 24 hours. At Station 128, only two fish died after 72 hours, yielding a survival of 80%; the surviving fish were quite healthy and responsive, showing little abnormal behavior or stress. All of the control fish at Station 129 survived the test.

d. Heavy metal analyses of fish tissue

The concentrations of aluminum and copper in the head, skin, and internal organs (composite) subsample of fish from Station 127 were much higher

than the values for these metals at any of the other stations in the study (Appendices 14-25). These concentrations indicate that the cause of fish mortality in the bioassay at Station 127 was very likely due to these two metals. The results of fish tissue analyses for the Stillwater stations are presented in Table 4.

B. Clarks Fork - Glengary Mine Area

1. Chemical Sampling

a. Basic Chemical Parameters

Four stations were sampled in the headwater area of the Clarks Fork of the Yellowstone from August 5 through September 16, 1975. As was true of the Stillwater drainage, the high stream runoff period was not sampled - this peak flow occurred in early July. The four sampling dates were therefore all within the low flow, high temperature stream stage.

With two exceptions - total alkalinity and pH, the concentrations of the basic chemical parameters increased (1) with decreasing flow and (2) with increasing distance from the mine site. Both total alkalinity and pH increased at the stations downstream from the mine, but slowly decreased as the flow, in turn, began to subside. It should be noted, however, in Table 5, that these latter two parameters demonstrated a rather sporatic response to changes in flow - a reflection of the poor buffering capacity of streams in the Upper Clarks Fork drainage.

b. Heavy Metals

Even at the furthest upstream Station (207) the heavy metal concentrations were far lower than those found in the upper stations of the Stillwater - McLaren Mine area. At Station 207, aluminum and copper were the most concentrated dissolved metals, the former being found in the 1.9 to 2.7 mg/l range, and the latter in the 0.7 to 0.8 mg/l range. Dissolved iron was never

TABLE 4. Heavy metal concentrations in fish flesh from the Stillwater/McLaren Mine Stations. All concentrations are in ug/g dry weight.

September 1975

(head, skin, and internal organs composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
127	730	1.05	279	803	113
128	260	1.34	153	254	249
129	69	1.22	9	119	95

(flesh and bones composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
127	54	<.60	335	86	68
128	37	<.60	151	254	32
129	21	<.60	6	54	75

TABLE 5. Basic water quality concentrations (mg/l) and flows from the Fisher Creek/Clarks Fork stations.

	Calcium Date				Total Alkalinity Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	8.70	11.60	16.50	18.00	0.00	0.00	0.00	0.00
209	10.70	11.70	11.70	11.30	12.00	14.00	7.00	6.00
213	8.00	8.70	9.50	10.20	19.00	16.00	16.00	15.00
214				10.57				12.00

	Magnesium Date				Conductivity (umhos) Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	2.44	3.30	4.70	5.40	225.40	289.30	340.20	350.40
209	2.00	3.10	2.80	3.00	98.60	100.60	105.50	105.10
213	1.40	1.80	2.10	2.10	64.80	75.40	80.70	83.50
214				2.14				85.50

	Sulfate Date				pH Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	57.10	77.50	101.50	107.40	3.38	3.89	3.62	3.85
209	28.00	31.00	37.00	38.00	6.02	5.72	5.91	5.56
213	10.90	14.80	19.40	27.00	7.00	5.54	6.34	5.82
214				23.60				6.93

	Silica (SiO_2) Date				Flow (m^3/sec) Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	13.50	17.80	22.50	23.40	0.016	0.016	0.009	0.025
209	7.10	9.10	9.40	9.00	0.340	0.254	0.057	0.085
213	5.20	5.60	6.10	6.30	0.343	0.259	0.226	0.339
214				6.60				0.071

found above 0.3 mg/l, and zinc was always less than 0.2 mg/l. The dissolved cadmium and lead concentrations were always less than 0.01 mg/l. At Station 209, 4.0 km below the mine, and at Station 213, below the confluence of Lady of the Lake Creek, no dissolved heavy metal ever exceeded 0.1 mg/l. These data are presented in Table 6.

c. Stream Sediment Analyses

Stream gravels were collected at Stations 209, 213, and 214. The results of the fine (-200 mesh) gravels are in Table 7.

TABLE 7. Heavy Metal Analyses of Stream Gravels (all concentrations are in ug/g).

STATION	ALUMINUM	CADMIUM	COPPER	IRON	LEAD	ZINC
209	80,690	2.5	3,130	73,650	153	320
213	68,800	3.5	2,070	67,750	133	400
214	72,530	3.8	2,300	62,850	163	460

In the stream sediment analyses, no distinct patterns of heavy metal precipitation were evident. In fact, three metals - cadmium, lead, and zinc were more concentrated in the sediments of the control station than at either of the affected stations.

2. Biological Studies

a. Benthic Insects

An improvement in total number of benthic insects can be seen with distance downstream from the mine. At Station 209, an average of 5.25 organisms per square foot were collected, and by Station 213, this average had increased to 9.75. These values were significantly lower than the control Station (214), where 12.0 organisms/square foot were collected.

b. Fish Shocking

On September 18, 1975, three, 300 foot stream segments were shocked in the vacinity of Stations 209, 213, and 214. No fish were found at any of the stations. Although the physical habitat at all stations appeared suitable to support fish, the electrical conductivity of the water was quite low, which

TABLE 6. Heavy metal concentrations (mg/l) from the Fisher Creek/Clarks Fork stations. Total concentrations are in parenthesis below each corresponding dissolved concentration.

	Aluminum Date				Lead Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	1.87 (2.05)	2.37 (2.47)	2.69 (2.69)	2.69 (2.69)	0.006 (0.006)	---- (----)	0.010 (-----)	0.007 (-----)
209	0.11 (0.24)	0.06 (0.28)	0.05 (0.05)	0.10 (1.19)	0.008 (0.008)	0.002 (0.002)	0.006 (0.006)	0.003 (0.005)
213	0.09 (0.15)	0.06 (0.10)	<0.05 (<0.05)	<0.05 (<0.05)	<0.002 (<0.002)	<0.002 (<0.002)	0.006 (0.006)	0.003 (0.007)
214				<0.05 (<0.05)				0.003 (0.004)

	Copper Date				Cadmium Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	0.70 (0.70)	---- (----)	0.82 (----)	0.79 (----)	<0.001 (<0.001)	---- (----)	0.001 (-----)	0.001 (-----)
209	0.05 (0.05)	0.07 (0.11)	0.06 (0.07)	0.06 (0.15)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
213	0.02 (0.03)	0.01 (0.02)	0.01 (0.01)	0.01 (0.01)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
214				0.01 (0.02)				<0.001 (<0.001)

	Iron Date				Zinc Date			
STA	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
207	0.09 (3.49)	0.07 (4.50)	0.17 (4.10)	0.26 (3.80)	0.075 (0.075)	---- (----)	0.132 (-----)	0.141 (-----)
209	0.02 (0.23)	0.03 (0.11)	0.03 (0.14)	0.03 (0.64)	0.020 (0.030)	0.017 (0.020)	0.023 (0.023)	0.027 (0.027)
213	0.00 (0.10)	0.01 (0.06)	0.03 (0.10)	0.01 (0.09)	0.010 (0.010)	0.001 (0.003)	0.009 (0.009)	0.013 (0.013)
214				0.04 (0.13)				0.012 (0.014)

greatly lowered the efficiency of the shocking unit. Fish may have been present, but possibly were not attracted to the unit's probes.

c. Bioassays

One 72 hour in-situ bioassay was conducted from September 16 through September 19, 1975. Fish cages were placed at Stations 209, 213, and 214. No mortalities occurred at any of the stations. However, the test at Station 209 was terminated at 60 hours by vandals, who removed the cage from the stream.

d. Heavy Metal Analyses of Fish Tissue

In this drainage, the metal concentrations contained in the bioassay fish were far lower than the values found in fish from the other two study areas. (Appendices 14-25). This should be expected, since no fish mortalities were recorded at any of the Clarks Fork stations. The fish tissue analyses for this drainage are presented in Table 8.

C. Soda Butte - McLaren Area

1. Chemical Sampling

a. Basic chemical parameters

Water samples for complete analyses were collected on eight dates from May 19 through September 14, 1975. The mill tailings had a moderate influence on the basic water chemistry of Soda Butte Creek. In fact, the concentration of major cations increased slightly at Station 322 over the values recorded at Station 317. These values decreased rather sharply at Station 325, due to the influence of Woody Creek, which enters Soda Butte Creek 4.0 km above Station 325. Although this tributary was not sampled extensively, one sample taken near its mouth on June 17, revealed that it is a typical soft-water mountain stream, with major cation and anion concentrations 2 to 4 times lower than those found at Station 322. The flow of Woody Creek throughout the sampling period was roughly equal to the flow of Soda Butte Creek at their confluence. Below Station 325, water samples taken at Stations 326 and 327

TABLE 8. Heavy metal concentrations in fish flesh from the Clarks Fork/Glengary Mine Stations. All concentrations are in ug/g dry weight.

September 1975

(head, skin, and internal organs composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
209	325	<.60	37	346	120
213	78	<.60	8	67	108
214	81	.68	11	240	125

(flesh and bones composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
209	27	<.60	7	52	79
213	24	<.60	5	67	75
214	19	<.60	8	60	76

demonstrated that the concentrations of the major cations gradually increased. This information is illustrated on Figure 2, using calcium and magnesium as typical major cations.

The major anions demonstrated slightly different concentration patterns from those of the cations. As expected, the sulfate concentration jumped sharply at Station 322, and then decreased sharply by Station 325, after which it continued to decrease slowly at the downstream stations. One notable exception to this pattern was on July 2 during the peak runoff, when the sulfate concentration at Station 317 was much higher than at all other stations. This information is presented on Figure 3. The concentration pattern for total alkalinity (the sum of the carbonate, bicarbonate and hydroxide components) was very similar to that of the major cations with one obvious exception, a reduction in concentration, rather than an increase, below the tailings. This again was expected, but the amount of reduction was less than what normally occurs below most acid-mine wastes. Again, a notable exception to this pattern was during the early July runoff (Figure 4).

The above information illustrates the pertinent basic water chemistry trends. All basic water quality data for Soda Butte Creek is presented in Appendices 3 through 7.

b. Heavy Metals

Throughout the study period, at all sampling stations, iron was by far the dominant heavy metal. Even at Station 322, which is immediately below the mill tailings, the dissolved concentrations of aluminum, copper, cadmium, lead, and zinc exceeded 0.1 mg/l on only one occasion; this was during the early July runoff, when the concentration of dissolved aluminum was 4.55 mg/l and the concentration of dissolved copper was 0.50 mg/l. At Stations 325, 326, and 327, the concentrations of these five metals was even less, never exceeding 0.02 mg/l. The complete summary of this data is presented in Appendices 8 through 13. Quite in contrast to the other metal concentrations was the dissolved iron, which

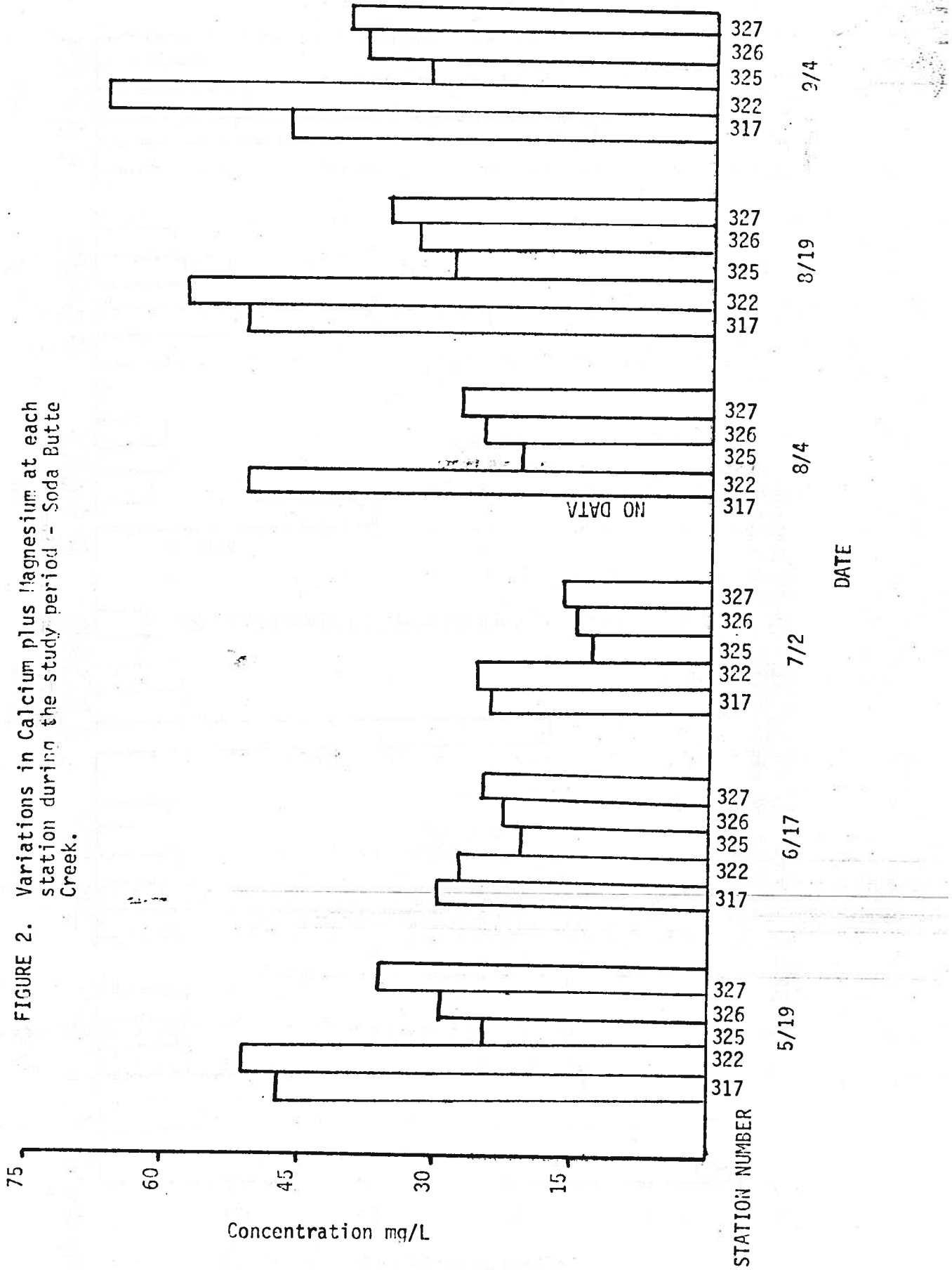


FIGURE 2. Variations in Calcium plus Magnesium at each station during the study period - Soda Butte Creek.

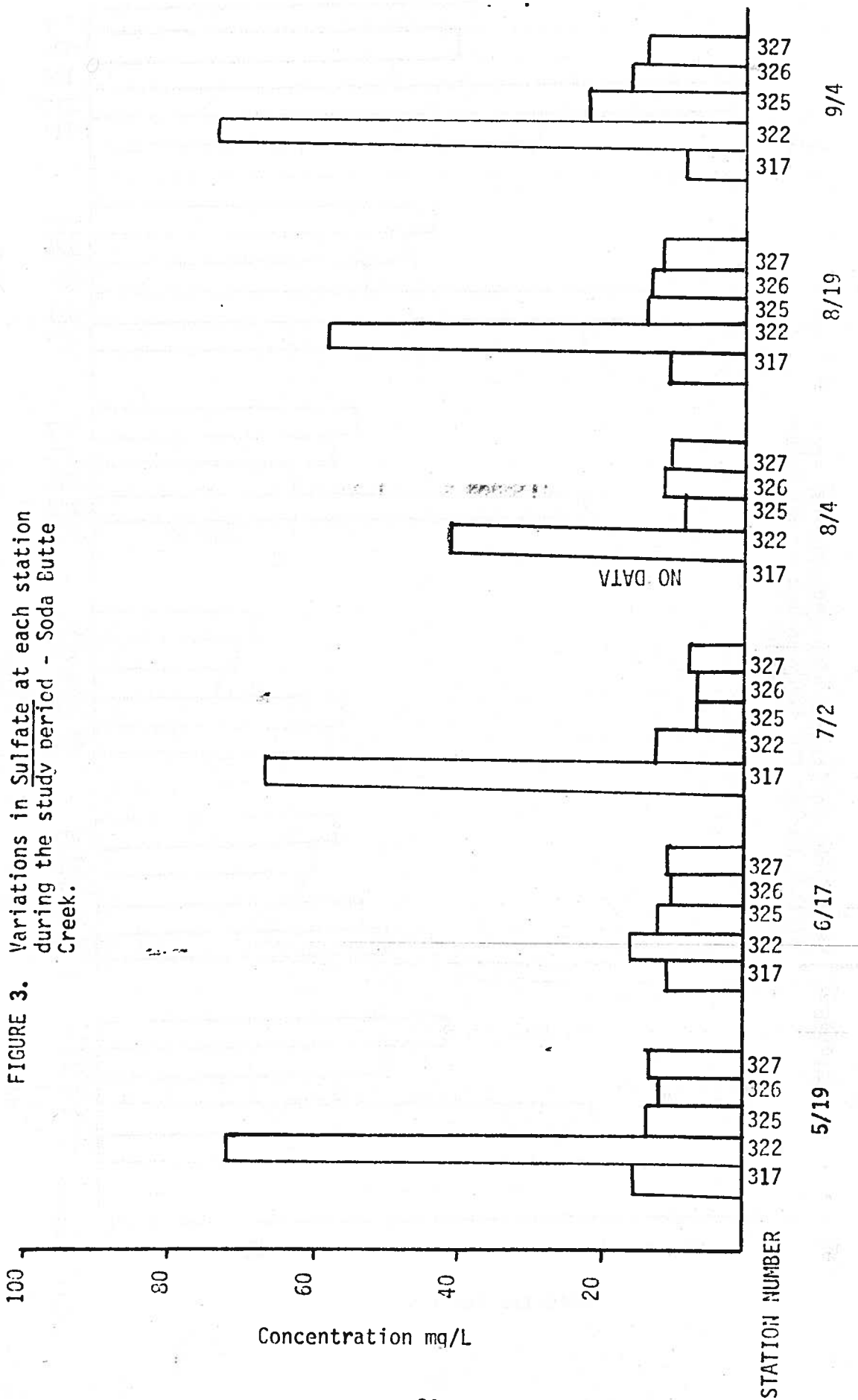


FIGURE 3. Variations in Sulfate at each station during the study period - Soda Butte Creek.

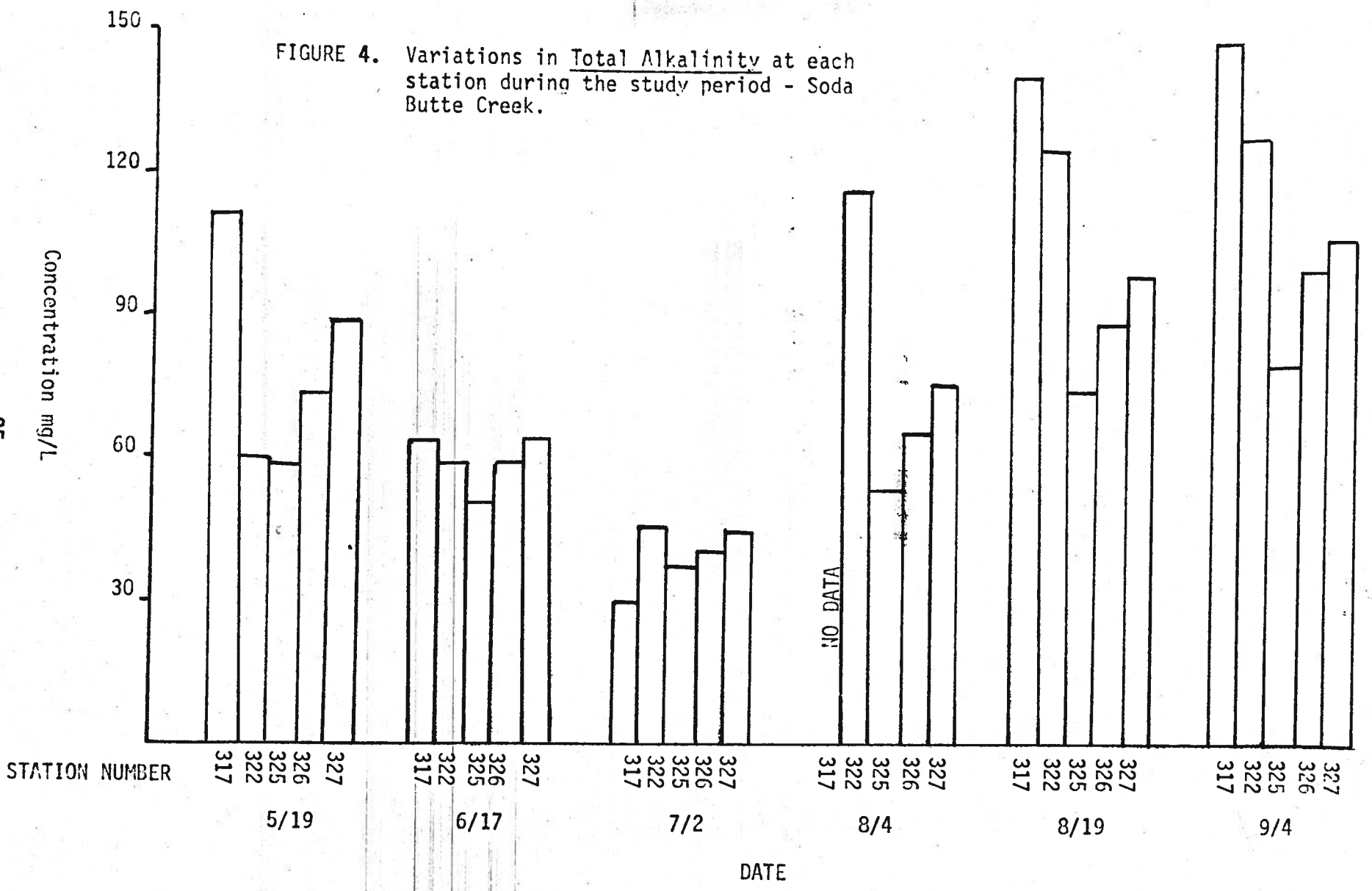


FIGURE 4. Variations in Total Alkalinity at each station during the study period - Soda Butte Creek.

was often several orders of magnitude more concentrated than the other five metals. Most significantly, at Station 322, it was found as high as 11.60 mg/l, with values often occurring within the 3.0 to 6.0 mg/l range. Not surprisingly, there was a very significant decrease in dissolved iron at Station 325, 326, and 327, with the concentration exceeding 0.1 mg/l on only two occasions. In late summer, iron concentrations at these downstream stations were always less than 0.02 mg/l (Figure 5).

c. Stream Sediment Analyses

The results of the heavy metal determinations for the fine (-200 mesh) gravels from Soda Butte Creek are presented in Table 9.

TABLE 9. Heavy Metal Analyses of Stream Gravels (all concentrations are in ug/g).

STATION	ALUMINUM	CADMIUM	COPPER	IRON	LEAD	ZINC
322	63,780	2.6	1,060	134,600	141	24[illegible]
325	79,270	2.4	165	68,750	74	174
326	79,190	1.8	128	75,600	64	139

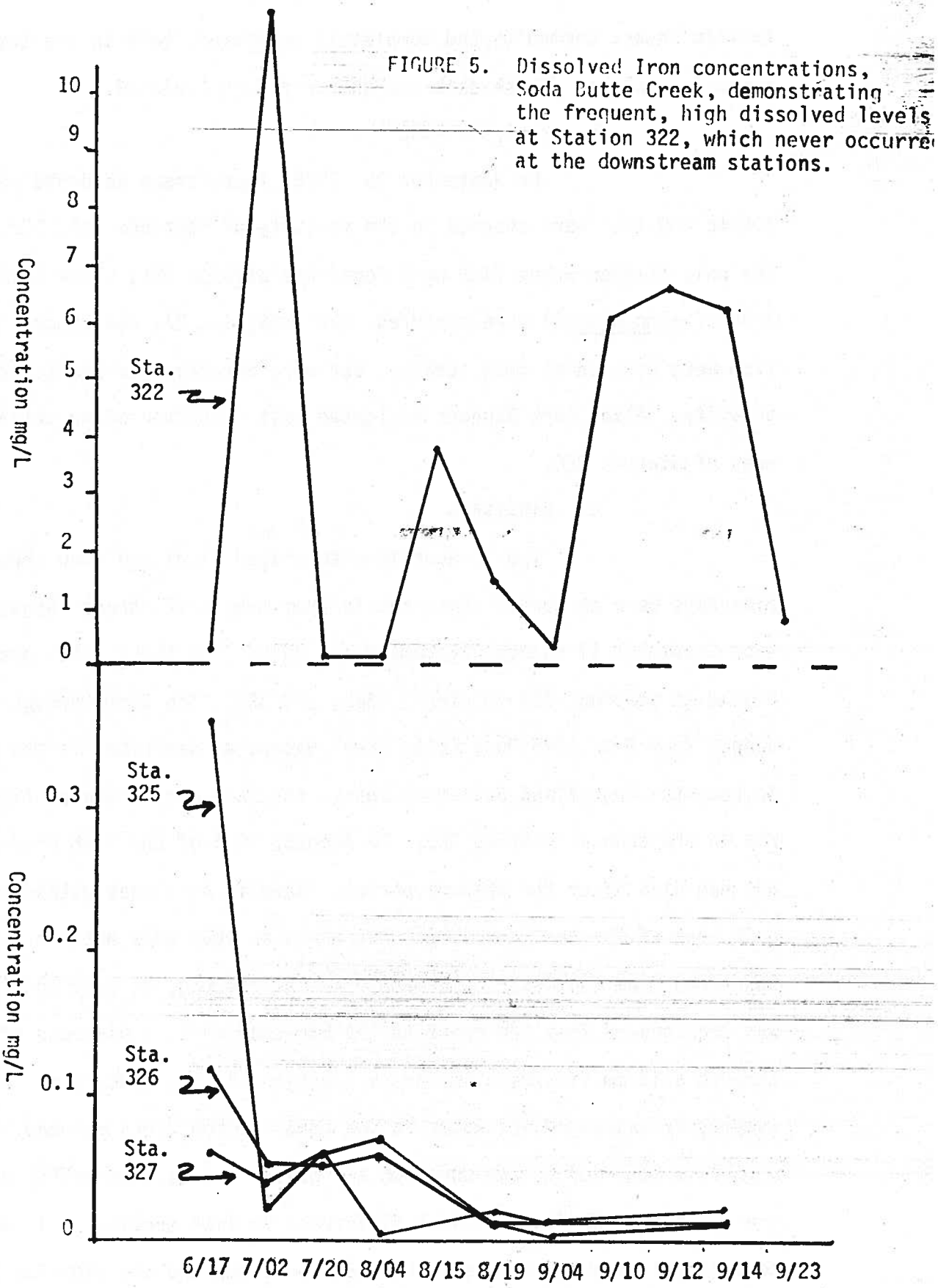
The highest concentrations of precipitated metals were generally found at Station 322, with lower concentrations being found further below the tailings. This decrease in concentration is nearly proportional to the distance from the tailings. Exceptions were with aluminum, which was more concentrated at the downstream stations, and iron, which was more concentrated at Station 326 than at Station 325.

2. Biological Studies

a. Benthic Insects

The total number of benthic insects was severely reduced immediately below the tailings at Station 322; the percent of sensative orders was also lower than at the control Station (317). By Station 325, the total number of benthics had nearly recovered, although the percentage of sensative orders was still depressed. Inside Yellowstone Park, at Stations 326 and 327 the

FIGURE 5. Dissolved Iron concentrations, Soda Butte Creek, demonstrating the frequent, high dissolved levels at Station 322, which never occurre at the downstream stations.



benthic insect community had completely recovered, both in the total and percent sensative values. These data are summarized in Table 10.

b. Fish Shocking

On September 19, 1975, four stream segments ranging from 100 to 400 feet were shocked in the vacinity of Stations 317, 322, 325, and 326. The only station where fish were found was Station 326; three Yellowstone Cutthroat Trout (Salmo clarki) were captured, measuring 11, 27, and 29 cm. Several other fish were stunned at this station, but were not captured due to the high stream velocity. Also, Park Rangers indicated that sportsman often catch fish in the area of Station 326.

c. Bioassays

Two 96-hour in-situ (caged fish) and flow through (aquaria) bioassays were conducted concurrently from August 12 through August 16 and again from September 11 through September 15, 1975. For the in-situ portion, cages were placed at Stations 317 (control), 322, and 325. The flow-through concentrations ranged from 0 to 100% Soda Butte Creek water, as described in the methods section. In both the August and September tests, the only occurrence of fish mortality was in the cage at Station 322. In August, 100% of the fish died and in September 80% had died after the 96-hour period. Keep in mind that within the flow-through unit, one of the test concentrations was also 100% Soda Butte Creek water, which was taken from the creek immediately beside the cage at Station 322. This water was transported from the creek to the bioassay unit, a distance of 50 meters, through a 13 mm (inside diameter) polyvinyl chloride (PVC) pipe, where a pump completely exchanged the water in the aquarium ten times per day. However, no mortality occurred in the aquarium and nearly complete mortality occurred in the creek proper. Why this radical difference in fish survival? If we look at the comparative water quality data between the creek and the aquarium (Table 11), one difference immediately stands out - the dissolved iron concentrations. In the creek this parameter ranged from 3.82 to 6.70 mg/l, while in the aquarium containing

TABLE 10. Total and average number of benthic insects collected (per square foot) in Soda Butte Creek. "Percent Sensative" refers to the relative number of typically pollution-intolerant insects in each sample.

DATE	PLE	TRI	EPE	DIP	OTH	TOT	% SEN	PLE	TRI	EPE	DIP	OTH	TOT	% SEN
	Sta 317							Sta 326						
5/19	11	20	25	8	0	64	87	17	4	37	6	0	64	91
6/17	0	0	2	0	0	2	100	0	4	3	4	0	11	64
7/15	0	0	7	1	0	8	87	1	0	10	0	0	11	100
8/04	14	0	19	3	5	41	80	0	2	14	1	0	17	94
8/19	24	1	12	6	3	46	80	4	3	24	2	4	37	84
9/04	4	0	15	7	2	28	68	3	2	10	0	0	23	100
9/14	45	4	20	12	1	82	73	2	4	31	1	2	40	92
TOT.	98	25	100	37	11	271		27	19	137	14	6	203	
AVE.	14.0	3.5	14.2	5.3	1.5	38.7	82	3.8	2.7	19.6	2.0	0.8	29.0	90
	Sta 322							Sta 327						
5/19	0	1	2	0	0	3	100	14	6	27	10	0	47	79
6/17	0	0	1	0	0	1	100	0	15	8	7	1	31	74
7/15	0	0	1	1	0	2	50	-	--	--	--	-	--	---
8/04	0	0	0	0	0	0	---	0	0	1	0	0	1	100
8/19	1	0	2	3	0	6	50	26	3	41	4	1	75	93
9/04	0	0	0	1	0	1	0	5	1	14	2	0	22	91
9/14	0	0	1	1	0	2	50	6	6	41	1	1	55	96
TOT.	1	1	7	6	0	15		41	31	132	24	3	231	
AVE.	0.1	0.1	1.0	0.8	0.0	2.1	60	6.8	5.2	22.0	4.0	0.5	38.5	89
	Sta 325													
5/19	2	3	18	0	2	25	92							
6/17	0	0	3	0	0	3	100							
7/15	0	2	3	0	0	5	100							
8/04	0	1	3	0	0	4	100							
8/19	2	2	10	1	0	15	93							
9/04	5	6	23	1	0	35	97							
9/14	10	10	27	81	0	128	37							
TOT.	19	24	87	33	2	215								
AVE.	2.7	3.4	12.4	11.8	0.3	30.7	61							

PLE = Plecoptera (stoneflies)
TRI = Tricoptera (mayflies)
EPE = Ephemerontera (caddisflies)
DIP = Diptera (common flies)
OTH = Other benthic insects
TOT = Total
% SEN = percent of pollution sensative (PLE, TRI, EPE) benthics

TABLE 11. Comparative Water Ouality Data from Station 322 (in-situ bioassay) and 100% Soda Butte Creek water (in the flow-through bioassay tank), showing particularly, the reduction in dissolved iron between the creek (322) and the bioassay unit (100%). All concentrations are in mg/L.

Date	8/15		9/10		9/12		9/14	
Station	322	100%	322	100%	322	100%	322	100%
Aluminum - Dis.	0.050	<0.050	<0.050	0.050	0.050	<0.050	0.050	<0.050
Aluminum - Tot.	0.050	0.050	<0.050	0.050	0.050	0.050	0.050	0.050
Cadmium - Dis.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium - Tot.	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper - Dis.	<0.001	0.002	0.004	<0.001	0.004	<0.001	0.004	<0.001
Copper - Tot.	0.011	0.003	0.007	0.003	0.004	0.006	0.004	0.006
Iron - Dis.	3.820	0.300	6.200	0.630	6.700	0.660	6.400	0.500
Iron - Tot.	6.900	4.380	10.600	6.500	10.500	8.460	10.530	10.000
Lead - Dis.	0.007	0.003	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
Lead - Tot.	0.009	0.003	0.010	0.003	0.004	0.008	0.009	0.004
Zinc - Dis.	<0.001	<0.001	0.017	<0.001	0.018	<0.001	0.013	<0.001
Zinc - Tot.	0.004	<0.001	0.039	0.011	0.018	0.012	0.013	0.010
Calcium	45.000	45.980	52.000	46.400	52.000	51.740	51.500	51.580
Magnesium	9.900	10.300	13.400	11.000	13.200	13.020	13.500	12.530
Sodium	1.300	1.300	1.400	1.400	1.400	1.400	1.400	1.500
Potassium	1.000	1.100	1.400	1.200	1.300	1.400	1.300	1.300
Manganese	0.210	0.180	0.320	0.240	0.340	0.310	0.330	0.310
Bicarbonate	132.000	130.500	131.000	117.360	133.000	131.800	126.800	126.370
Sulfate	48.000	53.700	80.000	70.000	80.000	77.500	78.300	84.100
Conductivity - umohs	305.700	311.900	271.700	332.700	372.900	367.400	370.500	362.800
PH	6.010	6.070	6.410	6.480	6.490	6.540	6.240	6.930
Dissolved Oxygen	7.100	6.700	7.300	5.900	6.900	6.800	9.300	7.200
Temperature - ^{o}C	9.000	10.500	10.000	15.000	7.000	11.000	7.000	7.000

100% Soda Butte Creek water it ranged from 0.30 to 0.66 mg/l, clearly an order of magnitude difference. No other water quality constituent, dissolved or total, reflected such an extreme difference. The dissolved iron apparently precipitated on all available surfaces, including the PVC line and the glass aquarium, lowering its concentration to "safe" values (at least for an acute test) for the aquarium fish.

At Station 322, during both the August and September tests, fish mortalities were recorded every twelve hours. At these time intervals the total lengths of the dead fish were also measured to the nearest mm. These measurements, particularly during September when there was a wide variation in length between the test fish, demonstrated that the larger fish survived for longer periods in the highly concentrated dissolved iron water of Station 322 (Figure 6).

d. Heavy Metal Analyses of Fish Tissue

The metal analyses of the head, skin, and internal organs (composite) subsamples for the Soda Butte stations demonstrated that the iron concentrations were at least seven times more concentrated in the fish from Station 322 than at any of the other Soda Butte Creek stations (Table 12). The data in Appendices 14-25 also show that the iron values in the fish tissue at this station were far above those found at any of the other stations in the study. These data therefore support the water quality and bioassay information, both of which indicated that iron was the cause of mortality to the fish at Station 322.

FIGURE 6. Length - Mortality relationship in two, 96 hour in-situ bioassays at Station 322, Soda Butte Creek, demonstrating that smaller cutthroat trout are more susceptible to dissolved iron-induced mortality. In test #1, the fish were smaller (3.5-4.0 cm compared to 3.8-5.7 cm in the second test). They also exhibited less variation in length - the largest fish in the first test was only 1.15x larger than the smallest, compared to 1.50x in the second test.

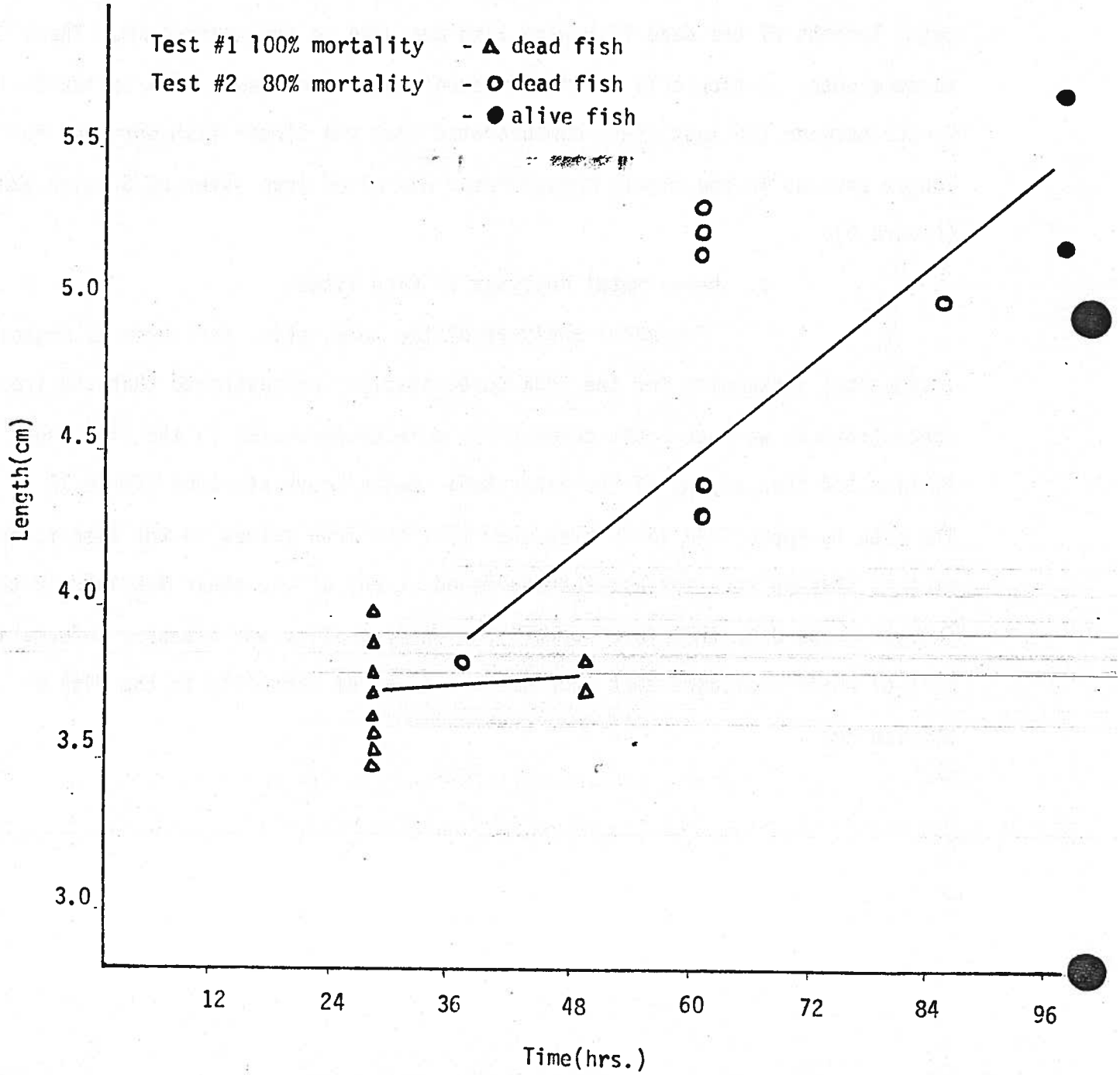


TABLE 12. Heavy metal concentrations in fish flesh from the Soda Butte/ McLaren Mine Stations. All concentrations are in ug/g dry weight.

August 1975

(head, skin, and internal organs composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
317	141	1.19	8	500	113
322	586	<.60	73	11,140	134
325	151	<.60	9	849	123
Bioassay tank - Soda Butte	59	<.60	10	585	115

(flesh and bones composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
317	31	<.60	8	163	101
322	64	<.60	17	460	110
325	5	<.60	10	153	103
Bioassay tank - Soda Butte	25	<.60	7	167	93

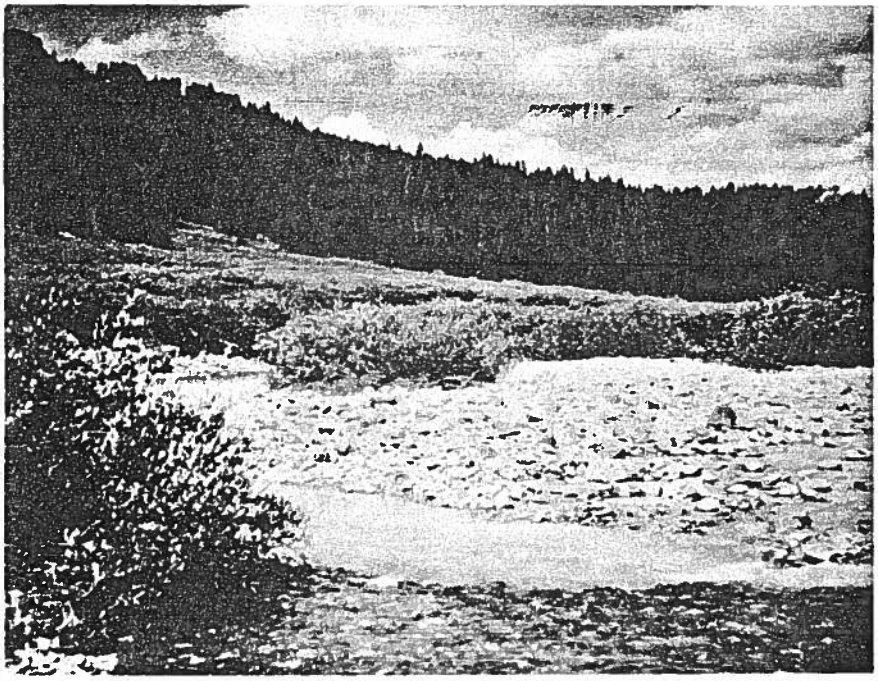
September 1975

(head, skin, and internal organs composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
317	85	2.57	7	728	110
322	52	.87	11	5,490	112
325	92	.60	8	632	127
Bioassay tank - Soda Butte	62	<.60	7	737	159

(flesh and bones composite)

STA	Aluminum	Cadmium	Copper	Iron	Zinc
317	32	<.60	5	96	80
322	38	<.60	8	300	108
325	51	<.60	6	180	96
Bioassay tank - Soda Butte	27	<.60	5	90	113



Appendix 1. Basic water quality parameters (mg/l) from the Daisy Creek/ Stillwater stations (those not listed in Table 2).

	STA 109 Date				STA 127 Date			
	8/5	8/20	9/5	9/15	8/5	8/20	9/5	9/15
Sodium	1.20	1.70	1.90	1.90	0.80	1.00	1.10	1.20
Potassium	0.70	0.80	0.80	1.00	0.50	0.60	0.70	0.80
Manganese	1.82	2.60	3.50	4.40	0.57	0.91	1.23	1.39
Chloride	2.30	1.50	0.25	0.25	1.00	0.40	0.60	0.30
Nitrate	0.63	0.36	0.11	0.25	0.90	0.00	0.60	0.60
Fluoride	0.30	0.30	0.40	0.50	0.10	0.30	0.20	0.30
Dis. Oxygen	----	----	----		6.10	6.51	8.40	8.70
Temp. (^{o}C)	8.50	9.00	13.00	13.00	14.20	11.00	11.00	12.00
Tot. Sus. Solids	61.73	-----	-----	-----	32.96	32.99	31.27	32.63
Tot. Hardness	153.00	188.00	237.00	269.00	108.00	105.00	175.00	207.00

	STA 128 Date				STA 129 Date
	8/5	8/20	9/5	9/15	9/15
Sodium	1.40	1.50	1.70	1.80	1.50
Potassium	0.30	0.30	0.40	0.40	0.30
Manganese	0.12	0.19	0.22	0.24	<0.01
Chloride	0.90	0.60	0.60	0.10	0.20
Nitrate	0.80	0.20	0.10	0.10	0.05
Fluoride	0.00	0.01	0.01	0.10	0.00
Dis. Oxygen	6.40	6.95	9.30	7.90	8.80
Temp. (^{o}C)	12.70	10.00	7.00	12.00	3.00
Tot. Sus. Solids	8.95	11.13	11.80	13.31	0.3
Tot. Hardness	70.00	83.00	96.00	100.00	72.00

Appendix 2. Basic water quality parameters (mg/l) from the Fisher Creek/ Clarks Fork stations (those not listed in Table 5).

	STA 207 Date				STA 209 Date			
	8/5	8/20	9/6	9/16	8/5	8/20	9/6	9/16
Sodium	1.80	2.40	3.10	3.40	1.00	1.20	1.40	1.40
Potassium	0.90	1.00	1.30	1.40	0.50	0.60	0.70	0.70
Manganese	0.47	0.65	0.88	1.00	0.06	0.08	0.08	0.08
Chloride	2.20	1.00	0.65	0.90	0.60	1.00	1.30	0.60
Nitrate	0.18	0.05	0.05	0.05	0.70	0.90	0.10	0.20
Fluoride	0.10	0.20	0.20	0.20	0.00	0.00	0.00	0.00
Dis. Oxygen	----	----	----	----	7.60	7.05	7.90	9.50
Temp. (^{o}C)	10.00	9.00	11.00	10.00	5.50	7.00	12.00	7.00
Tot. Sus. Solids	6.47	5.56	-----	-----	1.22	1.26	0.41	8.90
Tot. Hardness	32.00	43.00	61.00	67.00	34.00	42.00	40.00	40.00

	STA 213 Date				STA 214 Date			
	8/5	8/20	9/6	9/16				9/16
Sodium	0.80	1.00	1.10	1.20				1.20
Potassium	0.40	0.40	0.60	0.60				0.60
Manganese	0.02	0.01	0.01	0.00				0.02
Chloride	1.10	1.40	0.30	0.20				0.35
Nitrate	0.70	0.80	0.10	0.00				0.07
Fluoride	0.00	0.00	0.00	0.00				0.00
Dis. Oxygen	7.30	7.20	8.90	9.30				9.50
Temp (^{o}C)	9.00	8.50	10.00	7.00				4.50
Tot. Sus. Solids	0.83	0.51	0.21	0.61				2.09
Tot. Hardness	26.00	29.00	32.00	34.00				35.00

Appendix 3.

Basic Water Quality parameters (excluding heavy metals) for Station 317, Soda Butte Creek. All concentrations, unless labeled otherwise, are in mg/L.

Date Parameter	5/19	6/17	7/02	7/20	8/04	8/19	9/04	9/23
Calcium	40.00	25.00	19.80	34.80	----	39.40	40.00	38.80
Magnesium	6.80	4.50	4.00	5.70	----	7.00	7.40	6.80
Sodium	1.40	1.10	0.90	1.40	----	1.80	1.70	1.60
Potassium	0.60	0.90	0.70	0.60	----	0.60	1.10	1.00
Manganese	0.01	0.00	0.01	0.03	----	0.01	0.04	0.01
Silica	7.00	7.10	6.40	7.90	----	7.70	8.10	7.90
Bicarbonate	136.00	78.00	36.00	121.02	----	141.40	142.74	143.96
Carbonate	0.00	0.00	0.00	0.00	----	0.00	0.00	0.00
Chloride	2.20	0.60	1.20	0.30	----	0.80	0.20	0.20
Sulfate	14.50	10.30	62.00	9.90	----	10.50	8.20	7.20
Nitrate	0.40	0.00	3.90	0.02	----	0.05	0.07	0.05
Fluoride	0.00	0.00	0.00	0.00	----	0.10	0.00	0.00
Alkalinity - Tot.	112.00	64.00	30.00	121.00	----	141.00	143.00	144.00
Dissolved Oxygen	9.80	10.50	9.70	9.40	8.05	7.15	9.50	----
PH	7.94	6.93	6.78	7.76	----	7.67	8.20	7.54
Conductivity - umhos	239.00	151.30	121.80	206.40	-----	227.80	231.50	230.80
Temperature - ^{o}C	1.00	2.00	6.00	6.00	6.20	6.00	6.00	7.00
Total Suspended Solids	4.14	2.09	104.12	0.30	----	1.26	----	----
Flow M^3/sec.	0.094	0.920	1.622	----	----	0.146	0.079	0.071

Appendix 4.

Basic Water Quality parameters (excluding heavy metals) for Station 322, Soda Butte Creek. All concentrations, unless labeled otherwise, are in mg/L.

Date Parameter	5/19	6/17	7/02	7/20	8/04	8/19	9/04	9/23
Calcium	42.00	23.00	19.80	25.60	42.80	47.00	54.00	53.80
Magnesium	8.80	4.00	6.00	4.00	7.90	10.30	12.40	13.50
Sodium	1.40	1.00	0.80	1.10	1.40	1.50	1.50	1.70
Potassium	1.00	0.60	1.50	0.60	0.90	0.90	1.50	1.10
Manganese	0.17	0.00	0.29	0.03	0.12	0.21	0.28	0.32
Silica	6.00	7.00	5.60	6.30	7.30	7.50	7.90	7.50
Bicarbonate	73.00	72.00	56.00	75.80	117.10	126.40	128.10	128.10
Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloride	1.30	1.10	0.50	0.50	1.10	0.60	0.40	0.20
Sulfate	71.00	15.50	11.90	17.70	40.70	57.70	72.60	81.70
Nitrate	0.40	0.00	3.20	0.02	0.05	0.09	0.05	0.07
Fluoride	0.10	0.00	0.00	0.00	0.00	0.10	0.10	0.10
Alkalinity - Tot.	60.00	59.00	46.00	76.00	117.00	126.00	128.00	128.00
Dissolved Oxygen	8.95	10.30	9.85	9.40	7.60	6.70	9.70	-------
PH	7.24	6.57	6.74	7.18	6.77	7.14	6.97	7.29
Conductivity - umhos	279.20	147.50	104.00	154.50	277.40	307.70	349.50	367.00
Temperature - ^{o}C	0.50	2.00	4.00	8.50	8.50	8.00	7.00	7.00
Total Suspended Solids	------	3.94	631.56	7.60	10.09	19.14	------	-------
Flow M^3/sec.	0.074	1.121	2.697	0.905	0.272	0.110	0.095	0.049

Appendix 5.

Basic Water Quality parameters (excluding heavy metals) for Station 325, Soda Butte Creek. All concentrations, unless labeled otherwise, are in mg/L.

Date Parameter	5/19	6/17	7/02	7/20	8/04	8/19	9/04	9/23
Calcium	19.10	16.00	10.40	9.70	17.10	23.00	26.00	28.00
Magnesium	5.30	4.00	2.10	2.10	3.50	5.10	6.50	6.50
Sodium	3.10	2.80	2.10	2.50	3.40	3.30	3.50	3.40
Potassium	0.50	0.40	0.40	0.30	0.40	0.60	0.60	0.60
Manganese	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Silica	7.90	8.60	7.30	7.10	9.40	8.90	9.10	8.80
Bicarbonate	72.00	61.00	45.00	40.00	66.00	90.00	98.00	110.00
Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloride	0.40	0.60	1.90	0.40	0.07	2.00	0.20	0.00
Sulfate	12.90	11.40	6.40	6.10	8.00	12.70	22.00	11.10
Nitrate	1.10	0.80	0.20	0.40	1.10	0.80	0.00	0.20
Fluoride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity - Tot.	59.00	50.00	37.00	33.00	54.00	74.00	80.00	90.00
Dissolved Oxygen	10.15	10.25	9.65	8.90	6.95	7.40	8.50	8.60
PH	7.47	7.91	6.73	6.41	6.46	5.96	6.79	6.79
Conductivity - umhos	143.00	121.20	91.30	79.40	128.80	169.40	196.60	206.30
Temperature - ^{o}C	0.40	4.10	5.30	9.00	12.20	10.00	14.00	11.00
Total Suspended Solids	------	------	1942.88	274.40	8.39	3.46	20.57	4.87
Flow M^3/sec.	1.245	8.292	19.895	11.037	2.038	0.821	0.708	0.6

Appendix 6.

Basic Water Quality parameters (excluding heavy metals) for Station 326, Soda Butte Creek. All concentrations, unless labeled otherwise, are in mg/L.

Date Parameter	5/19	6/17	7/02	7/15	8/04	8/19	9/04	9/14
Calcium	23.00	17.60	11.40	11.90	20.00	26.00	30.00	32.00
Magnesium	6.30	5.00	2.40	2.70	4.70	6.40	8.00	8.80
Sodium	3.50	3.00	2.50	2.80	3.50	3.70	3.80	3.80
Potassium	0.60	0.50	0.40	0.40	0.50	0.60	0.80	0.80
Manganese	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silica	10.90	9.40	8.30	8.80	10.10	10.30	10.70	10.30
Bicarbonate	90.00	72.00	49.00	50.00	81.00	109.00	122.00	125.00
Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloride	0.30	1.20	1.90	0.10	0.60	1.50	0.20	0.40
Sulfate	11.60	9.50	5.90	5.90	10.60	12.40	16.30	23.00
Nitrate	0.90	0.80	0.30	0.30	1.00	0.80	0.00	0.10
Fluoride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alkalinity - Tot.	74.00	59.00	40.00	41.00	66.00	89.00	100.00	103.00
Dissolved Oxygen	10.20	10.35	9.00	8.70	6.60	7.70	8.90	8.50
PH	7.72	7.92	6.67	6.55	6.52	5.98	6.92	6.65
Conductivity - umhos	174.20	136.40	95.20	94.50	149.80	192.80	225.70	240.10
Temperature - ^{o}C	0.70	4.70	8.10	10.50	13.80	8.00	13.00	11.00
Total Suspended Solids	------	------	529.64	117.80	7.58	3.35	1.88	1.02
Flow M^3/sec.	2.236	9.537	22.866	13.556	3.792	2.009	1.726	1.330

Appendix 7.

Basic Water Quality parameters (excluding heavy metals) for Station 327, Soda Butte Creek. All concentrations, unless labeled otherwise, are in mg/L.

Date Parameter	5/19	6/17	7/02	7/15	8/04	8/19	9/04	9/14
Calcium	26.00	19.20	12.80	13.60	23.00	28.00	31.00	33.00
Magnesium	7.80	5.00	3.10	3.60	4.60	7.20	9.20	9.40
Sodium	3.40	3.00	2.60	2.80	3.40	3.60	3.60	3.60
Potassium	0.80	0.60	0.50	0.50	0.60	0.70	0.90	1.00
Manganese	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silica	10.80	10.00	9.20	9.60	10.90	11.60	11.80	11.80
Bicarbonate	108.00	78.00	54.00	58.00	93.00	121.00	130.00	135.00
Carbonate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chloride	0.60	0.60	1.60	0.50	0.90	1.60	0.20	0.10
Sulfate	12.70	10.00	6.80	6.00	10.90	11.30	13.50	16.90
Nitrate	0.20	0.60	0.20	0.60	1.10	0.80	0.00	0.10
Fluoride	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Alkalinity - Tot.	89.00	64.00	45.00	47.00	76.00	99.00	107.00	111.00
Dissolved Oxygen	10.60	10.45	8.72	8.45	6.90	7.70	8.30	8.20
PH	7.87	7.95	7.39	7.62	6.49	6.28	8.05	7.32
Conductivity - umhos	203.80	144.80	103.70	109.20	159.90	202.50	222.10	246.40
Temperature - ^{o}C	3.30	3.70	10.20	9.80	13.10	7.00	11.00	12.00
Total Suspended Solids	------	------	489.68	83.00	7.16	3.37	1.23	1.12
Flow M^3/sec.	2.462	9.764	23.432	11.207	4.471	2.126	1.557	1.9

Appendix 8. Dissolved and Total Aluminum (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	0.10 (----)	0.11 (----)	0.10 (0.63)	0.13 (0.65)	0.10 (0.35)
6/17	0.08 (----)	0.08 (----)	0.11 (0.99)	0.08 (1.06)	0.10 (1.13)
7/02	<0.05 (----)	4.55 (----)	0.12 (29.00)	0.12 (12.20)	0.10 (14.20)
7/15			0.10 (4.00)	0.08 (2.79)	0.08 (2.84)
7/20	---- (----)	0.05 (----)			
8/04		0.11 (0.14)	0.07 (0.52)	0.10 (0.47)	0.05 (0.36)
8/19	<0.05 (<0.05)	<0.05 (0.11)	<0.05 (0.15)	0.06 (0.17)	0.07 (0.22)
9/04	<0.05 (0.05)	0.05 (0.05)	0.05 (0.40)	<0.05 (0.05)	<0.05 (0.05)
9/14			<0.05 (0.05)	0.06 (0.06)	<0.05 (<0.05)
9/23	0.06 (0.06)	0.05 (0.05)			

Appendix 9. Dissolved and Total Copper (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	0.010 (-----)	0.030 (-----)	0.002 (0.010)	0.002 (0.002)	0.001 0.001
6/17	0.100 (-----)	0.100 (-----)	0.003 (0.010)	0.002 (0.012)	0.003 0.009
7/02	0.080 (-----)	0.500 (-----)	0.002 (0.350)	0.002 (0.086)	0.003 (0.082)
7/15			0.002 (0.027)	0.001 (0.015)	0.001 (0.001)
7/20	0.040 (-----)	0.030 (-----)			
8/04		0.004 (-----)	0.002 (0.010)	0.001 (0.002)	0.002 0.002
8/19			<0.001 (<0.001)	<0.001 (0.002)	<0.001 (0.005)
9/04	0.005 (-----)	0.004 (-----)	0.002 (0.002)	0.002 (0.002)	0.002 (0.003)
9/14			0.003 (0.003)	0.006 (0.006)	0.005 (0.005)
9/23	0.011 (-----)	0.003 (-----)			

Appendix 10. Dissolved and Total Cadmium (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	<0.002 (-----)	< 0.002 (-----)	< 0.001 (<0.001)	< 0.001 (<0.001)	< 0.001 (0.001)
6/17			< 0.002 (<0.002)	< 0.002 (<0.002)	< 0.002 (<0.002)
7/02			< 0.001 (<0.001)	< 0.001 (<0.001)	< 0.001 (<0.001)
7/15			0.005 (0.005)	< 0.001 (<0.001)	< 0.001 (< 0.001)
7/20	0.010 (-----)	0.010 (-----)			
8/04		<0.002 (-----)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
8/19			<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
9/04	<0.001 (-----)	<0.001 (-----)	<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
9/14			<0.001 (<0.001)	<0.001 (<0.001)	<0.001 (<0.001)
9/23	<0.001 (-----)	<0.001 (-----)			

Appendix 11. Dissolved and Total Lead (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	0.050 (-----)	0.050 (-----)	0.006 (0.016)	<0.005 (<0.005)	<0.005 (0.015)
6/17		<0.005 (-----)	<0.005 (0.006)	<0.005 (<0.005)	<0.005 (<0.005)
7/02	<0.050 (-----)	0.070 (-----)	<0.005 (<0.005)	<0.005 (0.026)	<0.005 (0.028)
7/15			<0.005 (0.007)	<0.005 (0.008)	<0.005 (0.011)
7/20	<0.002 (-----)	0.050 (-----)			
8/04		<0.002 (0.006)	<0.005 (<0.005)	<0.005 (<0.005)	<0.005 (<0.005)
8/19			0.007 (0.007)	<0.002 (0.003)	0.007 (0.007)
9/04	0.005 (-----)	<0.005 (-----)	0.008 (0.008)	0.002 (0.008)	<0.002 (0.005)
9/14			0.004 (0.004)	0.005 (0.005)	0.007 (0.007)
9/23	<0.005 (-----)	<0.005 (-----)			

Appendix 12. Dissolved and Total Zinc (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	<0.010 (-----)	0.020 (-----)	0.002 (0.012)	0.006 (0.006)	<0.001 (0.005)
6/17	0.010 (-----)	0.010 (-----)	<0.005 (0.017)	<0.005 (<0.005)	<0.005 (0.006)
7/02	0.010 (-----)	0.080 (-----)	<0.002 (0.212)	<0.002 (0.055)	<0.002 (0.069)
7/15			<0.002 (0.025)	<0.002 (0.008)	<0.002 (0.007)
7/20	0.010 (-----)	0.010 (-----)			
8/04		0.007 (0.020)	<0.001 (0.030)	<0.001 (0.004)	<0.001 (0.006)
8/19			<0.001 (<0.001)	<0.001 (0.007)	<0.001 (0.017)
9/04	0.014 (-----)	0.009 (-----)	0.005 (0.005)	0.004 (0.009)	0.004 (0.029)
9/14			0.012 (0.012)	<0.001 (0.036)	0.019 (0.019)
9/23	0.012 (-----)	0.007 (-----)			

Appendix 13. Dissolved and Total Iron (mg/L).

Soda Butte Drainage

Total Concentrations are in parenthesis below each corresponding dissolved concentration.

Station	317	322	325	326	327
Date					
5/19	0.05 (----)	0.17 (7.90)	0.10 (1.17)	0.17 (0.94)	0.02 (0.53)
6/17	0.25 (0.25)	0.22 (0.47)	0.36 (1.44)	0.12 (1.55)	0.06 (1.64)
7/02	0.18 (2.80)	11.50 (16.20)	0.02 (55.60)	0.05 (19.10)	0.04 (19.80)
7/15			0.06 (6.58)	0.05 (4.11)	0.06 (3.68)
7/20	0.15 (0.15)	0.10 (1.25)			
8/04		0.06 (5.20)	0.07 (0.89)	0.06 (0.70)	0.00 (0.52)
8/19	0.03 (0.40)	1.46 (8.70)	0.01 (0.54)	0.01 (0.40)	0.02 (0.38)
9/04	0.28 (0.28)	0.36 (9.10)	0.01 (0.81)	0.00 (0.23)	0.01 (0.23)
9/14			0.01 (0.54)	0.01 (0.19)	0.02 (0.15)
9/23	0.12 (0.12)	0.84 (11.50)			

Appendix 14.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – flesh and bones composite

Measurement for: Ash and moisture

Lab Number	Station Number	Number of fish & date collected	% Ash	% Moisture
75-1808	127	5 fish - 9/17/75	1.56	80.07
75-1810	128	5 fish - 9/18/75	2.40	75.24
75-1811	129	5 fish - 9/18/75	2.35	74.39
75-1813	209	5 fish - 9/19/75	2.40	76.18
75-1815	213	5 fish - 9/19/75	2.13	78.02
75-1818	214	5 fish - 9/19/75	2.00	78.39
75-1820	317	5 fish - 9/14/75	2.63	75.97
75-1822	322	5 fish - 9/13/75	2.81	75.13
75-1824	325	5 fish - 9/14/75	3.19	74.85
75-1826	Tank-Soda Butte	5 fish - 9/14/75	2.63	76.17
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	2.74	76.51
75-1830	317	9 fish - 8/15/75	2.00	73.88
75-1832	322	6 fish - 8/13/75	2.14	76.08
75-1834	325	6 fish - 8/13/75	2.05	73.95
75-1836	Tank-Soda Butte	6 fish - 8/16/75	3.16	74.11
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	2.37	78.98

Note: Ash was measured using low temperature Oxygen Plasma.
Moisture was measured using oven dry temperature of 110° C.

LAW:rlw — Laurence A. Wegleitner — Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 15.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – head, skin and internal organs composite

Measurement for: Ash and moisture

Lab Number	Station Number	Number of fish & date collected	% Ash	% Moisture
75-1807	127	5 fish - 9/17/75	2.05	80.12
75-1809	128	5 fish - 9/18/75	3.00	75.89
75-1812	129	5 fish - 9/18/75	2.25	75.50
75-1814	209	5 fish - 9/19/75	3.45	73.95
75-1816	213	5 fish - 9/19/75	2.53	78.83
75-1817	214	5 fish - 9/19/75	2.96	78.14
75-1819	317	5 fish - 9/14/75	3.01	76.12
75-1821	322	5 fish - 9/13/75	3.08	73.76
75-1823	325	5 fish - 9/14/75	3.14	75.87
75-1825	Tank-Soda Butte	5 fish - 9/14/75	2.98	74.21
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	3.02	83.62
75-1829	317	9 fish - 8/15/75	3.41	71.28
75-1831	322	6 fish - 8/13/75	3.83	74.71
75-1833	325	6 fish - 8/13/75	2.83	74.47
75-1835	Tank-Soda Butte	6 fish - 8/16/75	3.21	72.82
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	3.25	70.37

Note: Ash was measured using low temperature Oxygen Plasma.
Moisture was measured using oven dry temperature of 110°C.

LAW:rlw

Lawrence A. Woytkie — Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 16.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – head, skin and internal organs composite

Measurement for: Aluminum (Al)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1807	127	5 fish - 9/17/75	7,561	780	155
75-1809	128	5 fish - 9/18/75	9,290	260	63.8
75-1812	129	5 fish - 9/18/75	757	69.4	17.0
75-1814	209	5 fish - 9/19/75	2,453	325	84.7
75-1816	213	5 fish - 9/19/75	653	78.2	16.6
75-1817	214	5 fish - 9/19/75	600	81.2	17.8
75-1819	317	5 fish - 9/14/75	669	84.5	20.2
75-1821	322	5 fish - 9/13/75	443	51.9	13.6
75-1823	325	5 fish - 9/14/75	706	91.8	22.2
75-1825	Tank-Soda Butte	5 fish - 9/14/75	532	61.8	15.9
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	262	32.9	7.92
75-1829	317	9 fish - 8/15/75	1,186	141	40.5
75-1831	322	6 fish - 8/13/75	3,874	586	148
75-1833	325	6 fish - 8/13/75	1,363	151	38.6
75-1835	Tank-Soda Butte	6 fish - 8/16/75	495	58.5	15.9
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	412	54.3	13.4

LAW:rlw

Laurence A. Woyden ——Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 17.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – flesh and bones composite

Measurement for: Aluminum (Al)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1808	127	5 fish - 9/17/75	692	54.0	10.8
75-1810	128	5 fish - 9/18/75	382	37.1	9.19
75-1811	129	5 fish - 9/18/75	224	20.6	5.26
75-1813	209	5 fish - 9/19/75	270	27.3	6.50
75-1815	213	5 fish - 9/19/75	246	23.7	5.20
75-1818	214	5 fish - 9/19/75	204	18.9	4.07
75-1820	317	5 fish - 9/14/75	295	32.3	7.76
75-1822	322	5 fish - 9/13/75	333	37.7	9.27
75-1824	325	5 fish - 9/14/75	434	51.4	12.9
75-1826	Tank-soda Butte	5 fish - 9/14/75	242	26.7	6.37
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	118	13.7	3.22
75-1830	317	9 fish - 8/15/75	400	30.6	7.99
75-1832	322	6 fish - 8/13/75	711	63.8	15.3
75-1834	325	6 fish - 8/13/75	607	4.78	12.5
75-1836	Tank-soda Butte	6 fish - 8/16/75	208	25.4	6.57
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	197	22.2	4.67

LAW:tlw

Lawrence A. Woodgerd—Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 18.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department

Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – flesh and bones composite

Measurement for: Cadmium (Cd)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1808	127	5 fish - 9/17/75	< 7.5	< .6	< .1
75-1810	128	5 fish - 9/18/75	< 7.5	< .6	< .1
75-1811	129	5 fish - 9/18/75	< 7.5	< .6	< .1
75-1813	209	5 fish - 9/19/75	< 7.5	< .6	< .1
75-1815	213	5 fish - 9/19/75	< 7.5	< .6	< .1
75-1818	214	5 fish - 9/19/75	< 7.5	< .6	< .1
75-1820	317	5 fish - 9/14/75	< 7.5	< .6	< .1
75-1822	322	5 fish - 9/13/75	< 7.5	< .6	< .1
75-1824	325	5 fish - 9/14/75	< 7.5	< .6	< .1
75-1826	Tank-Soda Butte	5 fish - 9/14/75	< 7.5	< .6	< .1
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	< 7.5	< .6	< .1
75-1830	317	9 fish - 8/15/75	< 7.5	< .6	< .1
75-1832	322	6 fish - 8/13/75	< 7.5	< .6	< .1
75-1834	325	6 fish - 8/13/75	< 7.5	< .6	< .1
75-1836	Tank-Soda Butte	6 fish - 8/16/75	< 7.5	< .6	< .1
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	< 7.5	< .6	< .1

LAW:rlw

Lawrence A. Nyegaard — Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 19.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department

Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue -- head, skin and internal organs composite

Measurement for: Cadmium (Cd)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1807	127	5 fish - 9/17/75	10.2	1.05	.21
75-1809	128	5 fish - 9/18/75	10.7	1.34	.32
75-1812	129	5 fish - 9/18/75	13.4	1.22	.30
75-1814	209	5 fish - 9/19/75	< 7.5	< .6	< .1
75-1816	213	5 fish - 9/19/75	3.63	< .6	< .1
75-1817	214	5 fish - 9/19/75	5.01	.68	.14
75-1819	317	5 fish - 9/14/75	20.4	2.57	.61
75-1821	322	5 fish - 9/13/75	7.45	.87	.23
75-1823	325	5 fish - 9/14/75	4.62	.60	.15
75-1825	Tank-Soda Butte	5 fish - 9/14/75	3.96	< .6	< .1
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	*14.1	*1.76	*.42
75-1829	317	9 fish - 8/15/75	10.0	1.19	.34
75-1831	322	6 fish - 8/13/75	< 7.5	< .6	< .1
75-1833	325	6 fish - 8/13/75	< 7.5	< .6	< .1
75-1835	Tank-Soda Butte	6 fish - 8/16/75	< 7.5	< .6	< .1
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	18.3	2.41	.60

LAW:rlw

Lawrence A. Lyle — Chief, Analytical Division

* contaminated sample
KK

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 20.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – head, skin and internal organs composite

Measurement for: Copper (Cu)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1807	127	5 fish - 9/17/75	2,707	279	55.6
75-1809	128	5 fish - 9/18/75	1,230	153	36.9
75-1812	129	5 fish - 9/18/75	98.9	9.07	2.22
75-1814	209	5 fish - 9/19/75	281	37.2	9.69
75-1816	213	5 fish - 9/19/75	65.8	7.88	1.67
75-1817	214	5 fish - 9/19/75	82.7	11.2	2.44
75-1819	317	5 fish - 9/14/75	58.9	7.43	1.78
75-1821	322	5 fish - 9/13/75	92.9	10.9	2.86
75-1823	325	5 fish - 9/14/75	58.7	7.63	1.84
75-1825	Tank-Soda Butte	5 fish - 9/14/75	60.8	7.06	1.82
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	*55,763	*6,982	*1,682
75-1829	317	9 fish - 8/15/75	66.8	7.94	2.28
75-1831	322	6 fish - 8/13/75	484	73.3	18.5
75-1833	325	6 fish - 8/13/75	77.9	8.63	2.20
75-1835	Tank-Soda Butte	6 fish - 8/16/75	84.2	9.96	2.70
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	68.6	9.04	2.23

LAW:rlw

* Contaminated sample
KK

Lawrence A. Wright — Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 21.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department

Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue -- flesh and bones composite

Measurement for: Copper (Cu)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1808	127	5 fish - 9/17/75	4,287	335	66.8
75-1810	128	5 fish - 9/18/75	1,558	151 KK	37.4
75-1811	129	5 fish - 9/18/75	61.7	~~174~~ 5.85	1.50
75-1813	209	5 fish - 9/19/75	65.2	6.58	1.57
75-1815	213	5 fish - 9/19/75	47.8	4.62	1.02
75-1818	214	5 fish - 9/19/75	83.1	7.68	1.66
75-1820	317	5 fish - 9/14/75	49.5	5.41	1.30
75-1822	322	5 fish - 9/13/75	68.7	7.75	1.92
75-1824	325	5 fish - 9/14/75	48.5	5.74	1.44
75-1826	Tank-Soda Butte	5 fish - 9/14/75	51.8	5.72	1.36
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	47.1	5.49	1.29
75-1830	317	9 fish - 8/15/75	100	7.65	2.00
75-1832	322	6 fish - 8/13/75	194	17.4	1.85
75-1834	325	6 fish - 8/13/75	121	9.56	2.49
75-1836	Tank-Soda Butte	6 fish - 8/16/75	41.7	6.98	1.80
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	74.2	8.37	1.76

LAW:rlw

Lawrence A. Woodin ------ Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 22.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – head, skin and internal organs composite

Measurement for: Iron (Fe)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1807	127	5 fish - 9/17/75	7,783	803	160
75-1809	128	5 fish - 9/18/75	2,047	254	61.5
75-1812	129	5 fish - 9/18/75	1,297	119	29.2
75-1814	209	5 fish - 9/19/75	2,611	346	90.1
75-1816	213	5 fish - 9/19/75	691	66.8	14.7
75-1817	214	5 fish - 9/19/75	2,009	240	50.9
75-1819	317	5 fish - 9/14/75	5,386	728	159
75-1821	322	5 fish - 9/13/75	46,809	5,490	1,440
75-1823	325	5 fish - 9/14/75	4,863	632	153
75-1825	Tank-Soda Butte	5 fish - 9/14/75	6,343	737	190
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	1,453	182	43.8
75-1829	317	9 fish - 8/15/75	4,211	500	144
75-1831	322	6 fish - 8/13/75	73,608	11,140	2,817
75-1833	325	6 fish - 8/13/75	7,662	849	216
75-1835	Tank-Soda Butte	6 fish - 8/16/75	4,947	585	159
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	1,792	236	58.2

LAW:rlw

Lawrence A. Woplin ——Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY.

Appendix 23.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department

Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue - flesh and bones composite

Measurement for: Iron (Fe)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1808	127	5 fish - 9/17/75	1,101	86.0	17.1
75-1810	128	5 fish - 9/18/75	2,047	254	61.5
75-1811	129	5 fish - 9/18/75	583	53.6	13.7
75-1813	209	5 fish - 9/19/75	515	52.1	12.4
75-1815	213	5 fish - 9/19/75	691	66.8	14.7
75-1818	214	5 fish - 9/19/75	645	59.7	12.9
75-1820	317	5 fish - 9/14/75	878	96.1	23.1
75-1822	322	5 fish - 9/13/75	2,659	300	74.7
75-1824	325	5 fish - 9/14/75	1,520	180	45.3
75-1826	Tank-Soda Butte	5 fish - 9/14/75	818	90.3	21.5
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	541	63.1	14.8
75-1830	317	9 fish - 8/15/75	2,200	168	44.0
75-1832	322	6 fish - 8/13/75	5,129	460	110
75-1834	325	6 fish - 8/13/75	1,942	153	39.9
75-1836	Tank-Soda Butte	6 fish - 8/16/75	1,367	167	43.1
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	1,060	120	25.4

LAW:rlw

Lawrence A. Vogel, Chief, Analytical Division

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS AND UNDERGROUND WATER SUPPLY

Appendix 24.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department — Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – head, skin and internal organs composite

Measurement for: Zinc (Zn)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1807	127	5 fish - 9/17/75	1,090	113	22.4
75-1809	128	5 fish - 9/18/75	1,999	249	60.0
75-1812	129	5 fish - 9/18/75	1,039	95.4	23.4
75-1814	209	5 fish - 9/19/75	906	120	31.3
75-1816	213	5 fish - 9/19/75	908	108	23.0
75-1817	214	5 fish - 9/19/75	924	125	27.3
75-1819	317	5 fish - 9/14/75	875	110	26.4
75-1821	322	5 fish - 9/13/75	957	112	29.5
75-1823	325	5 fish - 9/14/75	977	127	30.7
75-1825	Tank-Soda Butte	5 fish - 9/14/75	1,372	159	41.1
75-1827	Tank-Miller Cr.	5 fish - 9/14/75	*30,459	*3,814	*919
75-1829	317	9 fish - 8/15/75	956	113	32.6
75-1831	322	6 fish - 8/13/75	890	134	34.0
75-1833	325	6 fish - 8/13/75	1,110	123	31.4
75-1835	Tank-Soda Butte	6 fish - 8/16/75	974	115	31.3
75-1837	Tank-Miller Cr.	6 fish - 8/16/75	1,131	149	36.7

LAW:rlw

Lawrence A. Wagelin — Chief, Analytical Division

* CONTAMINATED SAMPLE KK

THE BUREAU OF MINES AND GEOLOGY WAS ESTABLISHED BY LAW IN 1919 AS A DEPARTMENT OF MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, TO PROMOTE EFFICIENT DEVELOPMENT OF MONTANA'S MINERAL RESOURCES BY GATHERING AND PUBLISHING INFORMATION ON THE GEOLOGY, TOPOGRAPHY, AND MINERAL DEPOSITS OF THE STATE, INCLUDING METALS, NON-METALS, COAL, OIL, GAS, AND UNDERGROUND WATER SUPPLY

Appendix 25.

MONTANA BUREAU OF MINES AND GEOLOGY
MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
BUTTE, MONTANA 59701
(406) 792-8321

Montana Fish and Game Department

Cooke City Study - Ken Knudson

February 18, 1976

Fish Tissue Analysis Report

Type of sample: Tissue – flesh and bones composite

Measurement for: Zinc (Zn)

Lab Number	Station Number	Number of fish & date collected	Ash Basis µg/gram	Dry Basis µg/gram	As rec'd Basis µg/gram
75-1808	127	5 fish - 9/17/75	864	67.6	13.5
75-1810	128	5 fish - 9/18/75	849	82.4	20.4
75-1811	129	5 fish - 9/18/75	814	74.9	19.2
75-1813	209	5 fish - 9/19/75	785	79.2	18.9
75-1815	213	5 fish - 9/19/75	770	74.5	16.4
75-1818	214	5 fish - 9/19/75	820	75.9	16.4
75-1820	317	5 fish - 9/14/75	730	79.9	19.2
75-1822	322	5 fish - 9/13/75	964	108	27.1
75-1824	325	5 fish - 9/14/75	807	95.6	24.1
75-1826	Tank-Soda Butte	5 fish - 9/14/75	1,025	113	27.0
75-1828	Tank-Miller Cr.	5 fish - 9/14/75	694	80.9	19.0
75-1830	317	9 fish - 8/15/75	1,320	101	26.4
75-1832	322	6 fish - 8/13/75	1,228	110	26.3
75-1834	325	6 fish - 8/13/75	1,262	103	26.9
75-1836	Tank-Soda Butte	6 fish - 8/16/75	760	92.7	23.9
75-1838	Tank-Miller Cr.	6 fish - 8/16/75	1,124	126	26.7

LAW:rlw

Lawrence A. Wegelin Chief, Analytical Division

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