The effects of metals on trout populations in the Upper Boulder River, Montana
by Frederick Allen Nelson

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University
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Abstract:
The effects of metals on the trout populations in the upper Boulder River were studied during 1975 and 1976. The water quality, shoreline cover, and trout populations were measured in Section A, located above Basin, Montana, and in Sections B and C, located between Basin and Boulder. The chemical and physical characteristics of the water in the study sections were similar, except for levels of metals. The median concentrations of total recoverable metals in Sections A, B, and C, respectively, were 0.02, 0.13, and 0.24 mg/l for zinc and <0.01, 0.02, and 0.04 mg/l for copper. The frequency of detectable levels of total recoverable lead progressively increased from Section A to C. Total cover in Section B was judged far superior to that in Sections A and C. Total cover in Section A was judged slightly superior to that in Section C. The estimated numbers of I+ and older trout in Sections A, B, and C were 650, 245, and 70/ha, respectively. The estimated standing crops of I+ and older trout in Sections A, B, and C were 37.7, 22.4, and 5.7 kg/ha, respectively. Zinc, copper, and lead were the measured metals probably depressing trout populations between Basin and Boulder.

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IN THE UPPER BOULDER RIVER, MONTANA

by

FREDERICK ALLEN NELSON

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

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Approved:

William R. Gould
Chairperson, Graduate Committee

James M. Pickett
Head, Major Department

Henry L. Parsons
Graduate Dean

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ABSTRACT

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Boulder River were studied during 1975 and 1976. The water quality,
shoreline cover, and trout populations were measured in Section A,
located above Basin, Montana, and in Sections B and C, located
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trout populations between Basin and Boulder.

INTRODUCTION

The mining and processing of gold, silver, lead, copper, and zinc within the Boulder River drainage between the towns of Basin and Boulder has been extensive. Since 1870 at least 51 ore producing mines and 11 mills have been located in this area (Roby *et al.*, 1960). In 1976 only one mine in this area produced ore in commercial quantities.

Metals from acid mine drainage and the leaching and erosion of old mill tailings and exposed overburden are impairing water quality in the Boulder River below Basin. Fragmentary water quality data presented by Braico and Botz (1974) showed concentrations of metals were lowest above Basin, increased substantially between Basin and Boulder, and persisted at relatively high levels to the river's mouth.

The depressed populations of trout found in a 36 km section of the Boulder River below Boulder were partially attributed to periodic metals pollution (Vincent, 1975). However, the effects of metals alone could not be assessed since the depressed populations also reflected the adverse effects of excessive sedimentation, severe dewatering, and the removal of streambank cover.

The primary purpose of this study was to measure the effects of metals on the fish populations in sections of the Boulder River between Basin and Boulder. In this area metals were the only major potential depressant. Information from this study will be useful in determining

if the influx of metals must be reduced to enhance the fish populations in the area. If control measures are adopted, this study also will provide data for evaluating improvements in water quality and fish populations. Field research was conducted from April, 1975 through August, 1976.

DESCRIPTION OF STUDY AREA

The Boulder River is located in southwestern Montana in Jefferson County. It originates in the Boulder Mountains near the continental divide at an approximate elevation of 2219 m and flows in a south-easterly direction for approximately 111 km to its confluence with the Jefferson River near Cardwell, Montana. Its drainage basin encompasses 1974 km². Approximately 14.4% of the natural channel has been altered by man (Bishop and Peck, 1962).

The study area was located on the Boulder River between the con-fluence of Red Rock Creek and the town of Boulder. In this area the river lies in a narrow, rocky canyon within the Boulder Mountains. Alder *(Alnus* spp.*)* and willow *(Salix* spp.*)* were dominant on the river banks, and conifers on the canyon slopes. Exposed strata were primar-ily quartz monzonite of the Boulder batholith (Roby *et al.*, 1960). Important tributaries in the study area were Basin, Cataract, and High Ore Creeks.

Mean, minimum, and maximum discharges of the Boulder River near Boulder for a 41 year period of record ending in 1972 were 206, 0, and 5933 m³/min, respectively (U.S.G.S., 1972). During this study, dis-charges were abnormally high. Minimum and maximum discharges near Boulder for the period April 26, 1975 through April 9, 1976 were 90 and 5972 m³/min, respectively (U. S. Soil Conservation Service, 1976).

Three study sections were established in the study area (Fig. 1). They were selected primarily on the basis of differences in their concentrations of metals as determined by preliminary sampling. Section A was established above the town of Basin. It began approximately 1.0 river km below the confluence of Red Rock Creek and extended 884 m downstream. Its approximate elevation was 1658 m. Construction of a now abandoned railway bed more than 50 years ago resulted in the straightening of 58% of the present channel. The minimum discharge measured was 60 m^3/min. This section served as the control. Its waters contained low levels of metals.

Sections B and C were established between the towns of Basin and Boulder. Section B began approximately 0.9 river km below the confluence of Cataract Creek and extended 847 m downstream. Its approximate elevation was 1597 m. The lower boundary of Section B was approximately 7.7 river km below the upper boundary of Section A. The water in this section contained intermediate levels of metals.

Section C began approximately 2.3 river km below the confluence of High Ore Creek and extended 1029 m downstream. Its approximate elevation was 1536 m. The minimum discharge measured was 72 m^3/min. The lower boundary of Section C was approximately 13.6 river km below the upper boundary of Section A and 6.7 river km below the upper boundary of Section B. The water in this section contained high levels of metals.
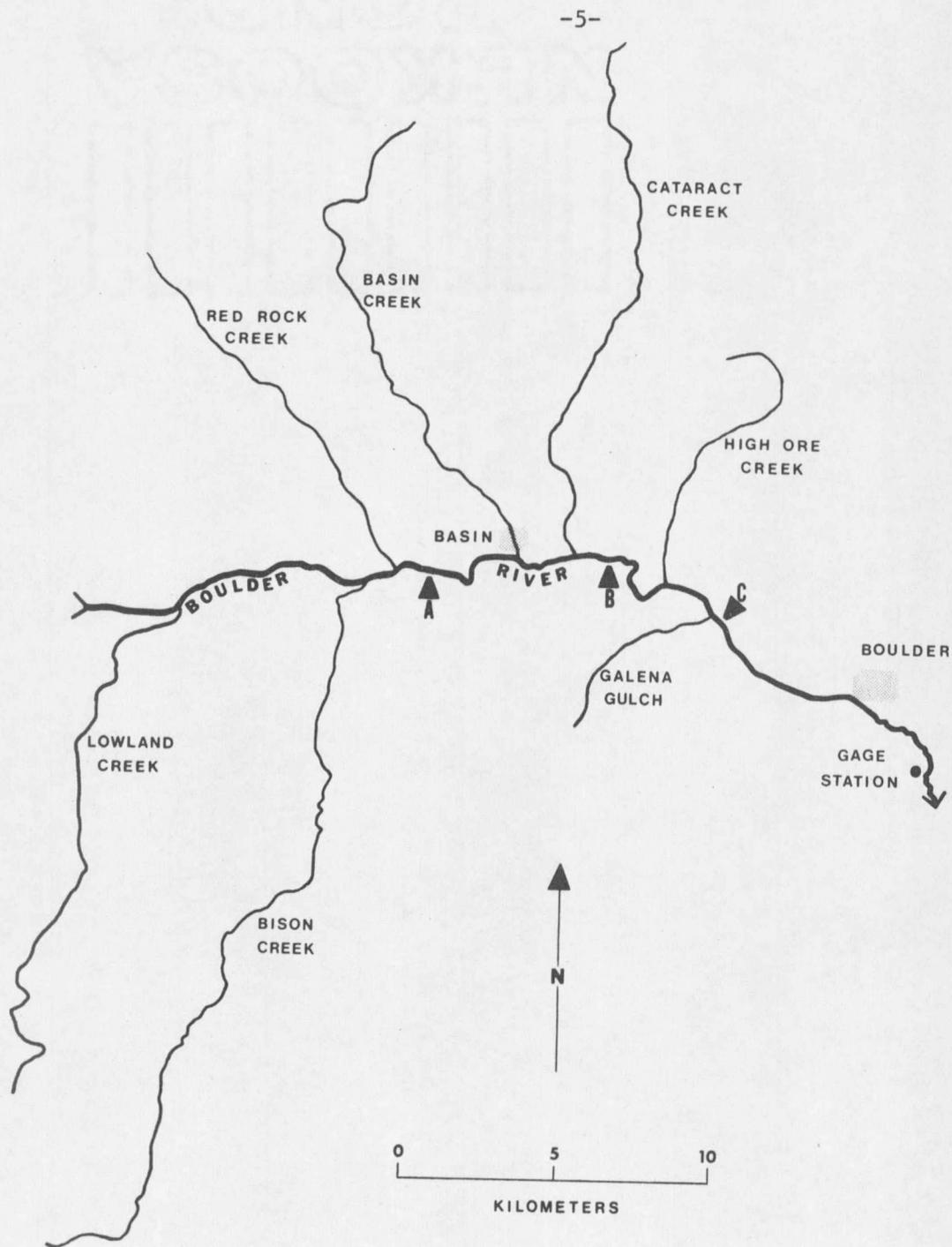
Figure 1. Map of the study area showing the location of the study
sections. Arrows indicate the direction of flow.

In all three study sections the Boulder River lies in a single, stable channel. The substrate in the sections was primarily gravel, rubble, and boulders.

Rainbow trout *(Salmo gairdneri)*, brook trout *(Salvelinus fontinalis)*, mountain whitefish *(Prosopium williamsoni)*, longnose sucker *(Catostomus catostomus)*, white sucker *(Catostomus commersoni)*, longnose dace *(Rhinicthys cataractae)*, and mottled sculpin *(Cottus bairdi)* were found in the study sections. Brown trout *(Salmo trutta)*, found by Vincent (1975) in the river below Boulder, were not taken in my study sections. No hatchery fish have been stocked in the study area since 1973.

METHODS

Water samples were collected at or near the lower end of each study section. Most chemical and physical characteristics were measured monthly.

Grab samples for metal analyses were collected in one liter polyethylene bottles, immediately acidified with 5 ml of distilled, concentrated nitric acid, and analyzed within the 6 month storage period recommended by EPA. Metal analyses were performed primarily by personnel at the Water Quality Laboratory, Department of Health and Environmental Sciences, Helena, Montana using flame atomic absorption spectrophotometry (AAS). Some iron, zinc, and copper analyses were performed by the investigator. The lower detection limits for iron, zinc, copper and cadmium were 0.05, 0.01, 0.01, and 0.001 mg/l, respectively. During the study, the lower detection limit for lead was increased from 0.02 to 0.05 mg/l. Concentrations of metals are reported as the total recoverable metal, and are a measure of both the toxic and non-toxic species of a metal.

Dissolved oxygen was measured by a modified azide-Winkler method using Hach Chemical Company reagents. Other chemical and physical analyses were performed according to Standard Methods (A.P.H.A., 1971). The pH was measured with a Beckman Expandomatic pH meter. Calcium and magnesium concentrations were measured by flame AAS, and sodium and

potassium concentrations by flame emission. Hardness was computed
from calcium and magnesium concentrations. Sulfate, ammonia, nitrate,
and orthophosphate concentrations were measured using filtered water
samples by the turbidimetric, phenolhypochlorite, Mullin and Riley
reduction, and single reagent methods, respectively. Chloride con-
centrations were measured by the nitrate method. Turbidity was
measured with a Hach 2100 turbidometer. Nonfiltrable residue was
determined by passing a 125 ml water sample through a predried Gelman
glass fiber type A filter, then drying at 105 C for one hour.

Water temperatures were monitored using Taylor maximum-minimum
thermometers. Discharges were calculated using velocity measurements
made with a Gurley type AA current meter at 0.6 of the depth below the
surface. Elevations and distances were obtained from U.S.G.S. maps.

The channel morphology and shoreline cover in each study section
were measured. Section length was measured down the center of the
channel. Transects were established 10 m apart at Section A and 15 m
apart at Sections B and C. River width was measured to the nearest
0.1 m along each transect. Water depth was measured to the nearest
0.1 ft (3.0 cm) at 0.5 m intervals along each transect. A mean depth
was computed for each transect. These values were averaged to obtain
the mean section depth. Aerial photographs were used to measure
sinuosity and evaluate channel stability. Gradient was measured with
a level and stadia rod. The surface area of shoreline cover 1.5 m on

each side of the transects was measured to the nearest 0.1 m^2. Cover

was defined as brush (overhanging, rooted, woody vegetation), debris

(unrooted driftwood, logs, and snags), and undercuts (overhanging

shelf of soil or grassy vegetation) having a mean water depth $\geq$ 0.3 m

under or surrounding it. Only brush and debris in the water or $\leq$ 1.0

m above the surface were considered cover. The length of each pool

was measured. Pools were distinct units having smooth surfaces, low

water velocities, and maximum depths $\geq$ 0.8 m.

Fish populations in the study sections were sampled by electro-

fishing. The weight and total length (TL) of each captured fish were

measured to the nearest gram and 0.1 in (2.54 mm), respectively.

Scales of rainbow trout were taken from the area between the dorsal

fin and lateral line. Fish were marked with a fin clip and released

for mark-recapture population estimates. Impressions of the scales

were made on cellulose acetate slides and examined on a scale projector

at 66X. Trout numbers were estimated using Chapman's modification of

the Petersen formula. Standing crops, age structures, and appropriate

95% confidence limits were computed using methods summarized by

Vincent (1971).

The regressions of total length on anterior scale radius of

rainbow trout in the study sections were linear (r=.870 to .915),

permitting the back calculation of total length at annulus formation

(age) with the direct-proportionality formula (Tesch, 1971):

$$\ln - C = \frac{Sn}{S} (1-C)$$

where $\ln$ = total length of fish at time of annulus "n" formation,

1 = total length of fish at time scale was taken,

Sn = radius of annulus "n",

S = total anterior scale radius, and

C = Y-axis intercept of total length: scale radius regression.

The length: weight relationship of rainbow trout ≥ 125 mm in TL was derived using the formula (Ricker, 1975):

$$\log W = \log a + b (\log L),$$

where W is the weight (g) and L is the total length (mm). This relationship and the grand mean total length at age were used to calculate the weight of rainbow trout at age. The slope (b) from the length: weight relationship was used in computing the mean instantaneous annual rates of increase in weight $(\overline{G})$, derived according to the method on page 219 of Ricker (1975).

The condition factor (K) was calculated using the formula (Rounsefell and Everhart, 1953):

$$K = \frac{W (10^5)}{L^3} ,$$

where W is the weight (g) and L is the total length (mm).

Three bioassays were conducted at the lower end of each study section. Two were conducted with the fingerlings and one with the

eyed eggs of hatchery rainbow trout. Trout cages and cylindrical egg sacs were constructed from fiberglass screening.

Statistical tests were made using methods in Dixon and Massey (1969). The term significant refers to statistical significance at the $p<.05$ level. Linear regressions were derived using the method of least squares.

Chemical and Physical Characteristics of Water Samples

The chemical and physical characteristics of water samples measured on each sampling period are presented in Appendix Tables 1 through 15. The median and range of the total recoverable metals in each study section are presented in Table 16. Median concentrations

TABLE 16. MEDIAN AND RANGE (IN PARENTHESIS) OF TOTAL RECOVERABLE METAL (TRM) CONCENTRATIONS (mg/1) FOR 14, 12, AND 14 WATER SAMPLES COLLECTED AT OR NEAR SECTIONS A, B, AND C, RESPECTIVELY, FROM APRIL 26, 1975 THROUGH APRIL 9, 1976.

| TRM | Section | | |
	A	B	C
Fe	.49 (.22–1.8)	.66 (.18–2.0)	.73 (.21–2.6)
Zn	.02 (<.01–.05)	.13 (.09–.25)	.24 (.07–.53)
Cu	<.01 (<.01–.02)	.02 (<.01–.09)	.04 (.01–.10)
Cd	<.001 (<.001–<.001)	<.001 (<.001–.001)	<.001 (<.001–.001)
Pb	<.05 (<.02–<.05)	<.05 (<.02–<.05)	<.05 (<.02–.10)

of iron, zinc, and copper progressively increased from Section A through C. Median cadmium and lead concentrations were lower than the detection limit of the procedure used. However, the maximum concentration of cadmium was highest in Sections B and C and the maximum

concentration of lead was highest in Section C. The frequency of

detectable levels of cadmium and lead also progressively increased

from Section A through C (Table 17), indicating concentrations during

TABLE 17. PERCENT OF 14, 12, AND 14 WATER SAMPLES COLLECTED AT OR
NEAR SECTIONS A, B, AND C, RESPECTIVELY, HAVING TOTAL
RECOVERABLE METAL (TRM) CONCENTRATIONS $>$ THE LOWER
DETECTION LIMIT OF AAS.

TRM	Lower Detection Limit (mg/l)	Section		
		A	B	C
Fe	.05	100	100	100
Zn	.01	71	100	100
Cu	.01	43	92	100
Cd	.001	0	25	43
Pb	.02 or .05	0	8	43

the study were probably lowest in Section A, intermediate in B, and

highest in C. Supplementary sampling (Appendix Tables 18 and 19)

implicated the extensive tailings deposits on the south bank at the

town of Basin and Basin, Cataract, and particularly High Ore Creeks as

major contributors of metals to the Boulder River above the town of

Boulder.

The median and range of the other chemical and physical charac-

teristics measured in each study section are presented in Table 20.

The medians for each characteristic were similar at all study sections.

The ranges for each characteristic, except turbidity and nonfiltrable

residue, were also similar. The maximum turbidity at Section B was

TABLE 20. MEDIAN AND RANGE (IN PARENTHESIS) OF CHEMICAL AND PHYSICAL
CHARACTERISTICS FOR WATER SAMPLES COLLECTED IN THE BOULDER
RIVER AT OR NEAR THE STUDY SECTIONS FROM APRIL 26, 1975
THROUGH APRIL 9, 1976.

Characteristic	Section A	Section B	Section C
pH	7.5	7.5	7.6
	(7.2-8.0)	(7.1-8.0)	(7.2-8.0)
Conductivity	140	142	152
(μmhos/cm at 25 C)	(87-174)	(77-160)	(80-172)
Alkalinity	43.5	41.0	42.3
(mg/1 $CaCO_3$)	(17.5-55.0)	(16.5-50.5)	(16.0-52.0)
Hardness	43.4	47.6	51.3
(mg/1 $CaCO_3$)	(28.5-64.2)	(25.7-61.8)	(27.1-74.3)
Calcium	12.8	14.2	14.9
(mg/1)	(8.6-19.1)	(7.8-18.3)	(8.2-23.8)
Magnesium	2.9	3.0	3.5
(mg/1)	(1.7-4.0)	(1.5-3.9)	(1.6-4.2)
Turbidity	5.0	7.0	10.0
(JTU)	(1.5-17.0)	(1.1-82.0)	(0.9-24.0)
Nonfiltrable Residue	17	8	21
(mg/1)	(0-189)	(0-256)	(0-116)
Sodium	7.6	6.3	6.4
(mg/1)	(7.5-7.7)	(6.2-6.4)	(6.2-6.5)
Potassium	1.4	1.4	1.6
(mg/1)	(1.2-1.5)	(1.2-1.5)	(1.2-2.0)
Chloride	1.5	1.4	1.4
(mg/1)	(1.4-1.6)	(1.3-1.5)	(1.3-1.4)
Sulfate	14.4	18.5	19.9
(mg/1)	(10.5-18.3)	(14.5-22.5)	(16.0-23.7)
PO_4^{-3}-P	.026	.021	.022
(mg/1)	(.024-.028)	(.020-.021)	(.019-.025)
NH_3-N	0	0	0
(mg/1)			
NO_3^--N	.040	.038	.046
(mg/1)	(.033-.047)		(.038-.053)

considerably greater than those at Sections A and C, which were similar. The maximum nonfiltrable residue was highest at Section B, intermediate at A, and lowest at C.

Water temperatures, monitored from July 22 through September 22, 1975 at two sites bracketing the study sections, ranged from 3.5 - 21 and 4 - 22 C near Sections A and C, respectively. Within a recording period, maximum and minimum temperatures near Section A were from 0 - 1 C lower than those near Section C.

Dissolved oxygen was measured frequently throughout the study at irregular intervals. The minimum dissolved oxygen concentration measured for each study section was 10 mg/l.

Channel Morphology and Cover

Channel morphology and shoreline cover were measured in the study sections between October 18 and November 2, 1975 when discharges were 123, 159, and 213 m^3/min at Sections A, B, and C, respectively. These discharges were abnormally high for this time of year.

The morphological characteristics are presented in Table 21. The mean depth, mean thalweg depth, and sinuosity were similar in all sections. The mean width of Section A was approximately 67% of the mean width of Sections B and C, which were similar. The gradient at Section C was approximately 69% of the gradient at Sections A and B, which were similar.

TABLE 21. MORPHOLOGICAL CHARACTERISTICS OF THE STUDY SECTIONS IN THE BOULDER RIVER MEASURED BETWEEN OCTOBER 18 AND NOVEMBER 2, 1975. STANDARD DEVIATION IN PARENTHESIS.

Section	Mean Width (m)	Mean Depth (cm)	Mean Thalweg Depth (cm)	Sinuosity	Gradient (m/km)
A	10.8 (±2.2)	33 (±6)	56 (±12)	1.07	9.6
B	16.1 (±3.5)	32 (±9)	61 (±16)	1.04	9.9
C	16.2 (±2.7)	37 (±6)	63 (±10)	1.07	6.7

The surface area of shoreline cover in each study section is presented on a comparable basis in Table 22. The total shoreline

TABLE 22. SURFACE AREA (m^2/500m) OF SHORELINE COVER IN THE STUDY SECTIONS OF THE BOULDER RIVER MEASURED BETWEEN OCTOBER 18 AND NOVEMBER 2, 1975.

| Section | Cover Type | | | |
	Brush	Undercut	Debris	Total
A	109.5	10.4	17.7	137.6
B	22.6	3.0	17.8	43.4
C	77.8	14.8	0	92.6

cover per 500 m in Section A was 217 and 49% greater than that in Sections B and C, respectively. Brush primarily accounted for the greater total shoreline cover in Section A.

Boulders and pools also provided cover in the study sections. Large boulders littered the channel in Section B, but were considerably less abundant in Sections A and C. Pools were also more prevalent in Section B. They comprised 8, 18, and 5% of the lengths of Sections

A, B, and C, respectively.

Considering all the types of cover available to fish, cover in Section B was judged to be far superior to that in Sections A and C. Cover in Section C was judged to be slightly inferior to that in Section A.

Fish Populations

The populations of rainbow trout, brook trout, mountain whitefish, white suckers, and longnose suckers were sampled from August 26 through September 11, September 9 through September 17, and August 27 through September 3, 1975 in Sections A, B, and C, respectively. Catch statistics for the five species collected are presented in Appendix Table 23. Rainbow trout was the dominant species in all study sections, comprising 55, 60, and 74% of the total fish collected in Sections A, B, and C, respectively.

Population estimates were made for rainbow trout in Sections A, B, and C and brook trout in Section A (Appendix Table 23). The small numbers of brook trout in Sections B and C, mountain whitefish in Section C, white suckers in all sections, and longnose suckers in Sections A and C captured during the electrofishing runs indicate populations were too sparse to estimate. Relatively large numbers of longnose suckers in Section B and mountain whitefish in Sections A and B were captured during the electrofishing runs. However, numbers

of longnose suckers in Section B could not be estimated because
insufficient recaptures were obtained. The numbers of mountain white-
fish in Sections A and B could not be estimated because adult whitefish
were suspected of entering the study sections subsequent to the marking
run, thereby violating a condition necessary for valid mark-recapture
estimates. Because whitefish may have moved between areas having
different concentrations of metals, comparisons of lengths and weights
at age, $\overline{G}$, and condition factors for those captured at Sections A and
B were not made.

Estimates of Numbers, Standing Crops, and Age Structures

Estimates of the numbers and standing crops of I+ and older
rainbow trout and brook trout in the study sections are presented on
comparable bases in Table 24. Total trout numbers per 500 m in
Sections B and C were 56 and 16%, respectively, and total trout
standing crops were 88 and 23%, respectively, of those in Section A.
Differences were more pronounced per hectare. Total trout numbers in
Sections B and C were 38 and 11%, respectively, and total trout
standing crops were 59 and 15%, respectively, of those in Section A.
Estimates were considered significantly different if 95% confidence
limits did not overlap. Of these estimates, all but the standing
crops per 500 m in Sections A and B were significantly different.

TABLE 24. ESTIMATES OF NUMBERS ($\overline{N}$), STANDING CROPS, AND AGE STRUCTURES OF TROUT IN THE STUDY SECTIONS OF THE BOULDER RIVER. 95% CONFIDENCE LIMITS IN PARENTHESIS.

| | | | Per 500 m | | Per ha | |
| | | | $\overline{N}$ | Standing Crop (kg) | $\overline{N}$ | Standing Crop (kg) |
Section	Species	Age-Group				
A	Rainbow Trout	I+	178	4.0	329	7.3
		II+	88	6.8	162	12.6
		III+ & Older	37	6.1	68	11.3
			303	16.9	559	31.2
			(225-381)	(13.4-20.4)	(416-702)	(24.7-37.7)
	Brook Trout	I+ & Older	49	3.5	91	6.5
			(34-64)	(2.4-4.6)	(64-118)	(4.5-8.5)
	Total Trout	I+ & Older	352	20.4	650	37.7
			(273-431)	(16.7-24.1)	(504-796)	(30.9-44.5)
B	Rainbow Trout	I+	91	2.8	113	3.5
		II+	42	3.6	53	4.5
		III+ & Older	63	11.5	79	14.4
			196	17.9	245	22.4
			(171-221)	(15.4-20.4)	(214-276)	(19.2-25.6)
C	Rainbow Trout	I+ & Older	57	4.6	70	5.7
			(32-82)	(2.6-6.6)	(39-101)	(3.2-8.2)

Most estimates for rainbow trout progressively declined between Sections A and C. Rainbow trout numbers per 500 m in Sections B and C were 65 and 19%, respectively, and rainbow trout standing crops were 106 and 27%, respectively, of those in Section A. Again, differences were more pronounced per hectare. Rainbow trout numbers in Sections B and C were 44 and 13%, respectively, and rainbow trout standing crops were 72 and 18%, respectively, of those in Section A. Of these estimates, all but the standing crops per 500 m and hectare in Sections A and B were significantly different.

Sufficient numbers of rainbow trout were sampled in Sections A and B to estimate the age structures and to partition standing crop estimates by age-groups (Table 24). Age-groups I+, II+, and III+ and older comprised 59, 29, and 12%, respectively, of the estimated numbers of rainbow trout in Section A, and 24, 40, and 36%, respectively, of the estimated standing crop. At Section B, the age structure was "top-heavy" compared to Section A. Age-groups I+, II+, and III+ and older comprised 46, 21, and 32%, respectively, of the estimated number of rainbow trout in Section B, and 16, 20, and 64%, respectively, of the estimated standing crop. The estimated numbers and standing crops of rainbow trout in age-groups I+ and II+ were higher in Section A than in Section B. However, the estimated numbers and standing crops of III+ and older rainbow trout were highest in Section B. This caused the estimates of the standing crops of rainbow trout in these sections

to be more similar than were the estimates of numbers.

Calculated Lengths and Weights at Age

The total length: scale radius regressions and the length: weight regressions used in the back calculations of lengths and weights, respectively, at age for rainbow trout in the study sections are given in Appendix Table 25. Calculated lengths and weights of rainbow trout at age are given in Table 26.

The grand mean lengths of fish at ages I and II in Section B were significantly greater than those in Sections A and C, which were not significantly different. Grand mean lengths of fish at age III in all sections were not significantly different, although fish in Section C were shortest.

Rainbow trout in Section B were heavier at ages I, II, and III than those in Sections A and C (Fig. 2). The calculated weights of fish at ages I and II in Section C were greater than those in Section A. The calculated weight at age III in Section C was the lowest among the study sections.

Mean Instantaneous Annual Rates of Increase in Weight

Mean instantaneous annual rates of increase in weight $(\bar{G})$ during the second and third years of life for rainbow trout in Sections A and B were compared in relation to the weight at the beginning of the year of life in Figure 3. Rates $(\bar{G})$ at Section B were less than those at

TABLE 26. CALCULATED MEAN TOTAL LENGTH (mm) AND WEIGHT (g) AT ANNULUS FORMATION (AGE) FOR RAINBOW TROUT IN THE STUDY SECTIONS OF THE BOULDER RIVER. STANDARD DEVIATION IN PARENTHESIS.

Section	Age-Group	N	Mean TL at Capture (mm)	Annulus 1	Annulus 2	Annulus 3
A	I+	148	129 (±15)	75^a		
	II+	88	198 (±25)	79^a	158^a	
	III+	42	251 (±31)	77^a	151^a	223
	Grand Mean Length			$77\ (\pm14)^d$	$155\ (\pm25)^d$	$223\ (\pm32)^d$
	Increment of Grand Mean Length			77	79	67
	Calculated Weight			4.6	36.7	106.0
B	I+	121	140 (±13)	85		
	II+	57	199 (±13)	92^b	162^b	
	III+	68	243 (±20)	90^b	168^b	223
	Grand Mean Length			88 (±13)	165 (±20)	$223\ (\pm22)^d$
	Increment of Grand Mean Length			88	77	58
	Calculated Weight			7.6	48.4	116.4
C	I+	25	134 (±13)	77^c		
	II+	27	196 (±15)	77^c	156^c	
	III+	8	236 (±25)	76^c	147^c	209
	Grand Mean Length			$77\ (\pm10)^d$	$154\ (\pm18)^d$	$209\ (\pm24)^d$
	Increment of Grand Mean Length			77	77	55
	Calculated Weight			6.3	43.2	102.2

[a, b, c] Means with the same letter designation under a given annulus are not significantly different (p>.05).

[d] Grand means so designated under a given annulus are not significantly different (p>.05).
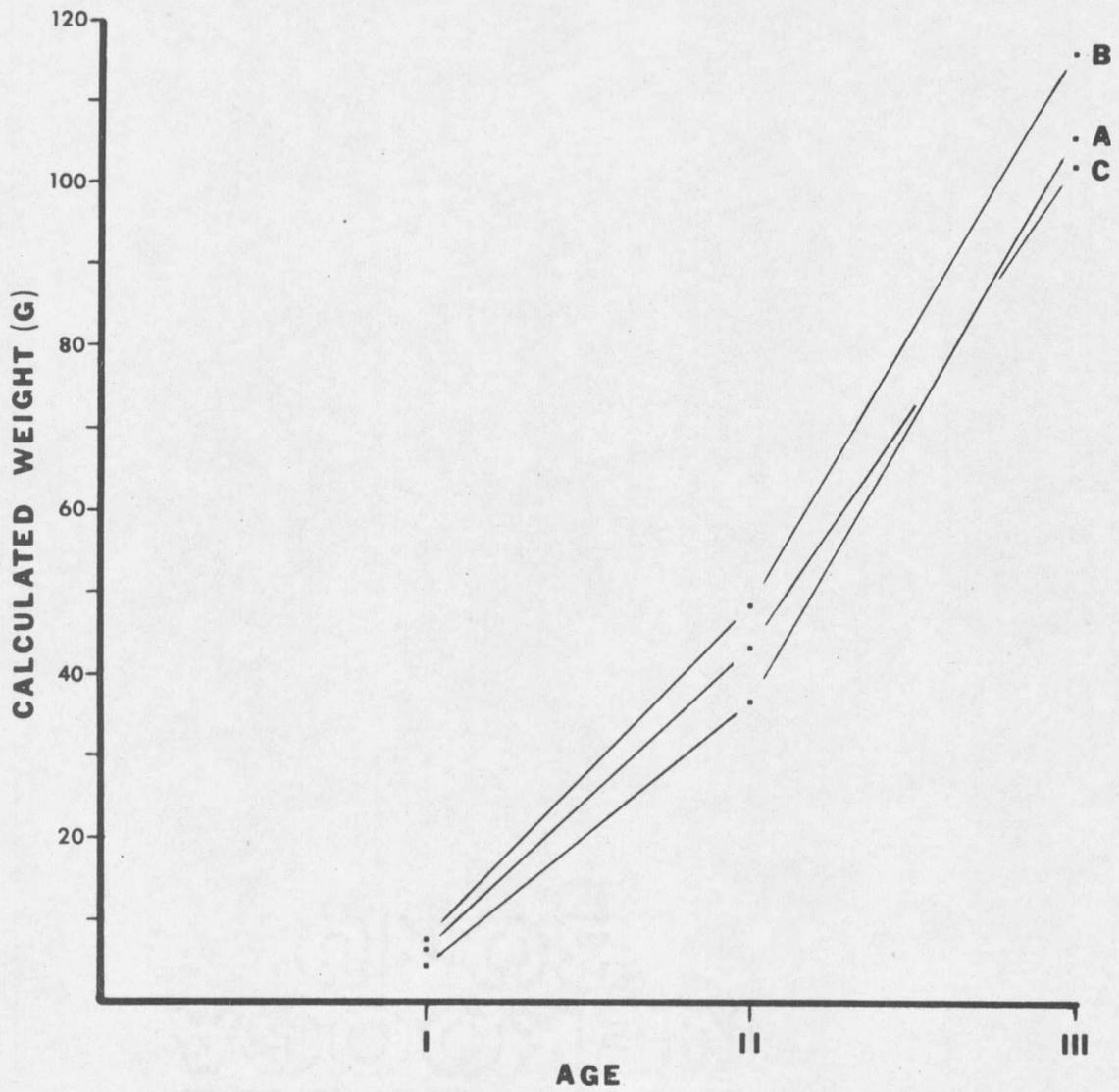
Figure 2. Calculated weights at age for rainbow trout in the study
sections of the Boulder River.
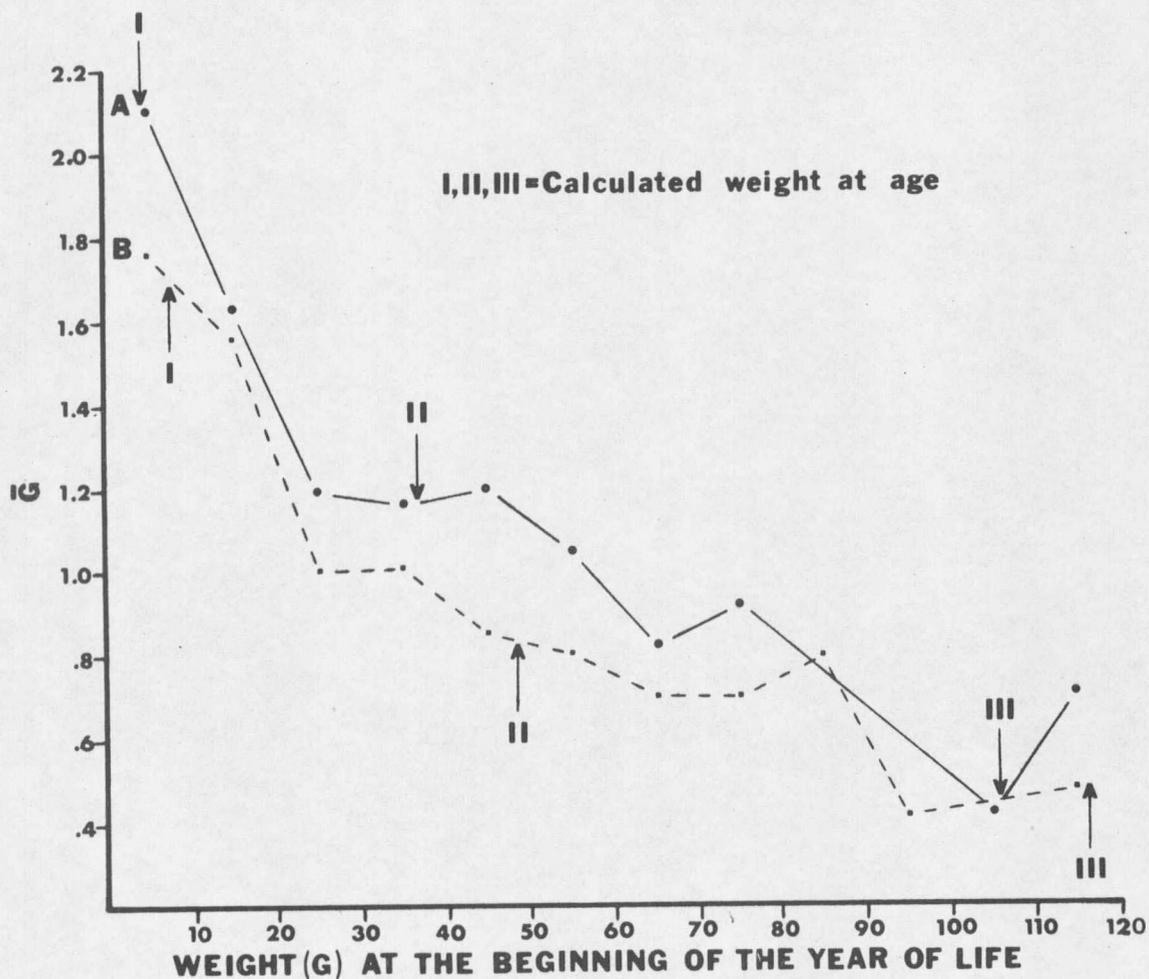
Figure 3.   Mean instantaneous annual rate of increase in weight (G̅)
            during the second and third years of life in relation to
            weight at the beginning of the year of life for rainbow
            trout in Sections A and B of the Boulder River.

Section A up to the 71-80 g weight interval. They appear to converge

at the higher weight intervals. The lower rates at Section B indicate

that the weight advantages rainbow trout in Section B have over those

in Section A at ages II and III (Fig. 2) were related to the superior

rate of growth in the first year of life. The weight advantage at

Section B was maintained at ages II and III by similar or superior

absolute increments of growth, not by superior instantaneous growth.

The sample for Section C was too small for comparison.

Condition Factors (K)

Mean condition factors (K) were computed for rainbow trout from

127 through 279 mm in TL in each study section (Table 27). Fish of

TABLE 27. MEAN CONDITION (K) OF RAINBOW TROUT FROM 127 THROUGH 279 mm
IN TOTAL LENGTH (TL) IN THE STUDY SECTIONS OF THE BOULDER
RIVER. STANDARD DEVIATION IN PARENTHESIS.

Section	N	Mean K	Mean TL
A	210	.98 ($\pm$.09)	179 ($\pm$42)
B	233	1.07 ($\pm$.09)	188 ($\pm$45)
C	61	1.16 ($\pm$.11)	187 ($\pm$44)

the same length interval were used to minimize the introduction of

length related bias. The mean condition factors increased from Section

A through Section C and all were significantly different from each

other.

Total length: condition regressions were computed for rainbow trout $\geq$ 125 mm in TL (Figure 4). Because correlation coefficients (r) are low, these regressions are of limited value for predicting the condition of a fish at a given length. However, they are useful for comparing trends between study sections. These regressions show K at length tends to be greatest for fish at Section C, intermediate at Section B, and lowest at Section A. Condition of fish at Section C was decreasing at a faster rate than at Sections A or B. All regressions were significantly different from each other.

Bioassays

The 17 day bioassay with eyed eggs of rainbow trout from the Ennis National Fish Hatchery was initiated on September 15, 1975. Two egg sacs, each containing mixed gravel and 100 eggs, were placed on the substrate in each study section. Each sac was covered with a mound of coarse gravel. At the 6 bioassay sites, water velocity at the 0.6 level ranged from 59-67 cm/sec and depth ranged from 30-37 cm. At the completion of the bioassay, live and dead sac fry were counted. The total sac fry count was subtracted from 100 to obtain the number of dead eggs per sac. The results from one egg sac at Section A were discarded. The death of many fry at this site was caused by the entanglement of their yolk sacs in the mesh of the fiberglass screening. Aberrant currents were believed responsible for these deaths.

Section	Regression	N	r
A	$K = -3.016 \times 10^{-4}$ TL $+ 1.032$[a]	238	$-.172$
B	$K = -4.260 \times 10^{-4}$ TL $+ 1.148$[a]	259	$-.249$
C	$K = -1.308 \times 10^{-3}$ TL $+ 1.403$[a]	61	$-.507$

[a]Slope of the regression is significantly less ($p<.05$) than zero.
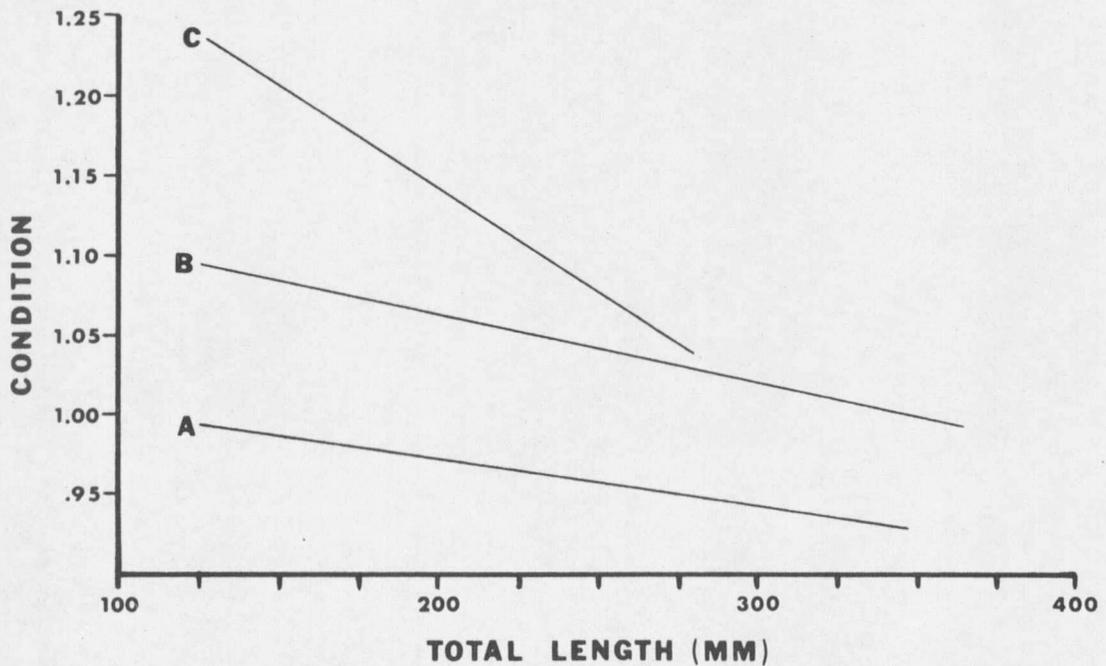
Figure 4. Total length (TL): condition (K) regressions for rainbow trout $\geq$ 125 mm in TL in the study sections of the Boulder River.

Chi square testing showed the results from the two egg sacs within Sections B and C were not significantly different, so the results for each section were summed. The summed results are presented in Table 28. The percent of live fry recovered progressively decreased

TABLE 28. RESULTS OF THE 17 DAY BIOASSAY INITIATED WITH THE EYED EGGS OF RAINBOW TROUT IN THE STUDY SECTIONS OF THE BOULDER RIVER ON SEPTEMBER 15, 1975. PERCENT OF EGGS TESTED IN PARENTHESIS.

Section	No. Eggs Tested	Live Fry Recovered	Dead Fry Recovered	Dead Eggs
A	100	86 (86.0)	0 (0)	14 (14.0)
B	200	151 (75.5)	13 (6.5)	36 (18.0)
C	200	116 (58.0)	21 (10.5)	63 (31.5)

from Section A through C while both the percent of dead fry recovered and dead eggs progressively increased. Chi square testing showed the results in Table 28 were significantly different for each study section.

During the egg bioassay, water temperatures ranged from 3 - 13, 4 - 13, and 4.5 - 13 C at Sections A, B, and C, respectively. The minimum oxygen concentration measured at each study section on September 15 and October 2, 1975 was 12 mg/l. Concentrations of metals were measured on September 23 and October 2, 1975 (Table 29). Sections B and C, which produced higher egg and fry mortalities than Section A,

TABLE 29. TOTAL RECOVERABLE METAL (TRM) CONCENTRATIONS (mg/l) IN THE
STUDY SECTIONS OF THE BOULDER RIVER DURING THE BIOASSAYS.

Date	Section	TRM				
		Fe	Zn	Cd	Cu	Pb
9/23/75	A	.22	.03	<.001	<.01	<.05
	B	.21	.13	<.001	.02	<.05
	C	.22	.22	<.001	.04	<.05
10/2	A	.29	<.01		.01	
	B	.24	.15		.04	
	C	.28	.24		.04	
10/7	A	.26	.03		.01	
	B	.24	.13		.04	
	C	.24	.26		.03	
4/22/76	A	.28	<.01			
	B	.25	.04			
	C	.27	.06			
4/25	A	.30	<.01			
	B	.27	.04			
	C	.28	.06			

had higher zinc and copper concentrations, suggesting the higher
mortalities were related to the higher levels of at least these two
metals.

Two cages, each containing 10 fingerlings, were placed in each
study section for each bioassay. The 4 day bioassay with fingerlings
from the Ennis National Fish Hatchery was initiated on October 3, 1975.
The fish ranged from 34 - 40 mm and averaged 37 mm in TL. The trout
suffered a 0, 95, and 100% mortality in Sections A, B, and C, respec-
tively.

During the fingerling bioassay, water temperatures ranged from 3.5 - 12, 4 - 12, and 4.5 - 12 C at Sections A, B, and C, respectively. The oxygen concentration measured on October 7, 1975 was 13 mg/l at all study sections. Iron, zinc and copper concentrations were measured on October 7, 1975 (Table 29). The higher concentrations of zinc and copper in Sections B and C appeared to be related to the severe fingerling mortalities in these sections.

The 3 day bioassay with fingerlings from the Bozeman Fish Cultural Development Center was initiated on April 22, 1976. The fish ranged from 46 - 74 mm and averaged 62 mm in TL. These trout suffered a 25, 10, and 90% mortality in Sections A, B, and C, respectively. Zinc and iron concentrations were measured on April 22 and April 25, 1976 (Table 29). During this bioassay, the increase in zinc concentrations between Sections A and C was not as great as in the previous bioassay, yet fingerlings still suffered a severe mortality in Section C.

In bioassays conducted in this study, the fingerlings of rainbow trout suffered a far greater mortality than the eyed eggs. This is consistent with the literature on the toxicity of metals to salmonids which reports the alevin-juvenile stage is generally the most sensitive in the life cycle.

DISCUSSION

An evaluation of the water quality, cover, and trout populations in the study sections strongly indicates metals were depressing trout populations in Sections B and C located between Basin and Boulder. Sections B and C had higher levels of metals than Section A. The estimated number of trout per 500 m and estimated number and standing crop of trout per hectare in Section B were significantly lower than in Section A. (Table 24) even though the total cover in Section B was judged far superior. The estimated number and standing crop of trout per 500 m and hectare in Section C were significantly lower than in Section A. (Table 24). The cover in Section C was judged only slightly inferior to that in Section A.

The abundance of mountain whitefish and mottled sculpins in the upper Boulder River also appeared to be inversely correlated with concentrations of metals. The number of mountain whitefish collected per 500 m of river by electrofishing progressively increased to Basin, then rapidly decreased between Basin and Boulder (Appendix Table 30). Sculpins, although not enumerated, were conspicuously abundant in Section A and scarce in Section C. In a 1973 survey, Boland (1973) also found a decrease in the abundance of mountain whitefish and mottled sculpins in the river between Basin and Boulder.

Zinc, copper, and lead were the measured metals apparently depressing trout populations between Basin and Boulder. Estimates of the highest concentrations of these metals having no adverse effect on the survival and growth of juvenile and adult rainbow trout or the hatchability of eggs have been derived from long term laboratory bioassays simulating the chemical and physical conditions that might occur in a soft water mountain trout stream. The estimated maximum safe level for zinc was between 140 and 260 µg/l (Sinley *et al.*, 1974). Zero, 25, and 86% of the measured zinc concentrations in Sections A, B, and C, respectively, exceeded 140 µg/l (Appendix Table 2). The estimated maximum safe level for copper was between 12 and 19 µg/l (Goetll *et al.*, 1974). Seven, 92, and 93% of the measured copper concentrations in Sections A, B, and C, respectively, exceeded 12 µg/l (Appendix Table 3). The estimated maximum safe level for lead was between 4.1 and 7.6 µg/l (Goetll *et al.*, 1974). At least 0, 8, and 43% of the measured lead concentrations in Sections A, B, and C, respectively, exceeded 4.1 µg/l (Appendix Table 5). The maximum safe values for copper and zinc may overestimate the safe levels for waters containing both metals. In laboratory bioassays with rainbow trout, mixtures of copper and zinc had an additive toxic interaction (Lloyd, 1961).

Silver and mercury are highly toxic metals that also may be contributing to the depression of trout populations between Basin and

Boulder. The estimated maximum level of silver safe for rainbow trout was between 0.09 and 0.17 μg/l (Goetll *et al*., 1974), making it the most toxic of the 5 metals they tested. The severe toxicity of mercury to aquatic organisms is well documented in the literature. Mercury was used at early-day mills in the study area to isolate silver. The old tailings deposits at these mill sites may be a source of mercury to the Boulder River. Van Meter (1974) found elevated mercury concentrations in the Clark Fork River drainage in Montana to be directly correlated with the location of old mills. Equipment to measure concentrations of silver <0.02 mg/l and mercury were not available for this study.

Concentrations of other metals were probably not high enough to harm trout populations in the study sections. The estimated maximum level of cadmium safe for rainbow trout was between 3.7 and 7.9 μg/l (Goetll *et al*., 1976). No measured cadmium concentrations in the study sections exceeded 1 μg/l (Appendix Table 4). The maximum level of iron safe for rainbow trout has not been established experimentally. However, an iron concentration of 6.0 mg/l as suspended ferric hydroxide in neutral to slightly alkaline bioassay waters did not affect the growth and survival of juvenile brook trout or the production and initial viability of eggs (Sykora *et al*., 1972a and 1972b). These results suggest the total recoverable iron concentrations of up to 2.6 mg/l measured in the study sections (Appendix Table 1) were not

detrimental to trout populations. The deposition of ferric hydroxide on the substrate and gills of fish was not evident in the study sections. McKee and Wolf (1963) concluded arsenic and manganese levels of up to 1.0 mg/1 were not deleterious to fish and aquatic life. Arsenic levels reported by Braico and Botz (1974) for the Boulder River drainage were much lower than 1.0 mg/1, except in High Ore Creek which was 3.7 mg/1. Metal analyses on file at the Board of Health and Environmental Sciences, Helena, Montana show concentrations of manganese in the Boulder River were <1.0 mg/1.

The metals in Sections B and C probably depressed the total number of trout in these sections by killing juvenile fish. In the laboratory bioassays estimating the maximum safe levels of metals for rainbow trout, the juvenile stage was generally the most sensitive in the life cycle. There was a progressive decrease in the estimated numbers of yearling trout between Sections A and C (Table 24). The metals in Sections B and C were highly toxic to the hatchery finger-lings used in the field bioassays. However, resident juveniles may be more resistant to zinc than the bioassay fish. Sinley *et al.* (1974) showed juvenile rainbow trout exposed to zinc as eggs may be as much as 4 times more resistant to zinc than unexposed juveniles. The acclimation of resident juveniles to the other metals present in Sections B and C also may have occurred.

In a soft water laboratory bioassay with brook trout, McKim and Benoit (1971) found copper concentrations of 32.5 µg/l reduced the growth of yearlings and 17.4 µg/l had a marked effect on the growth of alevins and juveniles. In Sections A, B, and C, respectively, 7, 92 and 93% of the measured copper concentrations exceeded 17.4 µg/l and 0, 33, and 57% exceeded 32.5 µg/l (Appendix Table 3). However, the calculated length and weight of rainbow trout at age I in Sections B and C were equal to or greater than those in Section A (Table 26). This may have been the result of the lower densities of trout in Sections B and C (Table 24). Although the density of yearling trout in Section C was lower than in Section B, the length and weight of trout at age I were lower at Section C. This lower growth in the first year of life of rainbow trout in Section C may have been caused by the higher levels of copper and other metals in this section.

RECOMMENDATIONS

The reclamation of High Ore Creek offers the best opportunity to
partially reduce the levels of metals in the upper Boulder River.
High Ore Creek appears to be the single major source of metals to the
upper river. Because fish populations in Section C below the mouth of
High Ore Creek are severely depressed, the potential exists to demon-
strate a substantial improvement in these populations if concentrations
of metals are reduced. Since the pollutants in High Ore
Creek originate from a single source, the Comet tailings, reclamation
would be relatively simple compared to the other polluted tributaries.
The tailings, covering an area of approximately five hectares, were
deposited in the narrow High Ore Creek canyon, burying the natural
channel. Presently, the creek is diverted onto the slope adjacent to
the tailings. This channel is not large enough to contain high water
flows. Seepage from the channel also enters the tailings and is
returned to the creek further downstream. Reclamation would entail
the enlargement and possible extension of the present diversion and
the lining of this channel with an impervious material to prevent
seepage.

APPENDIX

TABLE 1.   TOTAL RECOVERABLE IRON (mg/1) IN THE STUDY SECTIONS OF THE
BOULDER RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	.23	.21	.78
5/11	.38	.90	.70
5/24	1.8	1.5	2.0
6/2	.75	1.7	2.6
6/10	.50	.92	1.1
7/8	.69	-	.70
8/7	1.6	-	2.1
9/23	.22	.21	.22
11/3	.43	.42	.42
12/15	.47	.35	.40
1/10/76	.27	.18	.21
2/8	.28	.22	.28
3/10	.54	2.0	1.5
4/9	1.4	1.1	.75

TABLE 2. TOTAL RECOVERABLE ZINC (mg/1) IN THE STUDY SECTIONS OF THE
BOULDER RIVER DURING 1975 AND 1976.

| Date | Section | | |
	A	B	C
4/26-27/75	<.01	.14	.44
5/11	<.01	.20	.30
5/24	.05	.13	.24
6/2	.01	.13	.26
6/10	<.01	.09	.16
7/8	.02	-	.11
8/7	.02	-	.53
9/23	.03	.13	.22
11/3	.01	.10	.07
12/15	.03	.13	.24
1/10/76	.01	.13	.24
2/8	<.01	.15	.28
3/10	.02	.25	.30
4/9	.05	.09	.16

TABLE 3. TOTAL RECOVERABLE COPPER (mg/1) IN THE STUDY SECTIONS OF THE BOULDER RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	<.01	.02	.05
5/11	.02	.09	.10
5/24	.01	.02	.03
6/2	<.01	.06	.07
6/10	<.01	.04	.04
7/8	.01	-	.06
8/7	<.01	-	.05
9/23	<.01	.02	.04
11/3	<.01	.02	.01
12/15	.01	.02	.02
1/10/76	<.01	<.01	.02
2/8	<.01	.02	.02
3/10	.01	.06	.03
4/9	.01	.02	.04

TABLE 4. TOTAL RECOVERABLE CADMIUM (mg/1) IN THE STUDY SECTIONS OF THE
         BOULDER RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	<.001	<.001	.001
5/11	<.001	.001	.001
5/24	<.001	<.001	.001
6/2	<.001	.001	.001
6/10	<.001	<.001	<.001
7/8	<.001	-	<.001
8/7	<.001	-	<.001
9/23	<.001	<.001	<.001
11/3	<.001	<.001	<.001
12/15	<.001	<.001	.001
1/10/76	<.001	<.001	<.001
2/8	<.001	<.001	<.001
3/10	<.001	<.001	<.001
4/9	<.001	.001	.001

TABLE 5.   TOTAL RECOVERABLE LEAD (mg/l) IN THE STUDY SECTIONS OF THE BOULDER RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	<.02	<.02	<.02
5/11	<.02	.02	.02
5/24	<.05	<.05	.06
6/2	<.05	<.05	.09
6/10	<.05	<.05	.06
7/8	<.05	-	<.05
8/7	<.05	-	.10
9/23	<.05	<.05	<.05
11/3	<.05	<.05	<.05
12/15	<.05	<.05	<.05
1/10/76	<.05	<.05	<.05
2/8	<.05	<.05	<.05
3/10	<.05	<.05	.05
4/9	<.05	<.05	<.05

TABLE 6. THE pH IN THE STUDY SECTIONS OF THE BOULDER RIVER
DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	7.7	7.7	7.7
5/11	7.3	7.6	7.7
5/24	7.4	7.4	7.4
6/2	7.2	7.1	7.2
6/10	7.2	7.2	7.2
7/8	7.5	-	7.7
8/7	7.8	-	7.9
9/23	8.0	8.0	8.0
11/3	7.8	7.7	7.9
12/15	7.4	7.3	7.4
1/10/76	7.8	7.7	7.7
2/8	7.6	7.5	7.5
3/10	7.4	7.4	7.5
4/9	7.4	7.5	7.5

TABLE 7. CONDUCTIVITY (μmhos/cm at 25 C) IN THE STUDY SECTIONS OF THE BOULDER RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	160	160	171
5/11	136	142	148
5/24	141	122	141
6/2	93	82	87
6/10	87	77	80
7/8	94	–	92
8/7	125	–	163
9/23	139	142	150
11/3	157	151	157
12/15	174	151	167
1/10/76	150	154	157
2/8	160	155	172
3/10	159	133	153
4/9	99	102	103

TABLE 8. ALKALINITY (mg/1 $CaCO_3$) IN THE STUDY SECTIONS OF THE
BOULDER RIVER DURING 1975 AND 1976.

| Date | Section | | |
	A	B	C
4/26-27/75	48.5	-	47.5
5/11	42.0	40.5	42.0
5/24	26.0	24.5	27.0
6/2	19.5	17.5	17.0
6/10	17.5	16.5	16.0
7/8	27.5	-	25.0
8/7	37.5	-	40.0
9/23	45.0	42.5	47.5
11/3	45.0	42.5	42.5
12/15	55.0	50.5	51.0
1/10/76	49.5	45.5	48.0
2/8	52.5	46.0	52.0
3/10	49.5	41.0	46.5
4/9	34.5	35.0	34.0

TABLE 9. HARDNESS (mg/1 CaCO$_3$) IN THE STUDY SECTIONS OF THE BOULDER RIVER DURING 1975 AND 1976.

| Date | Section | | |
	A	B	C
4/26-27/75	49.6	56.8	74.3
5/11	42.0	49.0	51.9
5/24	43.9	42.3	44.4
6/2	31.8	28.4	29.2
6/10	28.5	25.7	27.1
7/8	32.4	-	31.9
8/7	37.0	-	47.2
9/23	42.9	45.2	50.7
11/3	56.1	53.6	56.6
12/15	64.2	61.8	65.5
1/10/76	53.3	53.7	59.0
2/8	55.4	56.2	63.2
3/10	51.1	46.3	58.0
4/9	38.1	37.0	38.5

TABLE 10.   CALCIUM (mg/1) IN THE STUDY SECTIONS OF THE BOULDER RIVER
DURING 1975 AND 1976.

	Section		
Date	A	B	C
4/26-27/75	14.9	16.8	23.8
5/11	12.2	14.5	15.0
5/24	12.8	12.3	13.0
6/2	9.6	8.4	8.7
6/10	8.6	7.8	8.2
7/8	10.0	-	9.8
8/7	10.7	-	13.6
9/23	12.7	13.3	14.7
11/3	16.7	16.0	16.7
12/15	19.1	18.3	19.3
1/10/76	16.2	16.2	17.5
2/8	16.9	16.9	18.7
3/10	15.5	13.9	17.1
4/9	11.3	11.0	11.3

TABLE 11. MAGNESIUM (mg/1) IN THE STUDY SECTIONS OF THE BOULDER
RIVER DURING 1975 AND 1976.

Date	Section		
	A	B	C
4/26-27/75	3.0	3.6	3.6
5/11	2.8	3.1	3.5
5/24	2.9	2.8	2.9
6/2	1.9	1.8	1.8
6/10	1.7	1.5	1.6
7/8	1.8	-	1.8
8/7	2.5	-	3.2
9/23	2.7	2.9	3.4
11/3	3.5	3.3	3.6
12/15	4.0	3.9	4.2
1/10/76	3.1	3.2	3.7
2/8	3.2	3.4	4.0
3/10	3.0	2.8	3.7
4/9	2.4	2.3	2.5

TABLE 12. TURBIDITY (JACKSON TURBIDITY UNITS) IN THE STUDY SECTIONS
OF THE BOULDER RIVER DURING 1975 AND 1976.

| Date | Section | | |
	A	B	C
4/26-27/75	-	-	-
5/11	10.0	16.0	13.0
5/24	7.0	9.0	15.0
6/2	9.0	15.0	23.0
6/10	5.0	7.0	10.0
7/8	5.0	-	6.0
8/7	12.0	-	24.0
9/23	1.5	1.1	0.9
11/3	2.8	3.1	2.9
12/15	1.6	1.7	1.6
1/10/76	1.8	1.5	1.5
2/8	1.7	1.8	1.7
3/10	6.1	82.0	19.0
4/9	17.0	18.0	22.0

TABLE 13.   NONFILTRABLE RESIDUE (mg/1) IN THE STUDY SECTIONS OF THE
             BOULDER RIVER DURING 1975 AND 1976.

Date	Section A	B	C
4/26-27/75	10	-	25
5/11	14	-	16
5/24	111	50	54
6/2	46	-	92
6/10	17	-	11
7/8	24	-	21
8/7	62	-	42
9/23	0	0	0
11/3	10	8	8
12/15	2	0	3
1/10/76	0	0	0
2/8	-	-	-
3/10	21	256	56
4/9	189	114	116

TABLE 14. SODIUM, POTASSIUM, CHLORIDE, AND SULFATE (mg/1) IN THE
          STUDY SECTIONS OF THE BOULDER RIVER DURING TWO SAMPLING
          PERIODS IN 1975.

	Section		
	A	B	C
Sodium			
9/23/75	7.7	6.4	6.5
12/4	7.5	6.2	6.2
Potassium			
9/23/75	1.2	1.2	1.2
12/4	1.5	1.5	2.0
Chloride			
9/23/75	1.4	1.3	1.4
12/4	1.6	1.5	1.3
Sulfate			
9/23/75	10.5	14.5	16.0
12/4	18.3	22.5	23.7

TABLE 15. ORTHOPHOSPHATE (mg/1 PO_4^{-3}-P), AMMONIA (mg/1 NH_3-N), AND NITRATE (mg/1 NO_3^--N) IN THE STUDY SECTIONS OF THE BOULDER RIVER DURING 1975 AND 1976.

| | Section | | |
	A	B	C
Orthophosphate			
9/23/75	.026	.021	.019
12/4	.024	.020	.022
3/26/76	.028	–	.025
Ammonia			
12/4/75	0	0	0
Nitrate			
12/4/75	.033	.038	.038
3/26/76	.047	–	.053

TABLE 18. TOTAL RECOVERABLE ZINC CONCENTRATIONS IN WATER SAMPLES COLLECTED ON JULY 17, 1975 FROM THE BOULDER RIVER DRAINAGE AT AND ABOVE THE TOWN OF BOULDER.

Site	Distance*	Total Recoverable Zinc (mg/l)	
		North Bank	South Bank
Highway 281 bridge at Boulder	0	.17	.16
Above highway 281 bridge	2.3	.17	.16
Above Kilborn Gl.	4.4	.15	
Galena Gl. road bridge	5.7	.17	.14
Galena Gl. at mouth	5.8		<.01←
Below Boomerang Gl.	6.38	.14	
Boomerang Gl. at mouth	6.4	→.03	
Above Boomerang Gl.	6.42	.16	.16
Below High Ore Cr.	8.2	.46	.09
High Ore Cr. at mouth	8.3	→4.5	
Above High Ore Cr.	8.32	.11	.10
Hwy. bridge above the mouth of High Ore Cr.	9.9	.10	.10
RR bridge at Pacific Silica Quartz Mine	11.6	.11	.10
Below Cataract Cr.	12.1	.17	.06
Cataract Cr. at mouth	12.2	→.32	
Above Cataract Cr.	12.22	.06	
Merry Widow mine bridge	13.1	.06	.06
Below Basin Cr.	13.55	.13	.05
Basin Cr. at mouth	13.6	→.14	
Above Basin Cr.	13.62	.04	.05
RR bridge below Sunnyside bridge	14.3		.11
Tailings pond outflow	14.5		.35←
Sunnyside bridge at Basin	14.6	.03	.18
Above Basin	19.1	.01	.01

Left margin label spanning Above Basin Cr. through Sunnyside bridge rows: "Tailings at Basin"

*Approximate river distance (km) of the site to the highway 281 bridge at Boulder.

→ = Tributaries and outfalls to the Boulder River.

TABLE 19. MEDIAN AND RANGE (IN PARENTHESIS) OF TOTAL RECOVERABLE METAL CONCENTRATIONS IN 7
TRIBUTARIES OF THE BOULDER RIVER ABOVE THE TOWN OF BOULDER. SAMPLES WERE COLLECTED
BETWEEN APRIL 27 AND JUNE 10, 1975 NEAR THE MOUTH OF EACH TRIBUTARY.

	N	TRM (mg/1)				
		Fe	Zn	Cu	Cd	Pb
Lowland Cr.	1	.68	<.01	<.01	<.001	<.05
Bison Cr.	3	.80 (.60-1.2)	<.01 (<.01-.03)	.01 (<.01-.02)	<.001 (<.001-<.001)	<.02 (<.02-<.05)
Red Rock Cr.	2	.62 (.30-.93)	<.01 (<.01-<.01)	<.01 (<.01-<.01)	<.001 (<.001-<.001)	<.05 (<.02-<.05)
Basin Cr.	3	.50 (.15-1.2)	.20 (.11-.31)	.02 (<.01-.03)	<.001 (<.001-.001)	<.05 (<.02-<.05)
Cataract Cr.	3	.85 (.10-1.1)	.54 (.25-.66)	.09 (.03-.23)	.007 (.001-.007)	<.05 (<.02-<.05)
High Ore Cr.	4	13.3 (2.3-19.0)	5.0 (3.9-6.4)	.18 (.03-.26)	.020 (.015-.025)	.15 (<.05-.64)
Galena Gl.	1	1.4	<.01	.01	<.001	<.05

TABLE 23. CATCH STATISTICS AND POPULATION ESTIMATES ($\bar{N}$) FOR FISH SPECIES COLLECTED IN THE STUDY SECTIONS OF THE BOULDER RIVER IN 1975.

Section	Species*	Size Group (mm)	Marked at Large (M)	Total Catch (C)	Total Recapture (R)	Marking Run Mortalities	$\bar{N}$
A (884m)	RB	94–152	53	107	18	1	307
		153–216	50	47	15	0	152
		217–348	36	44	20	0	78
							537
	BK	66–94	4	7	0	2	–
		119–290	41	43	20	0	87
	WF	142–404	87	47	3	6	–
	LNS	109–155	0	2	0	0	–
	WS	99–277	12	5	1	0	–
B (847m)	RB	66	0	1	0	0	–
		107–168	81	87	46	0	153
		173–234	57	63	33	0	108
		235–366	42	48	28	0	72
							333
	BK	155–267	3	5	3	0	–
	WF	147–373	43	52	12	9	–
	LNS	109–269	42	27	5	1	–
	WS	89–295	11	7	1	0	–
C (1029m)	RB	99–279	33	44	12	0	117
	BK	102–292	0	3	0	0	–
	WF	142–307	4	6	0	1	–
	LNS	–	–	–	–	–	–
	WS	66–218	1	8	0	0	–

*RB = rainbow trout   LNS = longnose sucker
 BK = brook trout   WS = white sucker
 WF = mountain whitefish

TABLE 25. FORMULAE USED TO BACK CALCULATE THE LENGTH AND WEIGHT AT
AGE OF RAINBOW TROUT COLLECTED IN THE STUDY SECTIONS OF
THE BOULDER RIVER DURING 1975.

Section	Regression	N	r
	Total Length: Scale Radius Regressions For Age-Groups I+, II+ and III+		
A	$Y = 3.038 \, X + 25.8$	278	.915
B	$Y = 2.938 \, X + 37.1$	246	.870
C	$Y = 2.952 \, X + 24.8$	60	.897

Y = Total length (mm)
X = Anterior-median scale radius (mm) X 66

	Total Length: Weight Regressions For Fish $\geq$ 125 mm in TL		
A	$\log W = -4.886 + 2.944 \log L$	238	.993
B	$\log W = -4.803 + 2.925 \log L$	259	.994
C	$\log W = -4.473 + 2.794 \log L$	61	.993

W = Weight (g)
L = Total length (mm)

TOTAL 30.   NUMBER OF MOUNTAIN WHITEFISH CAPTURED BY ELECTROFISHING
IN SECTIONS OF THE BOULDER RIVER ABOVE THE TOWN OF
BOULDER DURING 1975 AND 1976.

Section	Distance*	Sample Date	Length Range (mm)	No. Captured/ 500m/ 2 Runs
Carlson Ranch (320m)	22.1	Aug. 1976	191-422	41
A (884m)	18.8	Aug.-Sept. 1975	142-404	51
Tailings at Basin (401m)	15.6	Aug. 1976	123-388	101
B (847m)	12.0	Sept. 1975	147-373	54
C (1029m)	6.3	Aug.-Sept. 1975	142-307	5

*Approximate river distance (km) of the start of the section to the
hwy. 281 bridge at Boulder.

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