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TOXICITY PERSISTENCE IN PRICKLY PEAR CREEK, MONTANA

by

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ABSTRACT

Instream toxicity tests using the larval fathead minnow *Pimephales promelas* and the cladoceran *Ceriodaphnia reticulata* were conducted on Prickly Pear Creek, Montana waters to study toxicity persistence in a stream. The toxicity source was Spring Creek, a tributary of Prickly Pear Creek. Gold mining tailing and settling ponds in the Spring Creek drainage release zinc, copper and cadmium to Prickly Pear Creek via Spring Creek. Stream survey characterization of flow regimes, water quality, and biotic conditions was accomplished in conjunction with toxicity testing. The study objectives were to: 1) develop a data base for validation of a toxicity persistence model; 2) assess the applicability of data from the Prickly Pear Creek study relative to model assumptions; and 3) assess field techniques for acquiring model input data.

Toxicity to the test organisms was primarily due to zinc and copper in Spring Creek waters. Changes in Prickly Pear Creek toxicity downstream from the Spring Creek confluence were primarily due to dilution and complied with model assumptions. However, other unidentified toxicants were present in other tributary waters, and Spring Creek was not the sole source of toxicity in Prickly Pear Creek waters. *C. reticulata* was highly sensitive to toxicity in Spring Creek waters and provided model input data. *Pimephales promelas* had a higher tolerance, and bioassay data from these organisms could not be used for model input. In the field, test organism nutritional problems were encountered using procedures described in bioassay protocols for both of these organisms. The problem was eliminated in *C. reticulata* bioassays by using cerophyl as food. Either a quantitative food regime should be developed for *P. promelas* or a nonfeeding test used in the future.

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I. INTRODUCTION

In 1980, the U.S. Environmental Protection Agency's (EPA) Office of Water Regulations and Standards requested the assistance of the Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) in documenting water and biological quality in selected streams receiving mining, industrial, or municipal sewage treatment plant discharges. In response to this request, a toxic metals study was designed with four main objectives: 1) to document the concentration and distribution of toxic metals in selected streams receiving discharges from publicly owned treatment works, mining activities, or industrial wastes; 2) to determine the biological state of receiving waters where the aquatic life criteria for toxic metals were exceeded, including sampling and analyzing fish, benthic invertebrates, and periphyton communities; 3) to report the extent to which criteria levels were observed to be exceeded; and 4) to develop explanatory hypotheses when healthy biota existed where criteria were exceeded.

Fifteen streams were originally sampled to provide a broad geographical representation and range of watershed types and uses, pollution sources, water quality characteristics, biota, and habitats. Results from the 1980 study indicated that, in some cases, species of fish and invertebrates known to be sensitive to metal pollution existed where EPA's acute and chronic aquatic life criteria were exceeded (Miller et al. 1982). Analyses of preliminary data led to two hypotheses. First, organisms are able to acclimate to sublethal metal concentrations which allows them to tolerate potentially toxic ambient levels. Second, metals can be chelated by organic and inorganic compounds in effluents and receiving streams, and are thus rendered biologically unavailable.

Prickly Pear Creek, Montana typified conditions described above and intensive surveys and in situ bioassays were conducted during the summers of 1981 and 1982 (Miller et al. In Press; Miller et al. 1982; La Point et al. 1983) to test the first hypothesis. These studies characterized physical, chemical, and biological conditions in Prickly Pear Creek. Bioassays conducted in 1981 indicated that some resident species were able to acclimate to sublethal metal centrations (Miller et al. In Press); however, La Point et al. (1983) observed no significant difference in sensitivity between hatchery and resident brook trout. Relative to the second hypothesis, the present study was undertaken to assess the downstream persistence of metal toxicity in Prickly Pear Creek.

The Office of Water Regulations and Standards, Monitoring and Data Support Division (MDSD), is acutely aware of the need to examine questions relating to persistence and degradation rates of industrial and municipal toxic wastes discharged to streams. MDSD is seeking to identify methods most suitable for assessing instream persistence of whole effluent toxicity in receiving waters. Specifically, methods are required for site-specific assessment of effluent toxicities, both acute and chronic, prior to discharge, at the discharge point and at downstream locations where dilution, degradation, and partitioning to other compartments result in reduced toxicant concentrations. Particular interest centers on validation of toxicity models designed to predict instream toxicity persistence, and validation of methods for acquiring input data for these models. One concept currently receiving considerable attention by EPA deals with the conservative (not enhanced or degraded) nature of toxicity in receiving systems. The hypothesis being tested is that toxicity in receiving systems is essentially conservative, and its persistence can be explained through application of mass-balance models. That is, toxicity results obtained on tests conducted on effluents diluted at various proportions with receiving stream waters can be used to predict instream toxicity at various points downstream from the zone of complete mixing if sufficient hydrological data are available to determine dilution rates and time of travel. Naturally, the conservative nature of toxicity in any given discharge will depend upon the types of pollutants and associated degradation rates and mechanisms.

A stream dilution model developed by Di Toro et al. (1982) is presently being assessed. Model assumptions are: 1) toxic chemicals and toxicity itself follow a conservative mixing behavior; 2) physical, chemical, and biological interactions do not substantially alter toxicity at the point of complete mixing; and 3) variations in effluent toxicity are reflected in varying toxicity of the receiving waters and can be described by mass-balance relationships. Instream toxicity testing has recently been conducted at several sites by the Environmental Monitoring Systems Laboratory-Las Vegas and by the Environmental Research Laboratory-Duluth. Model validation will be based on results from these investigations.

The objectives of this study on Prickly Pear Creek were: 1) develop a data base to be used for model validation; 2) assess the applicability of Prickly Pear Creek data relative to model assumptions; and 3) assess field techniques for acquiring model input data. The study consisted of short term acute and chronic toxicity tests and stream survey characterization of flow regimes, water quality, and biotic conditions.

II. STUDY AREA

Prickly Pear Creek forms its headwaters in the Elkhorn Mountains approximately 32 km southeast of Helena, Montana (Figure 1). The stream flows north for 64 km before entering Lake Helena and the Missouri River. Gold mining in the Corbin and Spring Creek drainage basin began in the early 1860's. Tailing and settling ponds remain as prominent features within these drainages and release high concentrations of zinc, copper, and cadmium which are carried into Prickly Pear Creek via Spring Creek. Prickly Pear Creek has also undergone extensive mining operations in the 1900's. The Montana Water Quality Bureau (1981) reported over 75 percent of Prickly Pear Creek was subjected to streambed modifications and dredging during the mining process.

The present study reach was generally characterized by continuous riffle flow interspersed with distinct pools. The substrate was primarily cobble and gravel throughout. Prickly Pear Creek annual discharge at the U.S. Geological Survey (USGS) gaging station (Figure 1) ranged from 30 to 343 cubic feet per second (cfs)[1] with a mean of 55 cfs during the 1982-83 water year (unpublished USGS data). Spring Creek discharge during this study was 1.4 cfs.

Four principal stations on Prickly Pear Creek and one station on Spring Creek were utilized in this study (Table 1). Spring Creek was considered as an "effluent" site. Station 011 was used as a control. Station 013 was within a biological impact zone and stations 014 and 018 were within a biological recovery zone downstream from Spring Creek (La Point et al. 1983).

Additional secondary stations were established on Prickly Pear Creek downstream from each tributary and on the tributaries themselves. A number of these had been sampled by EMSL-LV during previous years (Miller et al. In Press; Miller et al. 1982; and La Point et al. 1983).

[1]cubic feet per second x 0.028317 = cubic meters per second

Prickly Pear Creek, Montana

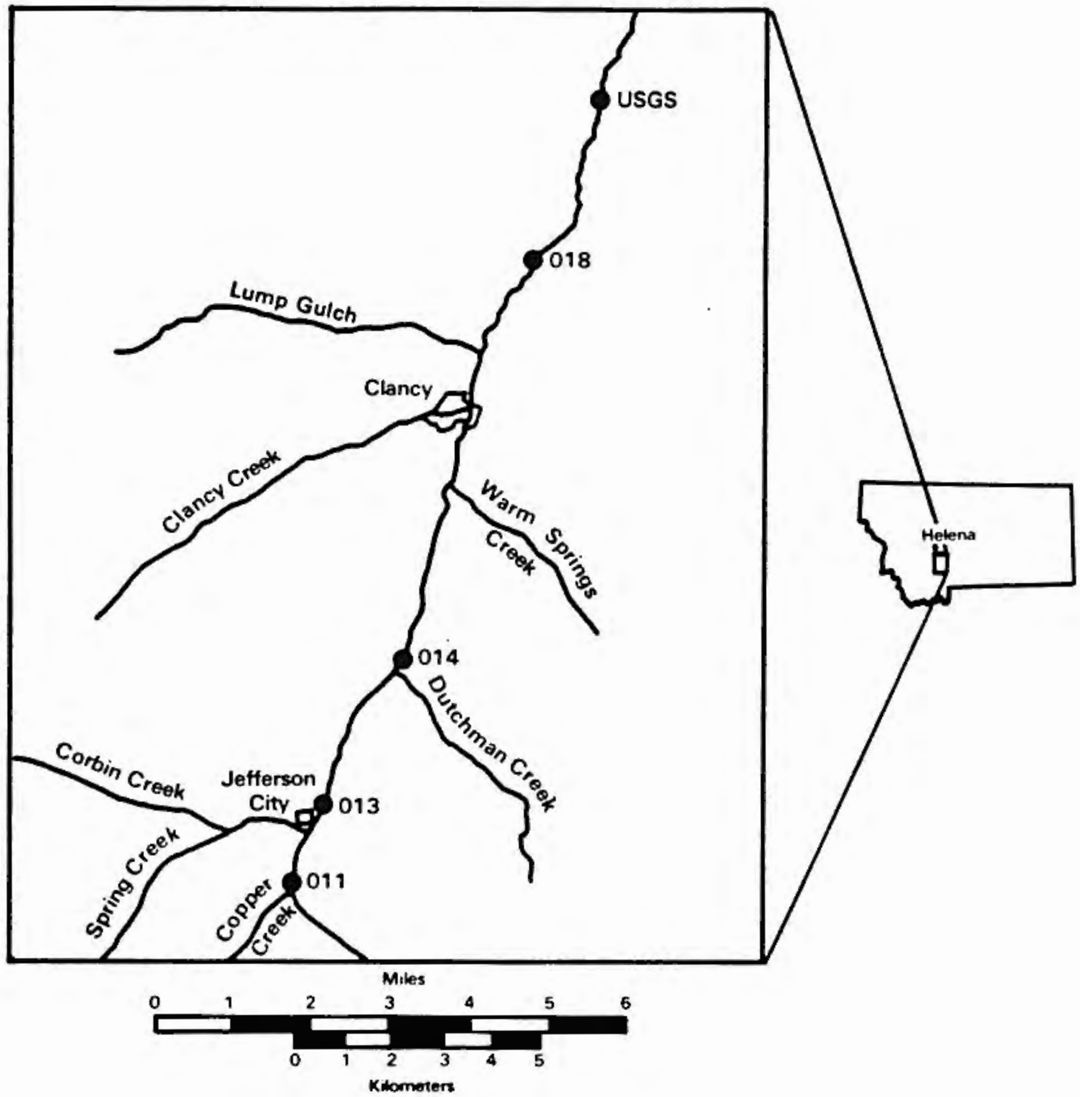

Figure 1. Station locations on Prickly Pear Creek, Montana, 1983.

TABLE 1. LOCATION OF STATIONS ON PRICKLY PEAR CREEK AND SPRING CREEK, MONTANA, 1983 WITH A CROSS REFERENCE TO 1982 STATIONS (La Point et al. 1983).

1983 Station No.	Description	1982 Station No.
011	Prickly Pear Creek, 1.1 km upstream from Spring Creek confluence	0111
Spring Creek	Spring Creek, 100 m upstream from Spring Creek confluence	012
013	Prickly Pear Creek, 300 m downstream from Spring Creek confluence	0133
014	Prickly Pear Creek, 3.8 km downstream from Spring Creek confluence, 100 m downstream from Dutchman Creek confluence	0142
018	Prickly Pear Creek, 12 km downstream from Spring Creek confluence, 3 km downstream from Lump Gulch confluence	017

III. METHODS

TOXICITY TESTS

Spring Creek toxicity and toxicity persistence in Prickly Pear Creek were determined using static renewal bioassays designed to measure both acute and chronic toxicity. Test organisms were the cladoceran *Ceriodaphnia reticulata*[1] and the larval fathead minnow *Pimephales promelas*. Toxicity tests were conducted on water collected from September 30 to October 9, 1983. Twenty-four hour composite samples were collected from Spring Creek (continuous pump) and at stations 013, 014, and 018 (1-hour ISCO composite). Grab water samples were collected each day at the control station. Five Spring Creek dilutions and three station treatments were used in the bioassays (Table 2). Spring Creek dilutions were predetermined in July 1983 based on range finding tests conducted on water shipped to Las Vegas. Triplicate water samples for metal analyses were taken from all test treatments. Sample bottles (Nalgene) were prerinsed with 10-percent Ultrex nitric acid and distilled water (three rinses).

TABLE 2. SPRING CREEK DILUTIONS AND PRICKLY PEAR CREEK SITE WATER USED IN BIOASSAY

Organisms	Dilution Treatments Percent Spring Creek						Station Treatments		
C. reticulata	0*	1	2.5	5	10	20	013	014	018
P. promelas	0*	6.25	12.5	25	50	100	013	014	018

*Control Prickly Pear Creek Station 011.

[1]Taxonomy uncertain; may be *C. affinis* or *C. reticulata* x *C. affinis*. From *Ceriodaphnia* Workshop (U.S. EPA Region VIII) in Fort Collins, Colorado, March 6-7, 1984, personal communication Dr. Dorothy Berner, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

Fathead minnow bioassays were conducted on site in a mobile laboratory trailer. All tests were initiated on the day of water collection. Renewal water was stored in 20-liter cubitainers and maintained in a water bath at ambient stream temperatures.

On site testing with *C. reticulata* was discontinued after the third day because of high control mortality and difficulties in maintaining cultures. These conditions were apparently related to nutritional problems associated with using yeast as a food media (see General Discussion). Results from on site testing with *C. reticulata* are not reported. Water collected on October 1 through 9 was shipped to Las Vegas in 1-liter cubitainers and was maintained at 4°C. *C. reticulata* bioassays were conducted on these waters in November.

Bioassay procedures are summarized in this report. For further details, see Mount and Norberg (In Press) and Norberg and Mount (unpublished manuscript).

Ceriodaphnia reticulata

Young *C. reticulata* (neonates), 2 to 12 hours old, were used to initiate the test. Test chambers were 1-ounce plastic cups (Anchor Hocking P.1.-1) containing 15 ml of water and a single neonate. An additional secondary control treatment using culture water was included in each test to evaluate Prickly Pear Creek (station 011) control results. Poor test results in Prickly Pear Creek control treatments relative to culture water treatments were attributed to control water toxicity. Ten isolated neonates were used in each test treatment. Usually, the first brood was produced by the test animals on the third or fourth day. Production of three broods in 80 percent of the Prickly Pear Creek control animals was required for test termination. Neonates produced by the test animals were removed daily and counted relative to brood number. Test duration was usually seven days with water renewals on days 3 and 5. Two drops of a cerophyl[1] supernate (15 g/l) were added to the test chambers daily as a food medium in bioassays conducted in Las Vegas. A yeast solution (5 g/l) was used as a food medium in the field testing. Temperature, dissolved oxygen, and pH were measured in special test chambers (no test animals) on days 0, 3, 5, and 7.

Acute toxicity was based on 48-hour mortality, and median lethal concentrations (LC-50s) were calculated using the Trimmed Spearman-Karber method (Hamilton et al. 1977). Significant differences in LC-50s were based on 95 percent confidence limits calculated with the Trimmed Spearman-Karber method. Mean number of neonates produced per surviving female per day were summed over the test period and used in determining chronic toxicity. Significant differences in neonate production between control and test treatments were determined by 95 percent confidence limits calculated using a "Boot Strap" procedure (Hamilton 1984).

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[1]Cerophyl-cereal grass leaves powder manufactured by Agritech, Inc. 434 E. 95th Street, Kansas City, Missouri.

Pimephales promelas

Newly hatched fathead minnows less than 24 hours old were used in seven-day toxicity tests. These were obtained from eggs shipped to the study site from the EPA's Environmental Monitoring Support Laboratory-Cincinnati (EMSL-Cin) satellite facility in Newtown, Ohio. Forty fry were used for each test treatment except where otherwise noted. Test chambers were 2-liter aquaria partitioned into four equal compartments (replicates) with 10 fry per compartment. A sump area resulted in some water exchange between compartments but allowed the aquaria to be drained via a siphon. Aquaria were drained and renewal water was added on days 3 and 5. Any particulate material that had accumulated on the bottom of the aquarium was removed at that time with a siphon vacuum. A minimum of one drop of a concentrated brine shrimp nauplii solution was added to each compartment three times a day during daylight hours. The food regime was theoretically designed to provide an overabundance of food and was not quantitative.

Acute toxicity was based on 96-hour mortality. Median lethal concentra tions and significant differences were determined as described for *C. reticulata*. At test termination, fish were frozen and shipped to Las Vegas where they were oven dried (105°C) and weighed (±0.1 mg). Fish were weighed in groups for each of the four replicates. Fish weights did not show a relationship to increasing toxicity; therefore, chronic toxicity could not be determined (see Results for further details).

STREAM SURVEY

Physical, chemical, and biological parameters were measured and/or sampled at the four Prickly Pear Creek stations (Figure 1). Additional physical, chemical, or hydrological measurements were made at: Copper Creek, Corbin Creek, Spring Creek upstream from Corbin Creek, Dutchman Creek, Warm Springs Creek, Clancy Creek, and Lump Gulch (Figure 1).

Water Quality

In situ measurements of temperature, dissolved oxygen, conductivity, and pH were measured with a Hydrolab 8000 Water Quality Analyzer (Table 3). Measurements were made at each station in triplicate representing a cross section of the stream. Samples for individual chemical analyses (Table 4) were taken in triplicate from a 10-liter grab sample collected at mid-stream. All sample bottles were Nalgene. Bottles used for metal samples were rinsed with 10-percent Ultrex nitric acid and distilled water (three rinses).

Hydrology

Stream stages and storm event markers were established at station 011, Spring Creek, and at Prickly Pear Creek 5 m downstream from the Spring Creek confluence. Stream stages were fixed meter sticks and event markers were 3-centimeter diameter clear plastic tubes containing carbon black on the inner water surface of the plastic tubes. Stream stage height was initially read every four hours but readings were reduced to once or twice a day after it was

TABLE 3. HYDROLAB DIGITAL 8000 WATER QUALITY MEASUREMENT SYSTEMS SPECIFICATIONS

A. Temperature Systems:

Method:	Linear thermistor
Range:	(-5 to +45)°C
Resolution:	+0.15°C
Accuracy (overall):	±0.15°C
Precision:	(2)
Calibration:	Factory calibrated (NBS traceable thermometer)
Response time (nominal):	2.5 s

B. pH System:

Method:	Glass electrode (sealed Ag/AgCl reference)
Range:	0 to 14 pH
Resolution:	0.01 pH
Accuracy (overall):	±0.05 pH (over 4 pH interval)
Precision:	(1)
Calibration:	Customer calibrated against buffer standards of good quality
Response time (nominal):	10 s at 20°C

C. Conductivity:

Method:	Four-electrode cell, temperature compensated (reference: 25°C)
Range (3):	(0-2K), (0-20K), (0-200K) µmhos/cm
Resolution:	0.05% of range selected
Accuracy (overall):	±0.5% of range selected
Precision:	(2) (3)
Calibration:	Customer calibrated in freshly prepared KCL standards
Response time (nominal)(2):	Negligible to conductivity change; 2.5 s for temperature change

D. Dissolved Oxygen:

Method:	Membrane covered, gold/silver polargraphic cell
Range:	(0-20) mg/l
Resolution:	0.01 mg/l
Accuracy (overall):	±0.15 mg/l
Precision:	(2)
Calibration:	Customer calibrated in atmospheric air or saturated water
Response time (nominal):	12 s at 20°C

Note: The circulator accessory should be employed at any time there is reason to suspect that there is insufficient natural circulation to maintain a stable dissolved oxygen measurement.

(1) Precision has not been field tested, the actual coefficient of variation is expected to be within 10 percent.

(2) Time required for 63 percent response to step change is variable.

(3) Instructions are provided for taking into account second-order variations in natural water conductivity-temperature coefficients.

Source: Oral communication with James Flynn, Hydrolab Corporation, Austin, Texas, 3/24/83.

TABLE 4. WATER SAMPLES COLLECTED AND TREATMENTS, PRICKLY PEAR CREEK, 1983

Parameter	Preservative	Disposition
Cyanide	Addition of NaOH to sample pH $\geq$ 10. Stored at 4°C.	Shipped to Lockheed-EMSCO, Las Vegas, Nevada
Total Organic Carbon	Addition of H_2SO_4 to sample pH $\leq$ 2.	Shipped to Dr. A. L. Lingg, Moscow, Idaho
Dissolved Organic Carbon	Filter through 0.4 μ Metricel filters. Addition of H_2SO_4 to sample pH <2.	Shipped to Dr. A. L. Lingg, Moscow, Idaho
Alkalinity and Ammonia	Stored at 4°C	Shipped to Lockheed-EMSCO, Las Vegas, Nevada
Total/Dissolved Metals	Stored at 4°C	Shipped to Lockheed-EMSCO[1,2], Las Vegas, Nevada
Total/Free Chlorine	None	Analyzed at field laboratory[3]
Turbidity	None	Analyzed at field laboratory[4]

[1]Includes bioassay sample.
[2]Some quality assurance samples taken from Spring Creek were preserved with HNO_3 to a pH $\leq$ 2. The dissolved fraction was filtered through 0.4 micrometer Metricel filters before preservation.
[3]Bausch and Lomb spectrophotometer using Hach reagents.
[4]Monitek 50 nephelometer.

established that little or no daily variation occurred in stream stage height. Hydrological data were also obtained from the USGS gaging station on Prickly Pear Creek located 2 km downstream from station 018.

Stream discharge was estimated from velocity measurements taken with a Marsh McBirney Model 57 current meter. Velocities were measured at 17 to 20 equal intervals across the stream at the six-tenth depth (USGS 1980). Discharge was estimated by summing the product of depth, width, and velocity for all intervals. Stream stage height did not substantially change; therefore, stream discharge was only determined once during the study period.

Time of travel (hydrological retention time) from the confluence of Spring Creek to the downstream Prickly Pear stations was determined using Rhodamine WT fluorescent dye (Wilson 1968). Dye was injected into Spring Creek at a rate of 3.5 ml/min for a 2-hour period. Hand grab samples were taken at half-minute intervals from Spring Creek just upstream from the Prickly Pear Creek confluence. Water samples at the downstream stations were taken at 2 to 20 minute intervals with an ISCO 1680 Automatic Water Sampler. Dye concentrations were determined with a Turner Design Model 10-field fluorometer calibrated with Rhodamine WT standards maintained at stream temperature. Standards were periodically checked during analysis but recalibration was not necessary. Dye peaks at the downstream stations reached a plateau due to the continuous dye injection. Time-of-travel was determined by elapsed time from the beginning of the dye injection at Spring Creek to the onset of the dye plateau at each of the stations. Contribution of Spring Creek water to the total flow at the downstream Prickly Pear Creek stations was determined using dye peak concentrations at the downstream stations and at Spring Creek. Proportions (Spring Creek:Prickly Pear Creek) are expressed as a percentage in this report.

Substrate Characterization

Station substrates were sampled by two different methods. First, an open bottom bucket was placed at least 5 cm into the stream bottom. All rocks larger than 0.5 cm were manually removed. The remaining sediment was scooped into a bucket with water, agitated, and quickly poured into a one-liter Nalgene Imhoff Cone. Volumes of each particle size were read after 5 minutes. It was impossible to differentiate size differences below 1.0 mm, hence, only two size classes were used. Very fine to coarse sands, approximately 0.1 to 1.0 mm diameter, were combined into one class of "fine sand." Silt and clay particles of size up to approximately 0.1 mm (that portion of substrate taking 5 minutes to settle) were combined. In the second method, fifty "rocks" (larger particles with a diameter greater than 0.5 cm) were randomly chosen, and the narrowest width of the flattest face was measured to the nearest 0.5 cm (La Point et al. 1983). These data are not included in this report, but will be included in any future report on macroinvertebrate data.

Streambed sediments were collected from the four Prickly Pear stations and Spring Creek to ascertain metal concentrations. Samples were collected in triplicate by scraping the upper 2 to 5 cm of sediments into acid-rinsed, Nalgene bottles. Samples were maintained at 4°C and shipped to Las Vegas for metal analysis.

Biological Communities

Relative abundance and distribution of fish were determined by electroshocking with a Coffelt backpack shocker. Three passes were made over a 100-meter reach at each station. All captured fish were identified, counted, and released except for randomly selected fish which were frozen for tissue metal analysis. Lengths and weights were measured on fishes used for tissue analysis.

Macroinvertebrates were collected with a Portable Invertebrate Box Sampler. Five replicate samples were collected at each station from riffle zones of uniform flow and velocity. Samples were preserved in 10-percent formalin and shipped to Las Vegas for future analyses. Additional invertebrate samples were taken with a kick net at each station and frozen for tissue metal analysis.

Periphyton samples were taken at the same riffle zone where macroinvertebrates were collected. Samples were collected from five replicate rocks selected from the riffle zones. Algae growing on or attached to the rocks were removed with a nylon brush from a 3772 mm^2 circular area delineated by a flexible rubber ring. Samples were preserved in acid-lugols to a final concentration of 1 to 5 percent and returned to Las Vegas for future analyses. Periphyton samples for tissue metal analysis were collected and frozen. Macrophytes were found only at station 014, therefore, just one macrophyte sample was collected and analyzed for metal content.

LABORATORY ANALYSES

All chemical analyses, except total and dissolved organic carbon, were performed by Lockheed-EMSCO (Tables 5 and 6). Organic carbon analyses were performed by Dr. A. L. Lingg, University of Idaho, Moscow. Water samples for metal analyses were split in the laboratory. The dissolved fraction was filtered through 0.4-micrometer Metricel filters and the total fraction was acid digested and analyzed for total recoverable metals (U.S. EPA 1983). Sediment samples for metal analyses were oven dried at 100°C and a 1-gram subsample was acid digested for total metal concentrations (U.S. EPA 1981). Whole fish, periphyton, and composite invertebrate samples were homogenized for tissue analysis. Subsamples were then removed, freeze dried, weighed, and digested for total metal concentration (U.S. EPA 1981).

TABLE 5. LABORATORY METHODS, PRECISION, ACCURACY, AND RANGE FOR SELECTED WATER QUALITY PARAMETERS

Parameter	Method	Precision as Std Dev (mg/l)	Accuracy as Bias (%)		Range (mg/l)
Hardness, Total (as $CaCO_3$)	APHA (1980) 314A	(1)	(1)		(1)
Organic Carbon, Total (TOC) Dissolved (DOC)	U.S.EPA (1983)[2]	3.93[2]	+15.27[2]		>1.0
Cyanide, Total (CN)	U.S.EPA (1983) 335.2	±0.003[3] ±0.007 ±0.031 ±0.094	85% recovery[4] 102% recovery		0.02-1.0
Chlorine, Total Dissolved	Hach Kit[5]	0.385[6] 1.032 1.450	±54.0[7] ±41.9 ±16.0	±82.46[8] ±8.06 ±18.37	0-0.5 0.6-1.2 1.2-1.5
Alkalinity	U.S.EPA (1983) 310.2	±0.5	100% recovery[9] 99% recovery		10-200
Ammonia	U.S.EPA (1983) 350.3	±0.038[10] ±0.017 ±0.007 ±0.003	91-96% recovery[11]		0.03-1400

[1]Dependent upon limitations of calcium and magnesium analyses.
[2]Based on results from twenty-one laboratories using distilled water containing increments of oxidizable organic compounds of 4.9 and 107 mg/l TOC.
[3]Based on EMSL-Cin test using mixed industrial and domestic waste samples at concentrations of 0.06, 0.13, 0.28, and 0.62 mg/l CN (U.S.EPA 1983).
[4]Based on EMSL-Cin test using mixed industrial and domestic waste samples at concentrations of 0.28 and 0.62 mg/l CN (U.S.EPA 1983).
[5]Personal communication, Larry B. Lobring, EMSL-Cin, June 23, 1982.
[6]Based on analyses of 16 samples with four replicates per sample.
[7]Percent positive bias based on analyses of same samples using Amperometric method.
[8]Percent positive bias based on analyses of same sample using Colorometric method.
[9]Based on EMSL-Cin test of surface water samples at conc. of 31 and 149 mg/l as $CaCO_3$ (U.S.EPA 1983).
[10]Based on EMSL-Cin test of surface water samples at conc. of 1.00, 0.77, 0.19, and 0.13 mg/l NH_3-N.
[11]Based on EMSL-Cin test of surface water samples at conc. of 0.09 and 0.13 mg/l NH_3.

TABLE 6. PRECISION, ACCURACY, SENSITIVITY, DETECTION LIMITS, AND OPTIMUM CONCENTRATION RANGE FOR ANALYSES OF SELECTED METALS IN WATER USING ATOMIC ABSORPTION (AA) AND ICP TECHNIQUES (source: U.S. EPA 1983)[1]

Metal (Method)	Detection Limit (μg/l)	Sensitivity (μg/l)	Precision % Std Dev	Accuracy % Recovery	Optimum Range (μg/l)
Arsenic					
Furnace	1	92.5	±1.6 - ±2.5	101-106	5-100
Cadmium					
Furnace	0.1	0.08	±3.2 - ±4.0	96-99	0.5-10
Calcium[3]					
ICP	10	NA[2]	0.9%	99	100-5000
Copper					
ICP	6	NA	1.0%	95-105	10-1000
Lead					
Furnace	1	2.0	±3.2 - ±5.2	88-95	5-100
Magnesium[3]					
ICP	30	NA	1.0%	100	20-1000
Silver					
Furnace	0.2	0.3	±1.2 - ±1.6	94-104	1-25
Zinc					
ICP	2	NA	0.8%	95-105	5-1000

[1]Precision and accuracy vary widely with concentration of metal. See U.S. EPA (1983) for details.

[2]NA = not available.

[3]Calcium and magnesium are measured to provide data for calculating hardness.

IV. RESULTS AND DISCUSSION

METAL CONCENTRATIONS

Spring Creek metal contributions caused significant increases in concentrations of metal in Prickly Pear Creek (Table 7). There was a consistent decline in downstream metal concentrations with approximately a twofold decrease between stations 013 and 018 due primarily to tributary inflow dilution. Metal concentrations were low in all other tributary streams except Clancy Creek (Table 8). Total recoverable copper in Clancy Creek was high and may have been partially responsible for additional downstream toxicity in Prickly Pear Creek. However, dissolved copper was below detection and the dissolved fraction could not have been toxic. Spring Creek was undoubtedly the primary source of metals to Prickly Pear Creek.

Total recoverable cadmium, zinc, and copper concentrations in Spring Creek and Prickly Pear Creek consistently exceeded U.S. EPA (1980) recommended acute criteria for aquatic life during the toxicity testing period (Table 7). Concentrations of arsenic and lead were below the aquatic life criteria at all stations. Silver exceeded the acute criteria on October 6 at station 013, but was well below the acute criteria for all other dates and stations including Spring Creek. Although cadmium exceeded the acute criteria, concentrations were below reported toxic levels for C. reticulata (Mount and Norberg In Press) and larval fathead minnows (Woltering 1983). Toxicity in test organisms was attributed to zinc and/or copper based on reported sensitivities for these organisms (Mount and Norberg In Press; Woltering 1983). However, C. reticulata bioassays indicated that another unidentified toxicant was present (see Results: Toxicity Test). Zinc and copper concentrations in Spring Creek were variable over the 10-day testing period (Figures 2 and 3) with peak total recoverable concentrations on test days 1 and 5 (test numbers refer to dates, September 30 - October 9). A small storm event occurred on September 30 and resulted in the October 1 (Test 1) peak (see Results: Hydrology). The cause of the October 5 peak in total recoverable concentrations was not determined.

TOXICITY TESTS

Ceriodaphnia reticulata

Acute and Chronic Toxicity in Dilution Treatments--

Spring Creek water resulted in acute effects (LC-50s) in C. reticulata at dilution volumes of approximately 5 to 20 percent (Figure 4). There were no significant differences in Spring Creek acute toxicity in tests 2 through 5, 8, and 9, but toxicity was significantly higher in tests 1, 6, and 7. Higher

TABLE 7. TOTAL RECOVERABLE CONCENTRATIONS OF SELECTED METALS IN SPRING CREEK AND PRICKLY PEAR, AND U.S. EPA CALCULATED ACUTE CRITERIA FOR AQUATIC LIFE. Mean values are 10-day averages (September 30-October 9 1983). Number of days criteria were exceeded are given in parentheses.

Total Metals (µg/l)		Station 011	Spring Creek	013	014	018
Cadmium*	$\overline{x}$	2(6)	7.6(9)	5(10)	4(5)	3(6)
	Range	1-3	6-12	2-9	1-6	2-9
	Criterion Range	1.5-1.8	4.7-6.1	2.0-2.7	1.9-2.8	2.2-3.2
Lead	$\overline{x}$	13(0)	72(0)	30(0)	19(0)	15(0)
	Range	7-22	44-238	20-54	11-26	8-28
	Criterion Range	74-100	291-389	108-155	103-160	121-183
Zinc*	$\overline{x}$	100(10)	2119(10)	580(10)	236(10)	203(0)
	Range	49-183	1260-3625	481-656	261-372	169-232
	Criterion Range	180-224	464-562	238-303	230-308	255-338
Copper*	$\overline{x}$	12(2)	84(10)	28(9)	14(3)	12(0)
	Range	6-13	37-220	12-47	<6-22	7-15
	Criterion Range	12-15	33-41	16-20	15-21	17-23
Silver	$\overline{x}$	0.6(0)	1.6(0)	1.9(1)	0.2(0)	0.1(0)
	Range	<0.2-0.9	0.2-3.1	<0.2-11.2	<0.2-0.5	<0.2-4.3
	Criterion Range	1.2-1.9	8.5-12.8	2.1-3.5	2.0-3.6	2.5-4.4
Arsenic	$\overline{x}$	2(0)	27(0)	6(0)	4(0)	10(0)
	Range	<0.5-11	1.5-84	3-10	3-7	8-12
	Criterion Range	440	440	440	440	440

*Consistently exceeded recommended acute criteria for aquatic life.

toxicity in test 1 corresponded to high total recoverable and dissolved concentrations of zinc and copper in Spring Creek on that date (Figures 2 and 3). The increase in total recoverable concentrations of these metals on October 5 had no apparent effect on toxicity. Metal concentrations generally declined on October 6 and 7 and the increase in toxicity in tests 6 and 7 was not due to an increase in any of the metals analyzed in this investigation (Appendix C). There was no mortality in the controls for tests 6 and 7 (Appendix A), indicating that mortality in the Spring Creek dilution treatments was due to toxicity. Chemical analyses for other parameters were not possible and the toxicant was not identified.

TABLE 8. TOTAL RECOVERABLE AND DISSOLVED METAL CONCENTRATIONS (µg/l) IN TRIBUTARY STREAMS TO PRICKLY PEAR CREEK, MONTANA, OCTOBER 1983. Analysis are for a single sample.

	Copper Creek		Dutch Creek		Warm Sp. Creek		Clancy Creek		Lump Gulch	
	Total Recov.	Diss.	Total Recov.	Diss.	Total Recov.	Diss.	Total Recov.	Diss.	Total Recov.	Diss.
Cadmium	1.6	0.2	0.9	0.3	2.4	0.8	1.8	1.4	0.5	0.5
Lead	12.8	3.3	9.2	5.0	10.4	8.3	31.9	7.0	8.7	7.6
Zinc	142.0	39.0	92.0	<24.0*	125.0	44.0	86.0	35.0	54.0	<24.0*
Copper	6.6	<6.0	<6.0	<6.0	<6.0	<6.0	37.2	<6.0	<6.0	<6.0
Silver	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	2.7	1.7	4.4	1.5	26.7	17.5	10.5	5.7	1.9	<1.0

*A concentration of 24 µg/l zinc was at detection limits for these samples.

Chronic toxicity, resulting in reduced neonate production, was only evident in tests 5 through 8 and occurred at dilution volumes of 5 to 10 percent Spring Creek water (Table 9). Reduced neonate production in tests 1 through 4 and 9 (Table 9) was in part or totally due to mortality (Appendix A) and chronic effects were not evident. Spring Creek toxicity, resulting in chronic effects, was greatest in tests 5 through 7 with significantly lower neonate production at dilution volumes of 5 percent Spring Creek water (Table 9). Greater chronic toxicity in tests 6 and 7 was associated with greater acute toxicity, as previously stated, and was due to the unidentified toxicant. The increased toxicity resulting in chronic effects in test 5 was due to either the initial occurrence of the unidentified toxicant or to the increase in total recoverable zinc and copper on that day (Figures 2 and 3). Overall, the relationship between toxicity and metal concentrations was poor. This was primarily due to the occurrence of the unidentified toxicant.

Control water toxicity was also evident in tests 1 through 3 with significantly lower neonate production in the control treatments relative to the culture water treatments (Table 9). Bioassays conducted on water collected from the tributary streams on October 16 revealed a potential source of control water toxicity (Table 10). Copper Creek, located 100 m upstream from the control station 011, was chronically toxic, resulting in low neonate production and may have been a source of control water toxicity. Significant difference was also found in test 5, but this was probably due to nutritional differences in the culture water and control treatments, and not to control water toxicity. The culture water supported high concentrations of algae (Closterium) and bacteria, and provided additional food for C. reticulata in the culture water treatments. This resulted in higher neonate production in the culture water treatments for almost all tests.

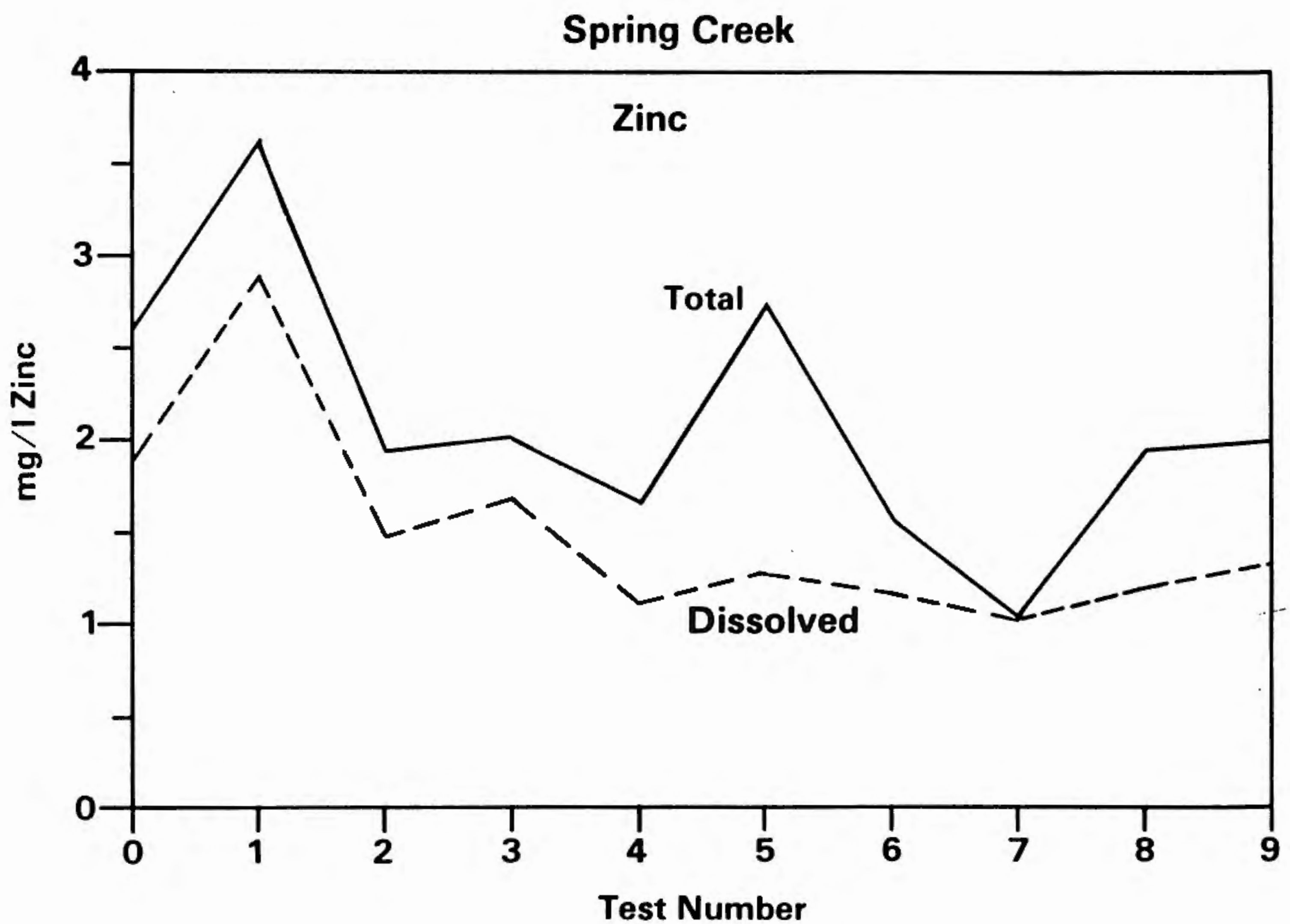

Figure 2. Total recoverable and dissolved zinc concentrations, Spring Creek, September 30 - October 9, 1983.

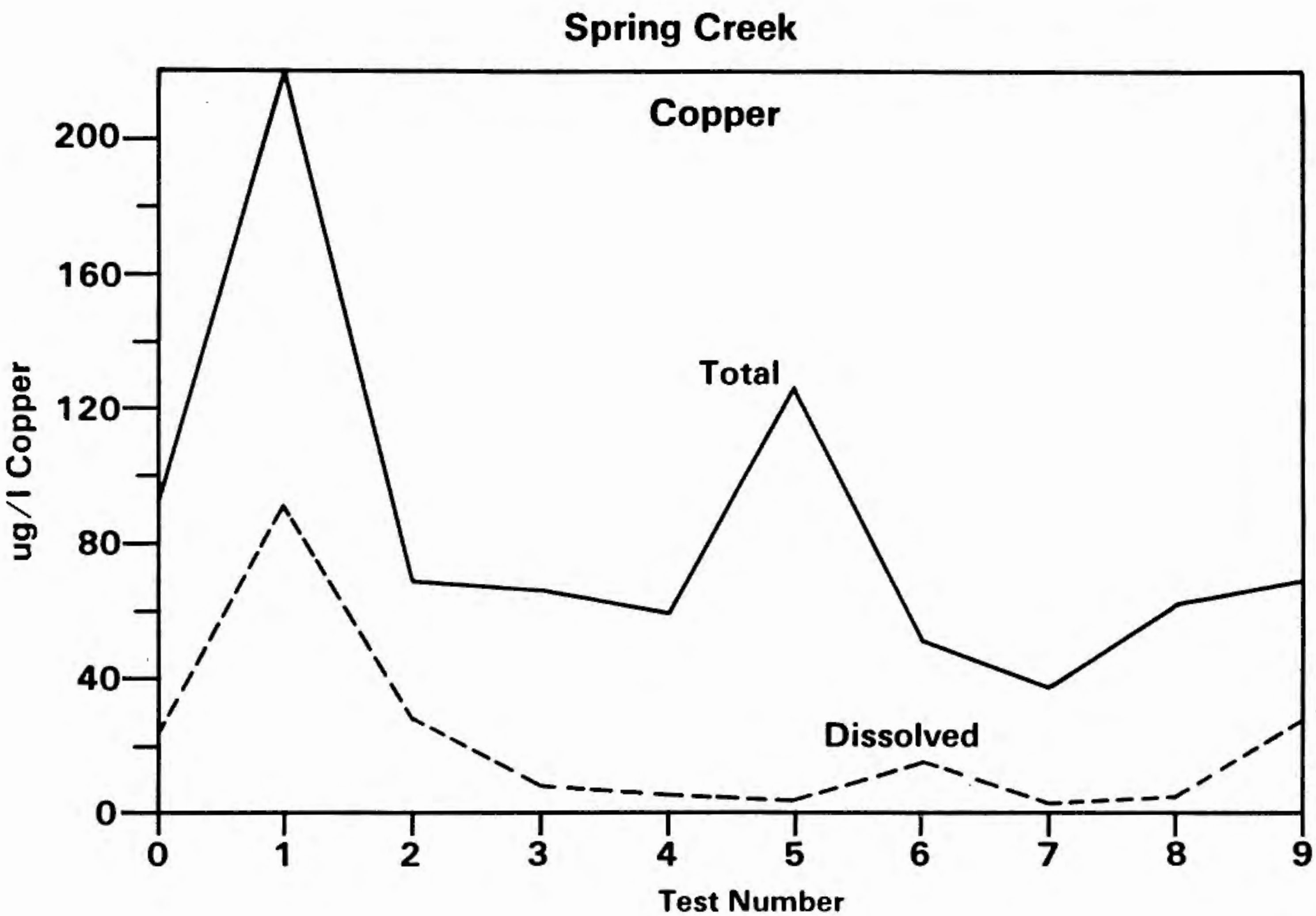

Figure 3. Total recoverable and dissolved copper concentrations, Spring Creek, September 30 - October 9, 1983.

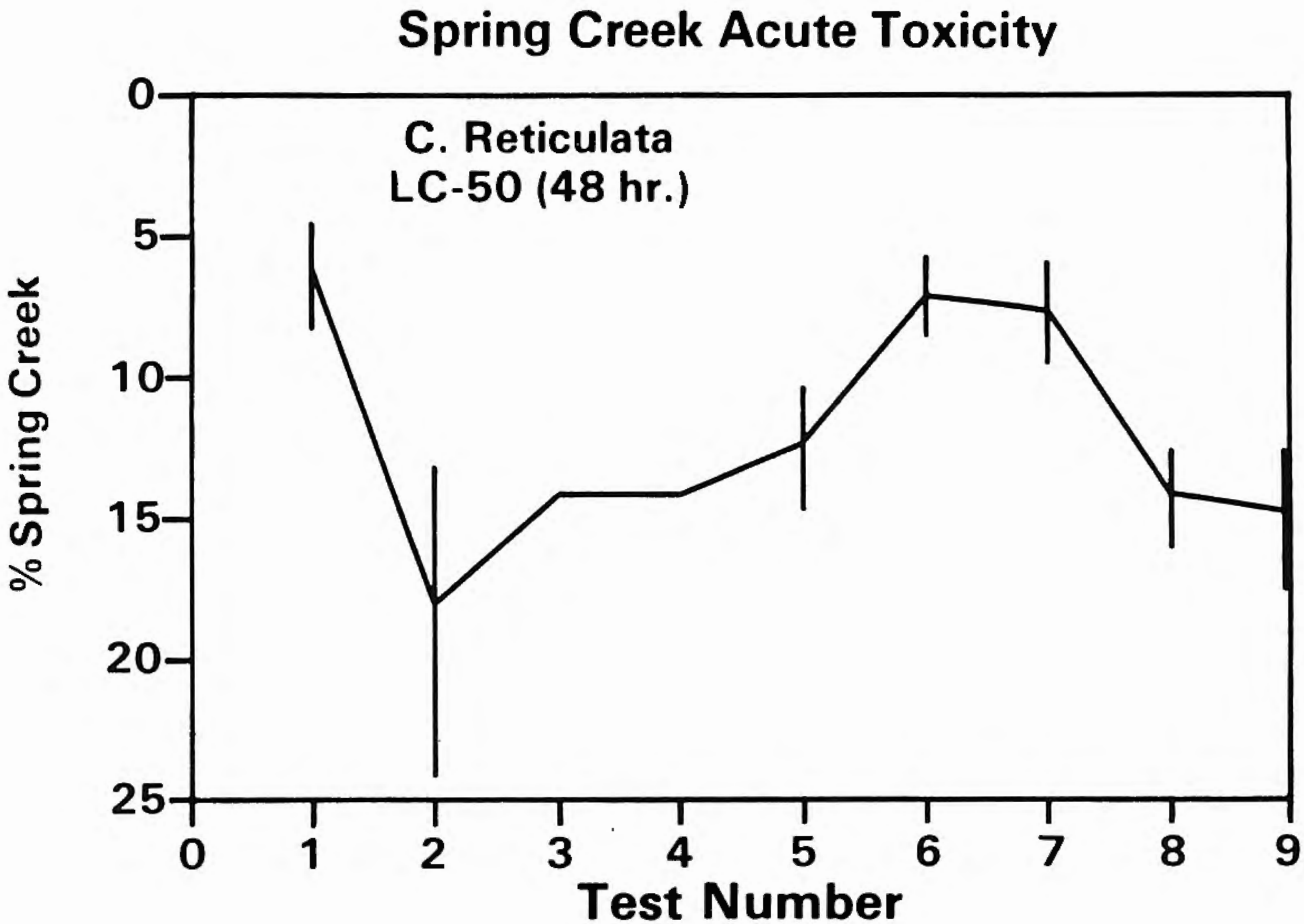

Figure 4. Percent Spring Creek water resulting in 48-hour LC-50s and 95 percent confidence limits, Ceriodaphnia reticulata tests. Confidence limits could not be determined for tests 3 and 4 because mortality was 100 percent in the 10 percent and 20 percent dilution treatments.

TABLE 9. MEAN NUMBER OF NEONATES PRODUCED AND 95 PERCENT CONFIDENCE LIMITS, C. RETICULATA TESTS 1 THROUGH 9
Chronic Effect Concentrations are Noted for Individual Tests.
Comparisons were not made between tests.

Dilution Treatment Spring Creek (%)	Test 1	2	3	4	5	6	7	8	9
Control $\bar{x}$	13.0	4.2	17.6	27.3	28.5	33.7	33.8	25.7	28.0
(95% C. L.)	(11.7-14.4)	(1.9-6.5)	(15.5-19.7)	(21.8-32.7)	(26.2-30.8)	(31.8-35.9)	(22.8-28.7)	(11.7-14.4)	(15.5-19.7)
1% $\bar{x}$	10.6	3.7	20.9	24.1	22.5	29.6	No	25.6	18.8
(95% C. L.)	(8.4-12.8)	(2.5-4.9)	(15.1-26.5)	(21.2-27.0)	(16.7-28.4)	(26.5-32.9)	Data	(23.2-28.1)	(14.0-23.9)
2.5% $\bar{x}$	10.3	6.0	25.9	27.4	25.6	34.2	28.7	22.8	23.8
(95% C. L.)	(8.6-12.0)	(2.5-9.4)	(23.4-28.4)	(26.6-28.2)	(22.6-28.6)	(33.2-35.2)	(27.0-30.3)	(17.5-28.2)	(20.9-26.6)
5% $\bar{x}$	10.1	7.2	25.3	21.8	9.9*	21.2*	22.9*	18.4	18.9
(95% C. L.)	(7.3-13.0)	(5.6-8.8)	(22.0-28.5)	(18.3-25.4)	(5.2-14.4)	(14.4-27.7)	(20.1-25.9)	(12.2-24.3)	(17.4-20.4)
10% $\bar{x}$	1.0*	7.0	17.7	3.8*	13.8	0	10	15.0*	13.5
(95% C. L.)	(-0.5-2.5)	(4.3-9.5)	(15.6-19.8)	---	(9.6-18.0)		---	(12.6-17.4)	(10.4-16.6)
20% $\bar{x}$	0	0*	0*	0	0	0	0	0	0*
(95% C. L.)									
Culture $\bar{x}$	23.3	26.5	28.6	38.5	37.9	35.8	30.9	25.3	25.2
Water (95% C. L.)	(20.1-26.8)	(22.4-30.6)	(26.8-30.5)	(32.6-44.3)	(35.1-40.7)	(34.0-37.6)	(28.7-33.0)	(22.6-28.1)	(21.8-28.6)

*Significantly different from control treatment, based on 95 percent confidence limits, indicating chronic effect level.

TABLE 10. *C. reticulata* BIOASSAY RESULTS FROM PRICKLY PEAR CREEK TRIBUTARY STREAMS (water was collected on October 16, 1983)

Test Treatment	48 hour Mortality Number	168 hour Mortality Number	Neonates $\bar{X}$	Neonates 95% C. L.
Culture water	0	0	25.3	(21.8-28.6)
Copper Creek	0	0	10.6	(8.2-13.2)
Corbin Creek	10	10	0	-
Spring Creek[1]	1	2	5.4	(2.3-8.4)
Dutchman Creek	0	0	15.3	(13.1-17.5)
Warm Spring Creek	0	0	21.2	(17.7-24.7)
Clancy Creek	0	0	11.0	(7.0-14.9)
Lump Gulch	0	0	18.2	(12.1-24.0)

[1]Spring Creek upstream from Corbin Creek.

Downstream Station and Dilution Treatment Comparisons--

Prickly Pear Creek station treatments were toxic to *C. reticulata*, and toxicity in the Spring Creek dilution treatments and in the downstream Prickly Pear Creek treatments was compared to determine if downstream changes in toxicity were due strictly to dilution of Spring Creek water. Validity of treatment comparisons was based on dilution volumes of Spring Creek water in the dilution and station treatments. Dilution volumes of Spring Creek water at the downstream stations 013, 014, and 018 were 17.3, 7.2, and 2.4 percent respectively, (see Results: Hydrology) and were similar to dilution volumes of Spring Creek water used in the *C. reticulata* dilution treatments (20, 10, and 2.5 percent).

Mortality in dilution and station treatments having comparable Spring Creek dilution volumes showed a high degree of similarity with differences only in tests 2 and 9, station 013 (Figure 5); tests 2 and 8, station 014 (Figure 6); and tests 6 and 7, station 018 (Figure 7). As previously stated, Spring Creek toxicity increased in tests 6 and 7 due to an unidentified toxicant. High mortality in the station 018 treatment for tests 6 and 7 relative to the comparable dilution treatment (2.5 percent) indicated that there was an additional downstream source of toxicity and that the toxicant may have been similar in nature to the unidentified toxicant in Spring Creek.

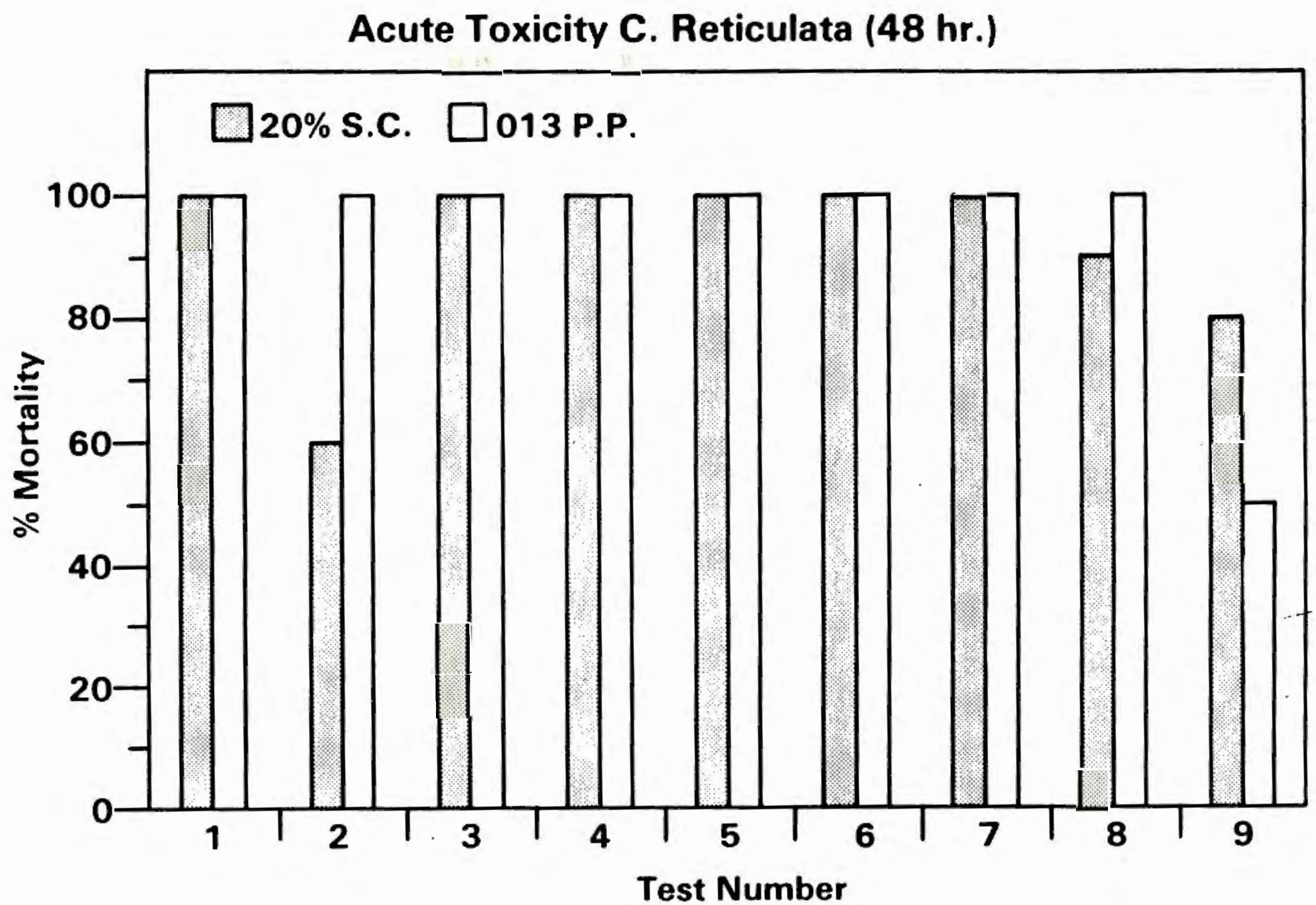

Figure 5. Percent mortality in 20 percent Spring Creek water and Prickly Pear Creek station 013 treatments, *Ceriodaphnia reticulata* tests.

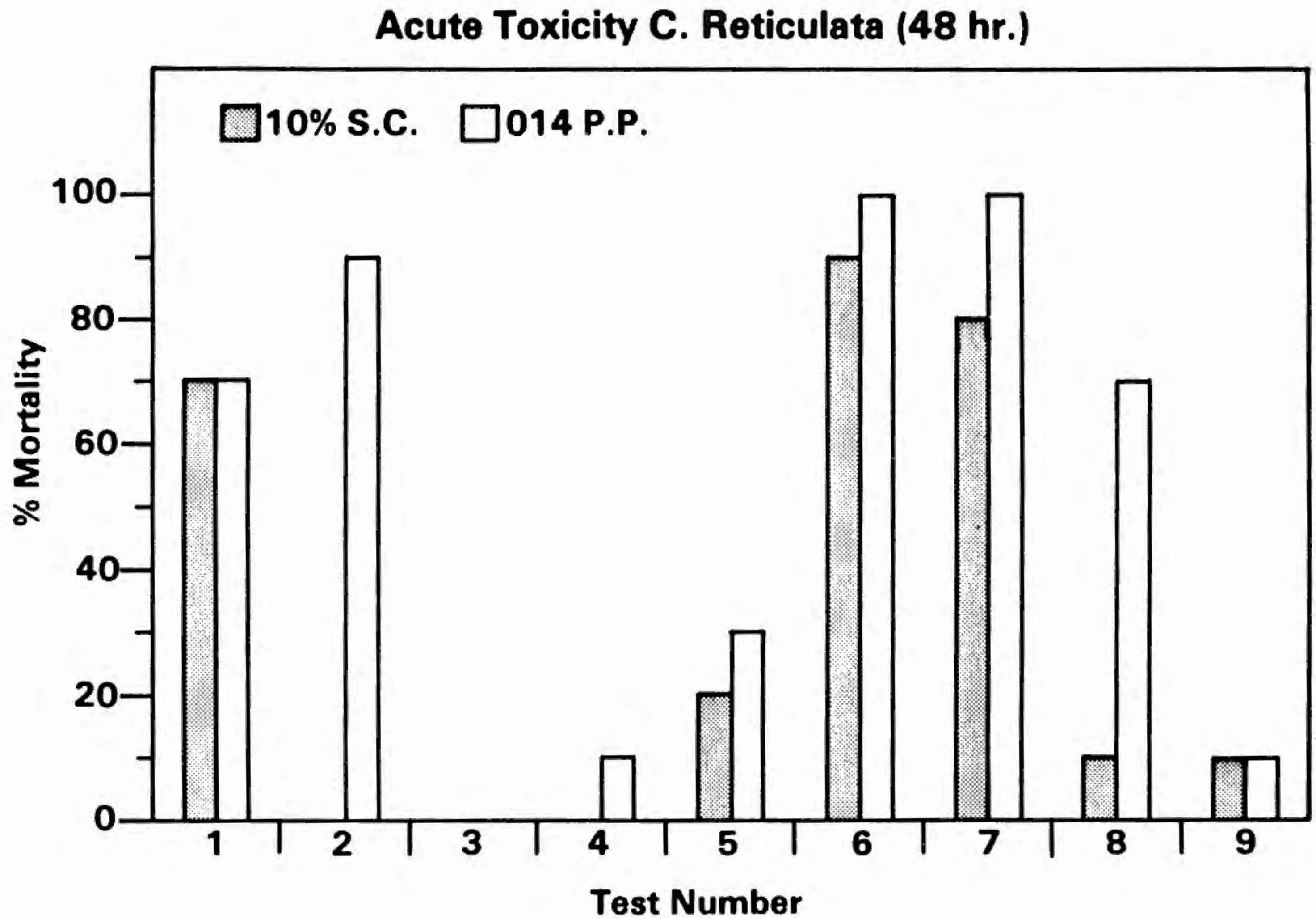

Figure 6. Percent mortality in 10 percent Spring Creek water and Prickly Pear Creek station 014 treatments, *Ceriodaphnia reticulata* tests.

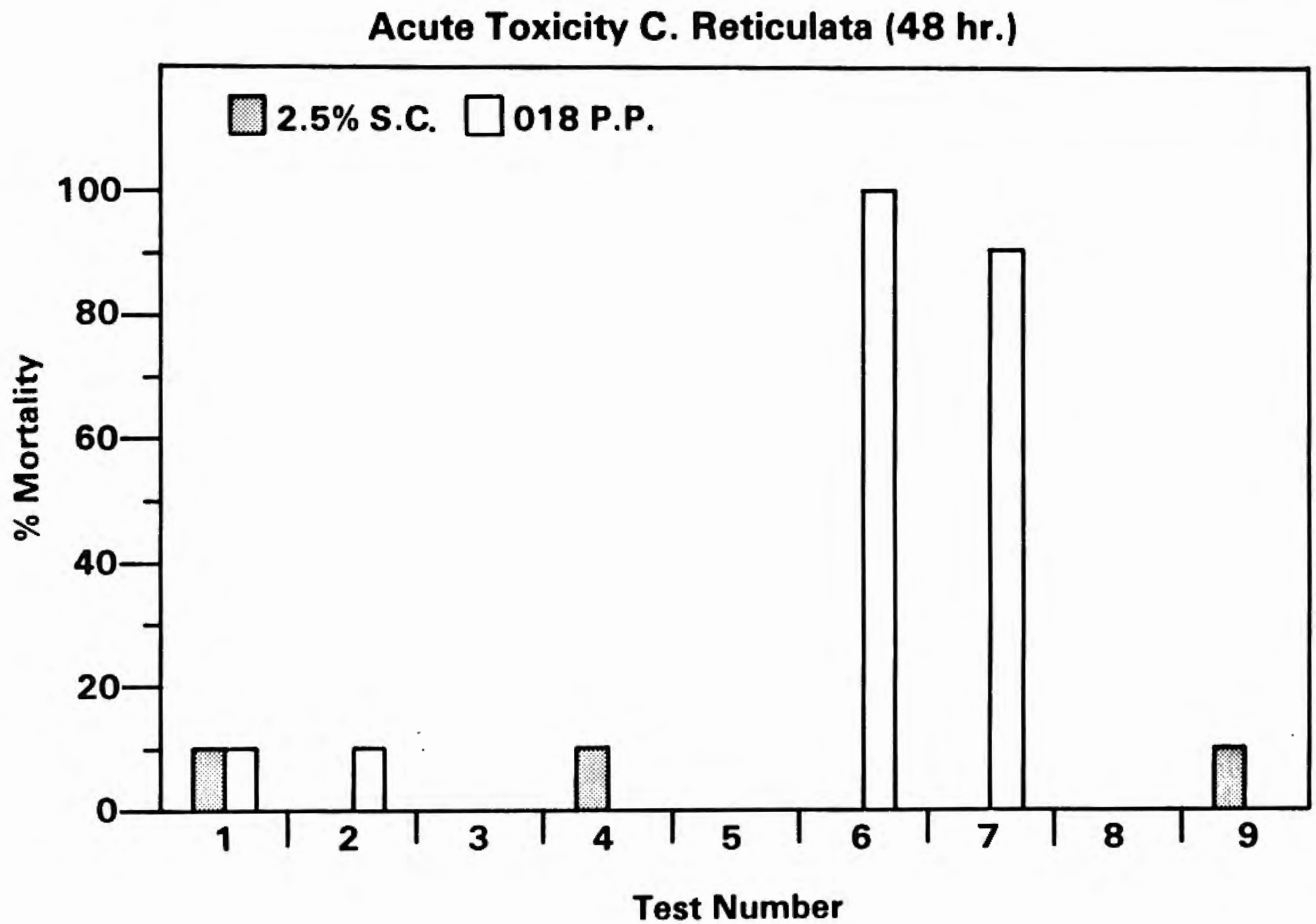

Figure 7. Percent mortality in 2.5 percent Spring Creek water and Prickly Pear Creek station 018 treatments, <u>Ceriodaphnia reticulata</u> tests.

Neonate production in dilutions and station treatment comparisons also showed no significant difference in a majority of the tests (Table 11). However, there was a trend for lower neonate production in the station treatments in most tests. This trend in higher toxicity in the downstream treatments resulted from either additional downstream sources of toxicity or downstream enhancement of Spring Creek toxicity. Clancy Creek and Dutchman Creek were chronically toxic (Table 10) and may have been responsible for increased downstream toxicity. However, toxicity from these tributary streams would have to be much greater than what was measured on October 16 to have had an effect in Prickly Pear Creek after dilutions.

Although one or both of the above processes may have occurred, differences in treatment comparisons were minimal and did not refute that variations in Prickly Pear Creek toxicity were primarily due to downstream dilution of the Spring Creek inflow. Downstream toxicity persistence, therefore, did appear to follow a conservative distribution pattern.

Pimephales promelas

Larval fathead minnows were more tolerant to Spring Creek toxicity than were *C. reticulata*. Estimated LC-50s for fathead minnows were at dilution volumes greater than 25 percent Spring Creek water (Figure 8). Dilution volumes of Spring Creek water at the downstream stations were less than estimated acute proportions (LC-50s), and this was reflected in the downstream station treatments having little or no mortality (Table 12).

Fathead minnow LC-50s indicated that Spring Creek toxicity was highly variable for this species. Minimal mortality occurred in tests 2, 8, and 9, and acute effects were not evident for those tests (Figure 8). There was a significant decline in toxicity in tests 6 and 7 (Figure 8) indicating that the unidentified toxicant resulting in toxicity to *C. reticulata* was not at toxic concentrations for fathead minnows. Higher toxicity in tests 0, 1, and 5 did correspond to higher total recoverable concentrations of zinc and copper; however, a strong relationship for these metal concentrations and toxicity was not clearly evident.

Part of the variability found in the fathead minnow test was probably not inherently related to Spring Creek toxicity. High control mortality occurred after the third or fourth day and at test termination mortality was greater than 30 percent (Appendix B) in six of the 10 tests (0, 1, 2, 4, 7, and 8). High control mortalities are usually indicative of procedural problems; however, mortality declined in the lower dilution treatments with little or no mortality at either 12.5 or 25 percent in all tests (Appendix B). The consistent decline in lower dilution treatment mortality relative to high control mortality strongly suggested that Spring Creek water was ameliorating conditions in the control water. This may have been due to either dilution of control water toxicity, or to the addition of some factor enhancing survival. Control water toxicity was evident in *C. reticulata* bioassays; however, reconstituted water (Hardness 80-90 mg/l $CaCO_3$) controls included in fathead minnow tests 6 and 7 resulted in mortalities of 12 and 32 percent, respectively (Appendix B). The high mortality in the reconstituted control in test 7 suggests that mortality was not entirely due to toxicity.

TABLE 11. MEAN NUMBER OF NEONATES PRODUCED AND 95 PERCENT CONFIDENCE LIMITS FOR COMPARABLE DILUTION AND STATION TREATMENTS, C. RETICULATA TESTS 1 THROUGH 9.

Comparable dilution and station treatments were 20 percent and station 013; 10 percent and station 014; and 2.5 percent and station 018. Comparisons were not made between tests.

	Treatment		Treatment		Treatment	
Test	20%	013	10%	014	2.5%	018
1 x̄ (95% C.L.)	0	0	1.0* (-0.5-2.5)	6.6 (3.8-9.3)	10.3* (8.6-12.0)	14.3 (12.5-16.0)
2 x̄ (95% C.L.)	0	0	7.0* (4.3-9.5)	0	6.0* (2.5-9.4)	11.8 (9.9-13.7)
3 x̄ (95% C.L.)	0	0	17.7 (15.6-19.8)	19.2 (18.1-20.3)	25.9 (23.4-28.4)	23.4 (18.8-26.8)
4 x̄ (95% C.L.)	0	0	3.8 ---	1.0	27.4 (26.6-28.2)	20.3 (13.9-26.6)
5 x̄ (95% C.L.)	0	0	13.8* (9.6-18.0)	3.5 (0.9-6.1)	25.6 (22.6-28.6)	30.6 (28.0-33.1)
6 x̄ (95% C.L.)	0	0	0	0	34.2* (33.2-35.2)	0
7 x̄ (95% C.L.)	0	0	10 ---	0	28.7 (27.0-30.3)	14 ---
8 x̄ (95% C.L.)	0	0	15.0* (12.6-17.4)	1.0 (-0.6-2.8)	22.8 (17.5-28.2)	12.6 (2.9-22.3)
9 x̄ (95% C.L.)	0	0	13.5 (10.4-16.6)	5.8 (-1.3-12.9)	23.8 (20.9-26.6)	23.0 (14.0-32.2)

*Significant difference in comparable dilution and station treatments based on 95 percent confidence limits.

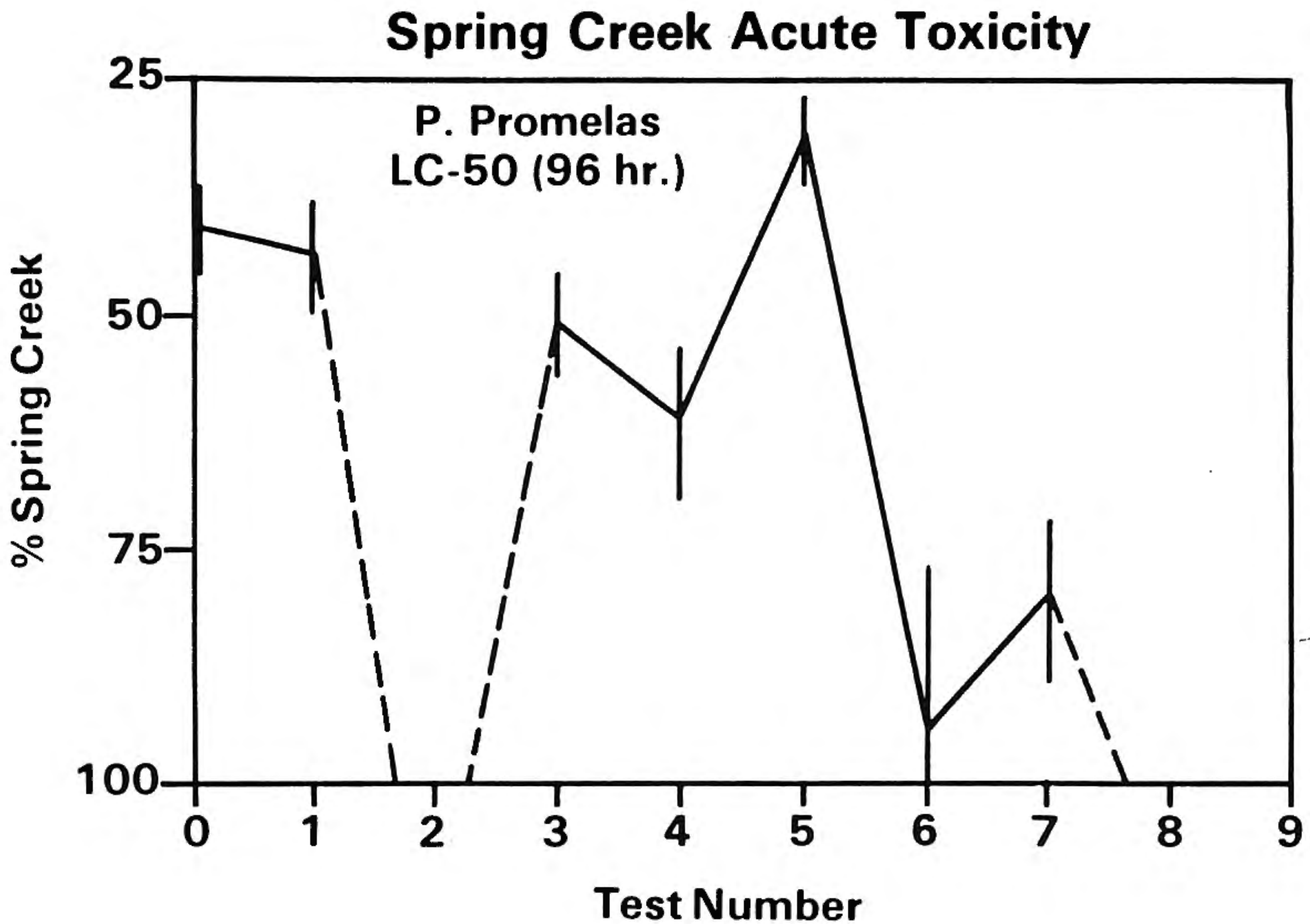

Figure 8. Percent Spring Creek water resulting in 96 hour LC-50s and 95 percent confidence limits, *Pimephales promelas* tests.

TABLE 12. PERCENT MORTALITY (96 HOUR) IN LARVAL FATHEAD MINNOWS IN PRICKLY PEAR CREEK STATION TREATMENTS

Station Treatment	Test Number 0	1	2	3	4	5	6	7	8	9
013	10	10	5	2	0	10	0	0	5	0
014	3	2	10	3	0	0	5	0	0	10
018	0	13	5	10	8	0	0	3	10	10

The inherent growth variability in fathead minnows precluded demonstrating in chronic effects. Final weights for replicate grouped fish showed no relationship with increased dilution volumes of Spring Creek water (Table 13). Growth was significantly increased with increased feeding in a separate feeding experiment, indicating test fish were probably underfed (Appendix B). However, growth appeared to be highly variable in overfed fish. Fathead minnows raised in the laboratory from identical egg batches showed variations in length approaching 400 percent after 30 days. This kind of growth variability would highly influence test results. Woltering (1983) and Lemke et al. (1983) have also observed high variability in growth of larval fathead minnows. A non-feeding lethality test has been suggested by Woltering (1983) because acute test results are usually highly correlated with chronic test results, are less variable, and are more efficient.

STREAM SURVEY

Water Quality

Metal water quality data were presented in a previous section of this report (Tables 7 and 8). Non-metal water quality parameters measured in the stream survey did not reveal any other sources of toxicity or toxicants (Table 14). Total organic carbon concentrations were low, ranging from 2 to 3 µg/l, and ammonia concentrations were below detection limits, indicating little or no contributions from either septic tanks or domestic animals within the study area. Cyanide and chlorine were also below detection limits. Spring Creek ion concentrations were moderate having a conductivity of 421 µmhos/cm, 2.7 times greater than at the control station 011. Conductivity at station 013 was 226 µmhos/cm, but increased to 269 µmhos/cm at station 018 as a result of additional secondary inflow sources high in ion concentrations downstream from Spring Creek. This was also reflected in alkalinity and hardness which showed similar downstream trends. Turbidity in Spring Creek was higher than in Prickly Pear Creek; however, water clarity or suspended solids were not a water quality problem during this investigation. Temperature, dissolved oxygen, and

TABLE 13. MEAN WEIGHTS FOR LARVAL FATHEAD MINNOWS IN SPRING CREEK DILUTION TREATMENTS
(weights are from four replicates per treatment; standard deviations are given in parentheses)

	Treatment											
	Control		6.25%		12.5%		25%		50%		100%	
Test	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
0	66	(27)	68	(10)	74	(5)	62	(8)	100	-	-	-
1	55	(17)	56	(11)	69	(7)	56	(8)	73	(23)	-	-
2	38	(18)	56	(27)	79	(2)	82	(4)	60	-	74	(10)
6	64	(9)	56	(8)	54	(8)	54	(8)	56	(8)	54	(8)
7	72	(24)	60	(9)	82	(38)	70	(9)	60	(7)	131	(25)
8	62	(16)	68	(7)	65	(10)	72	(6)	72	(10)	86	(11)
9	46	(9)	54	(32)	59	(7)	63	(10)	64	(3)	77	(16)

Note: Weights were not determined for tests 3 through 5. These fish were sent to Dr. Kenneth Jenkins, California State University, Long Beach for enzyme analyses.

pH levels were typical of fall conditions for temperate streams and were indicative of good water quality.

Hydrology

Stream flow at the USGS gaging station, located 2 km downstream from station 018, ranged from 35 to 42 cfs (Figure 9) during the toxicity testing period and was typical of seasonal low flows over the last 3 years (USGS provisional data water years 1981-83). The peak flow on October 2 was due to a small rain storm that occurred on September 30 and to snow melt from a storm that occurred on September 18 (Table 15). Changes in stream stage height readings of less than 1 cm at our stations were questionable and the only appreciable change in Spring Creek stage height was a 1 cm increase on September 30, which again was related to the small storm event on that date. No appreciable changes in stage height were found at the other gaging stations on Prickly Pear Creek (Appendix D).

Stream flow in Prickly Pear Creek increased from 11 cfs at station 011 to 37 cfs at station 018. Measured tributary inflows accounted for 62 percent of the increase in flow (Table 16). Estimated unmeasured inflows between stations 013, 014, and 018 were approximately 5 and 8 cfs, respectively. There were no other major surface inflows and the majority of the unmeasured increase in flow was due to groundwater inputs.

TABLE 14. SELECTED WATER QUALITY PARAMETERS MEASURED IN PRICKLY PEAR CREEK, MONTANA, SEPTEMBER 27-29, 1983

Parameter	Station 011	Spring Creek	013	014	018
Water Temperature (°C)	7.2	10.3	9.0	9.5	7.2
Dissolved Oxygen (mg/l)	9.8	8.9	8.6	8.8	9.5
Conductivity (µmhos/cm)	155	421	226	222	269
pH (std. units)	7.6	8.3	7.7	7.5	7.8
Turbidity (NTU)	0.5	6.2	1.7	0.7	1.0
Alkalinity (mg/l)	50	70	58	55	78
Hardness (mg/l)	61	187	86	85	96
T. Organic Carbon (µg/l)	2.0	2.6	2.1	3.0	2.6
D. Organic Carbon (µg/l)	1.7	1.4	-	2.1	-
Ammonia (µg/l)	<8	<8	<8	<8	<8
Cyanide (µg/l)	<6	<6	<6	<8	<6
T. Free Chlorine (µg/l)	<0.05	<0.05	<0.05	<0.05	<0.05

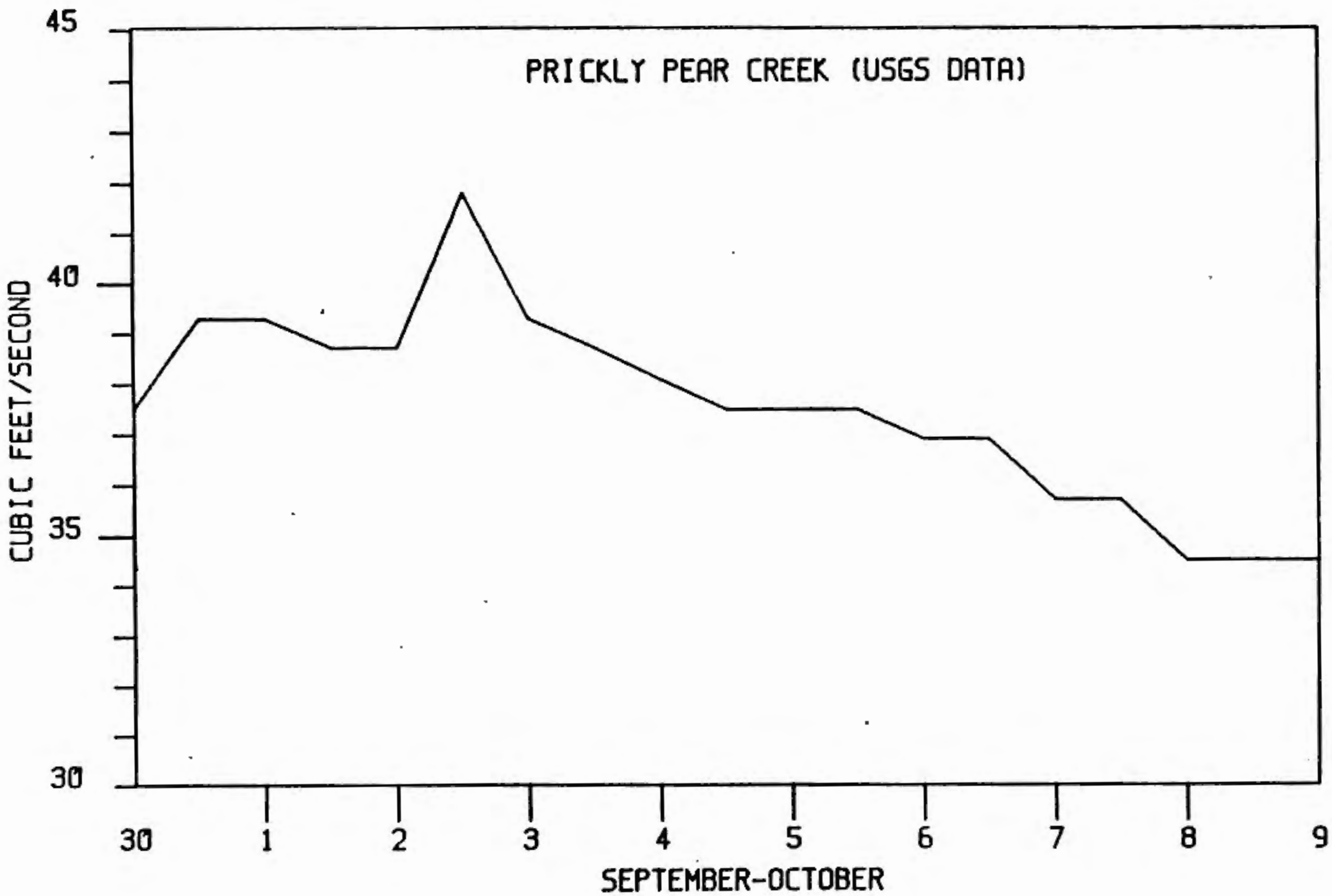

Figure 9. Prickly Pear Creek stream discharge, USGS gaging station September 30 - October 9, 1983.

TABLE 15. PRECIPITATION AT HELENA, MONTANA AIRPORT, LOCATED APPROXIMATELY 24 KM NORTH OF STUDY AREA

Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)
Sept. 18	1.75*	Oct. 1	-	Oct. 14	-
19	0.20	2	-	15	0.51
20	-	3	-	16	-
21	-	4	0.05	17	0.05
22	-	5	-	18	0.05
23	-	6	-	19	-
24	-	7	-	20	-
25	-	8	-		
26	-	9	0.13		
27	0.13	10	0.08		
28	-	11	-		
29	0.15	12	-		
30	0.63	13	0.03		

*13.0 cm of snow

TABLE 16. STREAM DISCHARGE AT PRICKLY PEAR CREEK STATIONS AND TRIBUTARY STEAMS

Prickly Pear[1] Creek Stations	Discharge cfs	Prickly Pear[3] Creek Tributaries	Discharge cfs
011	10.9	Spring Creek	1.4
013	10.0	Dutchman Creek	3.7
014	18.2	Warm Spring Creek	3.1
018	37.3	Clancy Creek	3.5
USGS gage[2]	38.7	Lump Gulch	4.4

[1]Measured September 27-29.
[2]Gage located 2 km downstream from station 018
[3]Measured October 16.

The volume percent of Spring Creek water to the total water volume at the downstream stations 013, 014, and 018 were 17.3, 7.2, and 2.4 percent respectively, based on concentrations of Rhodamine WT injected into Spring Creek on September 23 (Table 17). Dye retention time from the Spring Creek confluence to station 018 was just over 11 hours.

TABLE 17. RHODAMINE WT DYE STUDY PRICKLY PEAR CREEK SEPTEMBER 23-24, 1983

Station	Dye Peak Time	Dye Concentration µg/l	% Spring Creek* Water Volume	Travel Time
Spring Creek	2011	167	100	-
013	2030	29	17.3	19 min.
014	2340	12	7.2	3 hr. 29 min.
018	0720	4	2.4	11 hr. 9 min.

*Based on dye concentrations

Biota

Salmonid fishes were abundant at all Prickly Pear Creek stations (Table 18). However, there was a downstream shift in species abundance. Brook trout (*Salvelinus fontinalis*) was the only salmonid found at station 011. Both brook trout and rainbow trout (*Salmo gairdneri*) were abundant at stations 013 and 014, and brown trout (*Salmo trutta*) also occurred with the other salmonid species at station 018. The species shift in salmonids was probably not due to metal toxicity from Spring Creek, but rather to the increased frequency of pool habitats downstream (La Point et al. 1983).

Previous investigations have shown major reductions in both macroinvertebrate and periphyton numbers and diversity in the Prickly Pear Creek impact zone, station 013 and a gradual downstream reoccurrence of these species between stations 014 and 018, the recovery zone (Miller et al. 1982; La Point et al. 1983). Both of these studies were conducted in the summer. Quantitative analyses of periphyton and macroinvertebrate samples were not part of this investigation. A superficial examination of the macroinvertebrate samples at the time of collection revealed no obvious reduction in either species types or species numbers in the impact zone. This may have been a physiological response to lower temperatures and needs to be validated quantitatively. Water temperatures during this investigation were approximately 7°C compared to past summer temperatures of 16 to 20°C (La Point et al. 1983).

Sediment and Tissue Metals

Sediment metal concentrations at station 013 were approximately an order of magnitude higher than those found at the upstream station 011 (Table 19).

TABLE 18. RELATIVE ABUNDANCE ESTIMATES FOR FISH CAPTURED BY ELECTROSHOCKING PRICKLY PEAR CREEK, MONTANA, OCOTBER 1983.
Abundant (A) = >60%; very common (VC) = 31-60%; common (C) = 6-30% occasional (O) = 1-5%; rare (R) = <1% and absent = (-).

Fish Species	Station 011	013	014[1]	018
Cottus spp.	VC	-	C	C
Salvelinus fontinalis	VC	A	VC	C
Salmo gairdneri	-	C	VC	C
Salmo trutta	-	-	-	VC
Catostomus commersoni	-	-	-	O
Number of individuals	45	43	43	47
Species richness	2	2	3	5

[1]Fourteen immature salmonids captured; not included in estimates.

TABLE 19. MEAN SEDIMENT METAL CONCENTRATIONS IN SPRING CREEK AND PRICKLY PEAR CREEK, MONTANA, SEPTEMBER 27-29, 1983

	Sediment Metal Concentrations mg/kg				
Station	Cadmium	Lead	Zinc	Copper	Silver
011	3	135	502	133	1
Spring Creek	29	3612	4975	1142	36
013	30	3240	4937	967	34
014	14	1243	2765	372	12
018	9	668	1680	202	6

No arsenic analysis

Sediment metal concentrations at Spring Creek and station 013 were similar indicating high sediment deposition from Spring Creek in the area of station 013. Sediment concentrations decreased downstream from station 013 and were four to five times lower at station 018. However, concentrations at station 018 were substantially higher than concentrations found at the control station 011, further demonstrating the extent of downstream impacts from Spring Creek. Sediment metals were a potential source of downstream toxicity (Föstner and Wittmann 1979). However, hydrological conditions during the testing period were very stable (Figure 9), and increased downstream metal concentrations (toxicity), resulting from sediment resuspension, probably did not occur or was very minimal. Sediment water interactions were not determined in this study and should be investigated to determine the extent sediments act as a source or sink of metals under various hydrological conditions in Prickly Pear Creek.

Tissue metal concentrations were highest in periphyton followed by macroinvertebrates and fish (Table 20). Periphyton and macroinvertebrate tissue concentrations were substantially higher at station 013 and decreased downstream relative to ambient water and sediment concentrations. Metal uptake by periphyton and macroinvertebrates represented a potential metal sink; however, these organisms were also a source of metals when ingested by other organisms (Magee 1975). Fish tissue concentrations were not exceptionally high (Wilson 1981, Patrick and Loutit 1978) and there was no substantial difference in tissue concentrations at each of the stations. Miller et al. (1982) found significantly higher tissue metal concentrations in most organs (kidneys, gills, brains, heart, and gonads) from fish collected in the impact areas of Prickly Pear Creek in 1980. However, muscle tissue did not have elevated metal concentrations. In this investigation, whole fish were used for tissue analyses and the inclusion of muscle tissue probably masked metal concentrations in the organs.

TABLE 20. TISSUE METAL CONCENTRATIONS PRICKLY PEAR CREEK, MONTANA
SEPTEMBER 27-29, 1983

Organism	Station	Tissue Metal Concentrations (mg/kg)					
		Cadmium	Lead	Zinc	Copper	Silver	Arsenic
Periphyton	011	1	35	285	46	1	6
	013	37	1588	4640	1190	19	343
	014	9	175	1615	135	2	--
Macrophyte	014	12	252	2630	330	4	61
Macroinvertebrates	011	1	18	326	37	1	2
	013	12	165	2038	276	2	32
	014	4	47	660	65	1	8
	018	2	26	444	37	<1	7
Fish							
Salvelinus fontinalis	011	<1	3	70	11	<1	<1
	011	1	7	230	20	<1	1
	013	1	10	92	10	<1	<1
	014	1	5	145	14	<1	<1
	014	1	8	225	8	<1	1
Salmo gairdneri	014	1	12	255	16	<1	<1
Salmo trutta	018	1	10	220	12	<1	<1
Cottus spp.	011	<1	8	135	10	<1	<1
	014	1	6	265	28	<1	<1
	018	<1	6	255	7	<1	<1

V. GENERAL DISCUSSION

EFFLUENT AND INSTREAM TOXICITY TESTING

Early in 1984, the U.S. Environmental Protection Agency issued a policy statement on development of water quality-based permit limitations for toxic pollutants. EPA's approach to controlling toxic pollutants, beyond technology based requirements to achieve compliance with water quality standards and designated water use, utilizes an integrated strategy incorporating biological and chemical methods. State standards that contain numerical criteria for toxicants will be met through issuance of National Pollutant Discharge Elimination System permits containing limits on the quantities of toxic substances discharged. In addition, biological techniques will be used as necessary to achieve the general standard of "no toxic materials in toxic amounts." Where violations of water quality standards occur, water quality based effluent limits will be developed by the state and included in the permit. Where toxic effects occur in receiving water, permit limits may be based on effluent toxicity limits.

Depending upon the type of effluent and discharge situation, chemical testing may be more appropriate than biological, or visa versa. In some instances, both chemical and biological testing may be required for assessment of effluent impacts on water quality. Generally, where a discharge contains a few, well-qualified pollutants, whose interactions and effects are well known, pollutant-specific chemical analyses should be used. Pollutant-specific chemical techniques should also be used where health hazards or bioaccumulation are of concern. Where effluents are complex or combined effects of multiple pollutants are of concern, biological techniques should be used. Testing needs, chemical or biological, singly or in combination, will have to be determined on a case-by-case basis depending upon the nature of a particular effluent and receiving system.

An obvious advantage of biological effluent toxicity testing over pollutant-specific chemical methods is that the biological approach measures the effects of an effluent directly. On the other hand, chemical approaches require the identification and measurement of each individual pollutant and knowledge of how these pollutants are related, singly and in combination, to aquatic effects. This becomes particularly significant in assessing complex effluents containing pollutants which are not easily identified or quantified or for which little information is available regarding biological effects.

Instream toxicity measurements (after mixing of the effluent), along with assessments of stream communities, can provide a great deal of information about the nature and extent of effluent impacts on resident biota. These analyses, if properly conducted, aid in identifying needs for limiting effluent toxicity.

An important and often overlooked aspect of effluent and instream toxicity is the persistence of toxicity within a receiving system, and the potential spatial extent and severity of impact to the biota. Obviously, pollutants that are rapidly degraded to non-toxic forms, lost to the atmosphere, or rendered unavailable through other processes pose far less threat to biota than the more persistent forms.

WHOLE EFFLUENT TESTING, PRICKLY PEAR CREEK

There are various physiochemical processes that can degrade or enhance metal toxicity (Duce 1975); however, conditions in Prickly Pear Creek were such that conservative behavior in toxicity was favored. Hydrological retention time from the Spring Creek confluence to the downstream Prickly Pear Creek stations was relatively short (11 hours) and would limit oxidation and reduction processes, especially at stream temperatures (7°C) found during this investigation. Suspended solids and organic compounds were also very low and toxicity was not highly influenced by particle adsorption or by complexing with organic compounds. Prickly Pear Creek was not acutely toxic to larval fathead minnows, and bioassay results were not applicable to testing the fate of Spring Creek toxicity. C. reticulata was more sensitive than fathead minnows, and bioassay results did demonstrate a conservative behavior in toxicity. However, conclusions reached from these data have to be somewhat restrained because test waters were held for an extended period of time (approximately 30 days) before conducting the bioassays and change in toxicity may have occurred. Since it was not possible to determine to what extent toxicity had changed, these data cannot be quantified in that regard.

These data will be used in validation of a stream dilution model. C. reticulata bioassays did indicate control water and secondary sources of toxicity entering Prickly Pear Creek downstream from Spring Creek, making model validation somewhat more difficult. Model predictions will underestimate downstream toxicity, but this will probably not exceed significant levels in the model based on observed differences found in dilution and station treatment comparisons.

These bioassays supported the concept of biological whole effluent testing. C. reticulata bioassays revealed the additional occurrence of toxicity within the study reach; however, the toxicants were not identified by those chemical parameters analyzed in this investigation. Impacts from these toxicants would have been missed if a pollutant-specific chemical approach had been taken. The effects of the unidentified toxicant were measured in Prickly Pear Creek as a result of a biological approach, but the sources (discharges) would have to be determined if this was a situation where effluent limits were being set.

Furthermore, toxicity found in both test organisms clearly paralleled past changes in native fish and macroinvertebrate communities attributed to toxicity. Distribution and abundance of fish and macroinvertebrates in Prickly Pear Creek have been well documented for summer conditions in previous investigations (Miller et al. 1982, La Point et al. 1983). These studies have shown that toxicity from Spring Creek has little or no effect on native fish, but a definite impact zone and recovery zone were found in Prickly Pear Creek relative to macroinvertebrate community diversity and species abundance. If fathead minnows and _C. reticulata_ bioassays from this study were used to predict downstream biotic conditions in Prickly Pear Creek, identical impacts and/or zones would be designated. Therefore, it does appear that these bioassays reflect summer levels of toxicity affecting native fish and macroinvertebrate communities in this system.

WATER QUALITY BASED STANDARDS-TO-PERMIT PROCESS

The work reported here, addressing toxicity persistence in a receiving stream, represents an initial step toward field validation of procedures for establishing water quality based effluent limits using biological data. Although the primary source of metals to Prickly Pear Creek was a tributary stream rather than an effluent pipe, Spring Creek was treated as an effluent for which load limits and required reductions could be established and a permit issued. Data from this and other projects will provide information on the conservative (or nonconservative) nature of various types of pollutants in a range of receiving systems. Such case-history information will enable the Office of Water Regulations and Standards to assess the validity of the mass balance modeling approach to predicting instream toxicity persistence. An eventual goal is to include in this testing all steps leading to, and including, the issuance of permits using biological data. This will require participation by individuals from EPA's Office of Research and Development, several program officers, Regional offices, and the appropriate States. Analyses to be included in these tests would consist of:

1) identification of water quality limited systems,
2) water body survey and assessment,
3) review of and, if necessary, revision of designated uses,
4) establishment of appropriate criteria,
5) performance of waste load allocation,
6) identification of control technology requirements.

These analyses, when completed, would result in assurance of a water quality based permit that would allow the water quality standard to be met. Issuance of the permit would be followed by monitoring to ensure water quality improvements are being achieved.

RESEARCH NEEDS

Bioassay Protocols

Bioassay procedures used in the field tests were based on draft protocols and nutritional problems with both test organisms were encountered. _C. reticulata_ cultures could not be maintained and high control mortalities occurred in the field and these tests had to be discontinued. The problem was eliminated in the laboratory tests using cerophyl as food. At a recent workshop,[1] nutritional

[1] Ceriodaphnia Workshop (U.S. EPA Region 8) in Fort Collins, CO, March 6-7, 1984.

problems associated with using yeast were further documented and a yeast cerophyl-trout food mixture was suggested as an alternative food. Further research needs were outlined at that workshop in standardizing the testing procedure.

Chronic toxicity was not measured in the larval fathead minnow tests. This was apparently related to underfeeding. The food regime described in the protocol is not quantitative and is ill defined. A quantitative food regime should be developed if chronic toxicity is to be measured in future testing.

Natural Community Response

Seasonal differences in toxicity were noted in the macroinvertebrate communities in Prickly Pear Creek, based on qualitative examination. This may be related to physiological changes in toxicity tolerance as a result of decreased water temperature and should be examined in future investigations. Water temperatures were maintained at 25°C in the bioassay used in this study, and toxicity found in these test organisms appears to reflect summer toxic effects on native community structure. Further research is needed to determine the importance of the relationship between these bioassays and changes in biotic communities in assessing environmental impacts.

VI. CONCLUSIONS

Metal concentrations in Prickly Pear Creek were significantly increased downstream from its tributary, Spring Creek, which produced elevated levels due to gold mining tailing and settling ponds in the drainage basin. Concentrations of cadmium, zinc, and copper measured over a 10-day period exceeded U.S. EPA acute criteria for aquatic life at one or more of the downstream sampling stations in Prickly Pear Creek. Sediments were a potential downstream source of metals, but probably did not contribute to ambient water metal concentrations due to stable hydrological conditions. Elevated metal concentrations were the only water quality problems observed in Prickly Pear Creek during this investigation.

Spring Creek toxicity to test organisms (_C. reticulata_ and _P. promelas_) was primarily due to zinc and copper. Other unidentified toxicants were present and Spring Creek was not the only tributary serving as source of toxicity for Prickly Pear Creek waters. Although there were additional sources, changes in toxicity (persistence) in Prickly Pear Creek were primarily due to downstream dilution of Spring Creek water. Therefore, Spring Creek toxicity did exhibit a conservative behavior in its downstream distribution in Prickly Pear Creek and complied with toxicity model assumptions.

Sensitivity of the two test organisms to toxicity in Spring Creek and Prickly Pear Creek was very different. _C. reticulata_ was highly sensitive, and bioassay results were applicable in assessing toxicity persistence in Prickly Pear Creek. _P. Promelas_ had a higher tolerance and could not be used in assessing toxicity persistence. Although sensitivity of larval fathead minnows and the cladoceran was different, both appeared to be highly representative of toxic effects in Prickly Pear Creek native fish and macroinvertebrate communities found in studies.

Problems were encountered in the field bioassay procedures used for both organisms. These problems were related to the food regimen used in each of the bioassays. Cerophyl proved to be a better food source than yeast in _C. reticulata_ tests. Chronic toxicity was not measured in _P. Promelas_ apparently because of underfeeding, and either a quantitative food regime should be developed for this test or a nonfeeding test should be used in future field testing.

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APPENDIX A. *CERIODAPHNIA RETICULATA* BIOASSAY DATA

APPENDIX A-1. CERIODAPHNIA RETICULATA TOXICITY TEST RESULTS PRICKLY PEAR CREEK, MONTANA 1983

Test	Test Treatment	48-hr Mortality	168-hr Mortality	No. Reproductive Females	Total No. of Neonates
1	Culture Water	0	0	10	233
	Control	0	0	10	129
	1%	1	1	9	95
	2.5%	1	1	9	94
	5%	4	4	6	68
	10%	8	8	1	2
	20%	10	10	0	0
	018	1	2	8	114
	014	7	8	2	12
	013	10	10	0	0
2	Culture Water	0	0	10	265
	Control*	0	0	9	40
	1%	0	0	10	37
	2.5%	0	0	10	60
	5%	0	0	10	57
	10%	0	2	9	59
	20%	6	6	0	0
	018	1	1	9	106
	014	10	10	0	0
	013	10	10	0	0
3	Culture Water	0	0	10	286
	Control	0	0	10	176
	1%	0	0	9	182
	2.5%	0	0	9	229
	5%	0	0	10	253
	10%	0	0	10	175
	20%	10	10	0	0
	018	0	0	10	234
	014	0	1	8	154
	013	10	10	0	0
4	Culture Water	0	0	10	385
	Control	0	0	10	272
	1%	0	0	10	211
	2.5%	1	1	9	247
	5%	0	0	10	197
	10%	0	10	10	38
	20%	10	10	0	0
	018	0	4	10	142
	014	2	10	1	1
	013	10	10	0	0

*9 original females

(continued)

APPENDIX A-1. (Continued)

Test	Test Treatment	48-hr Mortality	168-hr Mortality	No. Reproductive Females	Total No. of Neonates
5	Culture Water	0	0	10	379
	Control	0	0	10	285
	1%	0	0	10	225
	2.5%	0	0	10	256
	5%	0	0	10	99
	10%	2	9	6	44
	20%	10	10	0	0
	018	0	2	10	228
	014	3	7	4	15
	013	10	10	0	0
6	Culture Water	0	0	10	358
	Control	0	0	10	337
	1%	0	0	10	296
	2.5%	0	0	10	341
	5%	1	3	8	159
	10%	10	10	0	0
	20%	10	10	0	0
	018	10	10	0	0
	014	10	10	0	0
	013	10	10	0	0
7	Culture Water	0	0	10	309
	Control	0	0	10	338
	1%**	3	10	7	29
	2.5%	0	0	10	286
	5%	1	1	9	203
	10%	8	9	1	10
	20%	10	10	0	0
	018	8	9	1	14
	014	10	10	0	0
	013	10	10	0	0
8	Culture Water	0	0	10	253
	Control	0	0	10	258
	1%	0	0	10	256
	2.5%	0	0	9	206
	5%	0	1	9	166
	10%	1	8	7	81
	20%	10	10	0	0
	018	0	5	6	65
	014	7	8	1	3
	013	10	10	0	0

*9 original females

(continued)

**Data not included in test results because of apparent contamination.

APPENDIX A-1. (Continued)

Test	Test Treatment	48-hr Mortality	168-hr Mortality	No. Reproductive Females	Total No. of Neonates
9	Culture Water	0	0	0	262
	Control*	0	0	9	164
	1%	0	0	0	186
	2.5%	1	2	9	194
	5%	0	1	9	169
	10%	1	4	7	83
	20%	8	0	0	0
	018	0	1	9	174
	014	1	7	3	20
	013	5	0	0	0

*9 original females

APPENDIX A-2. RANGE IN PHYSICAL CHEMICAL PARAMETERS MEASURED IN *CERIODAPHNIA RETICULATA* TEST, PRICKLY PEAR CREEK, MONTANA 1983

Test	Test Treatment	Seven Day Range		
		Temperature	Oxygen	pH
1	Culture Water	22.5-24.5	6.0-6.4	
	Control	22.5-24.5	6.4	
	1%	22.5-24.5	6.4	
	2.5%	23.0-24.5	5.0-6.4	
	5%	23.0-24.5	6.0-6.5	
	10%	23.0-24.5	6.2-6.5	
	20%			
	018	23.0-24.5	4.3-6.5	
	013	23.5-24.0		
	014	23.5-24.5	5.1-6.5	
2	Culture Water	23.0-24.5	5.8-6.8	
	Control	23.0-25.0	5.9-6.6	
	1%	23.0-25.0	5.8-6.6	
	2.5%	23.0-25.0	5.4-6.6	
	5%	23.0-25.0	5.6-6.6	7.0
	10%	23.0-25.0	5.8-6.9	
	20%	23.0-25.0	4.5-6.5	
	018	23.0-25.0	5.5-6.8	
	013	24.5		
	014	24.5		
3	Culture Water	22.5-25.0	5.5-7.0	7.6
	Control	22.5-25.0	5.3-6.8	7.6
	1%	22.5-25.0	5.0-6.7	7.6
	2.5%	22.5-25.0	5.6-6.7	7.6
	5%	22.5-25.0	5.8-6.7	7.6
	10%	22.5-25.0	5.7-6.7	7.6
	20%	24.0-25.0	6.2-6.3	
	018	22.5-25.0	5.8-6.9	7.5
	013	24.0-24.5	6.3	
	014	22.5-25.0	6.3-6.8	7.6
4	Culture Water	22.5-23.5	6.7-7.0	7.4-8.6
	Control	22.5-23.5	6.1-6.7	7.4-7.7
	1%	22.5-23.5	6.3-6.9	7.4-7.7
	2.5%	22.5-23.5	6.3-6.9	7.4-7.7
	5%	22.5-23.5	6.6-7.0	7.5-7.7
	10%	22.5-23.5	6.2-7.0	7.4-7.7
	20%	23.5	6.3	
	018	22.5-23.5	5.6-7.0	7.4-7.7
	013	23.5	6.6	
	014	22.5-25.0	6.3-6.8	7.6

(continued)

APPENDIX A-2. (Continued)

Test	Test Treatment	Seven Day Range Temperature	Oxygen	pH
5	Culture Water	22.5-24.0	6.5-6.9	7.43-8.3
	Control	22.5-24.0	5.9-6.5	7.41-7.7
	1%	22.5-24.0	5.9-6.5	7.36-7.7
	2.5%	22.5-24.0	6.1-6.7	7.35-7.7
	5%	22.5-24.0	6.4-7.0	7.36-7.7
	10%	22.5-24.0	6.0-6.9	7.41-7.7
	20%	23.5	6.3	
	018	22.5-24.0	6.1-7.0	7.4-7.6
	013	23.5	6.6	
	014	22.5-24.0	6.0-7.0	7.43-7.7
6	Culture Water	24.0-24.0	6.3-7.6	7.5-8.5
	Control	24.0-26.0	6.0-7.5	7.5-8.1
	1%	24.0-26.0	5.8-7.5	7.5-8.1
	2.5%	24.0-26.0	5.8-7.5	7.5-8.1
	5%	24.5-26.0	5.6-7.3	7.5-8.1
	10%	21.5-26.0	5.8-7.6	7.5-8.1
	20%	24.5	7.0	7.5
	018	24.5	7.1	7.5
	013	24.5	7.0	7.5
	014			
7	Culture Water	24.0-26.0	6.7-7.7	7.5-8.5
	Control	24.0-26.0	5.8-7.7	7.5-8.0
	1%	24.0-24.5	5.8-7.6	7.5-8.6
	2.5%	24.0-26.0	5.5-7.5	7.5-8.1
	5%	24.0-26.0	5.8-7.6	7.5-8.0
	10%	24.0-26.0	5.8-7.6	7.5-8.0
	20%	24.0-24.0	7.1	7.5
	018	24.5-26.0	5.8-7.6	7.5-8.0
	013	24.5	7.1	7.5
	014		6.9	7.5
8	Culture Water	23.5-24.0	6.1-7.4	7.4-7.6
	Control	23.5-24.0	5.9-7.5	7.4-7.7
	1%	23.5-24.0	5.9-7.4	7.4-7.8
	2.5%	23.5-24.0	5.9-7.4	7.3-7.8
	5%	23.5-24.0	5.0-7.4	7.3-7.8
	10%	23.5-24.0	5.0-7.4	7.4-7.8
	20%	24.0-24.5	5.5-7.4	7.3-7.4
	018	23.5-24.0	5.8-7.4	7.4-7.8
	013			
	014	23.5-24.0	5.7-7.4	7.4-7.6

(continued)

APPENDIX A-2. (Continued)

Test	Test Treatment	Seven Day Range		
		Temperature	Oxygen	pH
9	Culture Water	23.5-24.0	4.8-7.4	7.4-7.6
	Control	23.5-24.0	5.5-7.4	7.4-7.8
	1%	23.5-24.0	5.5-7.3	7.4-7.7
	2.5%	23.5-24.0	5.5-7.4	7.4-7.7
	5%	23.5-24.0	4.8-7.4	7.4-7.7
	10%	23.5-24.0	5.1-7.3	7.4-7.7
	20%	23.5-24.0	5.1-7.4	7.4-7.5
	018	23.5-24.0	5.1-7.3	7.4-7.8
	013	23.5-24.0	5.1-7.4	7.4
	014	23.5-24.0	5.1-7.4	7.4-7.8

APPENDIX B. *PIMEPHALES PROMELAS* BIOASSAY DATA

APPENDIX B-1. PIMEPHALES PROMELAS TOXICITY TEST RESULTS, PRICKLY PEAR CREEK, MONTANA

		96 Hours	168 Hours	End Weight (μg)	
Test	Treatment	No. Dead - No. Start[2]	No. Dead - No. Start	$\bar{X}$	SD
0	Control	9-40[1]	31-40[1]	66	27
	6.25%	2-40	9-39	68	10
	12.5%	0-40	1-40	74	5
	25%	2-40	3-40	62	8
	50%	30-40	30-40	100	0
	100%	40-40	40-40	-	-
	018	0-40	2-40	70	19
	014	1-40	12-40	64	6
	013	4-40	4-40	72	6
1	Control	8-40	14-40	55	17
	6.25%	4-40	10-40	56	11
	12.5%	1-41	2-40	69	7
	25%	4-41	4-41	56	8
	50%	14-40	14-39	73	23
	100%	40-40	40-40	-	-
	018	5-40	22-39	83	46
	014	1-42	3-42	54	5
	013	4-41	5-41	60	3
2	Control	4-17	14-17	38	18
	6.25%	0-19	3-19	56	27
	12.5%	1-20	1-20	79	2
	25%	0-20	0-20	82	4
	50%	0-20	0-20	60	0
	100%	3-20	3-20	74	10
	018	1-19	7-19	67	0
	014	2-20	2-20	71	6
	013	1-20	1-20	52	11
3	Control	0-40	0-40	N/A[4]	N/A
	6.25%	0-40	1-41	N/A	N/A
	12.5%	1-40	3-41	N/A	N/A
	25%	2-40	2-39	N/A	N/A
	50%	15-39	15-39	N/A	N/A
	100%	40-40	40-40	N/A	N/A
	018	4-40	4-36	N/A	N/A
	014	1-40	4-39	N/A	N/A
	013	1-41	2-40	N/A	N/A

(continued)

APPENDIX B-1. (Continued)

		96 Hours	168 Hours	End Weight (µg)	
Test	Treatment	No. Dead - No. Start[2]	No. Dead - No. Start	$\overline{X}$	SD
4	Control	14-42	14-42	N/A	N/A
	6.25%	11-45	14-40	N/A	N/A
	12.5%	5-41	10-41	N/A	N/A
	25%	0-42	1-42	N/A	N/A
	50%	7-39	7-39	N/A	N/A
	100%	22-41	22-41	N/A	N/A
	018	3-40	4-40	N/A	N/A
	014	0-41	1-41	N/A	N/A
	013	0-41	0-40	N/A	N/A
5	Control	2-41	2-41	N/A	N/A
	6.25%	4-41	6-41	N/A	N/A
	12.5%	1-40	10-40	N/A	N/A
	25%	13-41	13-41	N/A	N/A
	50%	34-40	34-40	N/A	N/A
	100%	41-41	41-41	N/A	N/A
	018	0-42	1-42	N/A	N/A
	014	0-41	0-39	N/A	N/A
	013	4-39	5-39	N/A	N/A
6	Rec Control[5]	1-41	5-40	62	7
	Control	4-41	5-41	64	9
	6.25%	3-41	3-41	56	8
	12.5%	0-40	0-40	54	8
	25%	1-40	1-40	54	8
	50%	1-39	1-39	56	8
	100%	22-39	22-39	54	8
	018	0-40	0-40	59	6
	014	2-41	2-41	77	10
	013	0-42	0-42	57	3
7	Rec Control	3-42	13-41	73	18
	Control	8-41	21-41	72	24
	6.25%	2-41	10-41	60	9
	12.5%	1-41	7-41	82	38
	25%	0-41	0-41	70	9
	50%	3-41	3-41	60	7
	100%	29-41	29-41	131	25
	018	1-40	3-40	51	28
	014	0-38	0-38	52	11
	013	0-41	0-41	49	27

(continued)

APPENDIX B-1. (Continued)

Test	Treatment	96 Hours No. Dead - No. Start[2]	168 Hours No. Dead - No. Start	End Weight (µg) $\overline{X}$	End Weight (µg) SD
8	Control	7-41	21-40	62	16
	6.25%	2-40	2-40	68	7
	12.5%	1-41	2-41	65	10
	25%	1-41	1-41	72	6
	50%	0-40	0-40	72	10
	100%	9-40	10-40	86	11
	018	4-42	8-42	79	7
	014	0-41	2-40	68	10
	013	2-41	2-39	85	10
9[6]	Control	4-40	7-40	46	9
	6.25%	4-41	10-41	54	32
	12.5%	0-41	1-41	59	7
	25%	0-40	0-40	63	10
	50%	3-41	3-41	64	3
	100%	15-40	15-40	77	16
	018	4-41	21-38	65	6
	014	4-42	15-39	69	21
	013	0-40	0-40	55	4

Notes:

1 One injured larvae may have produced a fungus outbreak in controls for test 0.

2 No. Start equals the number of larvae originally used minus losses due to screen entrapment, handling injury, overlooked larvae vacuumed during cleaning, original miscount or other reasons.

3 Only 20 P. promelas could be acquired for each dilution for test 2.

4 Weights were not determined for tests 3, 4, and 5. These fish were sent to Dr. Kenneth Jenkins, California State University, Long Beach for enzyme analysis.

5 Reconstituted control (Rec) water hardness was 80-90 µg/l $CaCO_3$.

6 A larval fathead growth experiment, run parallel to test 9, but only for six days resulted in mean weights of 34, 69 and 143 µg for fish fed nothing, standard test diet, and four times the quantity of the standard test diets, respectively.

APPENDIX B-2. RANGE OF WATER QUALITY PARAMETERS MEASURED FROM *P. PROMELAS* TOXICITY TESTS.

Test	Treatment	Temperature	Dissolved Oxygen	pH	Conductivity	Alkalinity
0	Control	22-26	5.8-8.5	7.4-7.4	154-179	47
	6.25%	22-25	6.0-8.8	7.3-7.4	170-181	-
	12.5%	23-25	5.9-8.7	7.3	191-199	-
	25%	23-26	5.9-8.7	7.2-7.4	226-241	-
	50%	23-26	5.9-8.6	7.3-7.9	301-309	-
	100%	23	8.5	7.4	421	69
	018	22-25	6.0-8.7	7.4-7.4	257-282	80
	014	22-25	6.0-8.7	7.3-7.4	221-241	48
	013	22-26	6.1-8.8	7.0-7.4	226-241	51
1	Control	22-26	6.3-7.1	7.0-7.8	154-160	48
	6.25%	23-25	6.0-7.7	7.0-7.1	173-178	-
	12.5%	23-25	6.3-7.9	7.0-7.8	194-195	47
	25%	23-25	6.2-6.7	7.0-7.7	249-249	-
	50%	23-25	6.8-8.2	7.0	287-314	57
	100%	25-25	6.5-7.5	7.1	-	-
	018	24-26	5.9-8.6	7.2-7.4	260-276	73
	014	24-25	5.9-8.2	7.2-7.6	239	58
	013	24-26	6.0-8.5	7.1-7.7	230-239	52
2	Control	24-27	5.9-8.6	7.2-7.6	135-156	45
	6.25%	24-26	6.3-7.7	7.2-7.5	169-175	-
	12.5%	23-25	6.1-8.7	7.2-7.4	195-201	49
	25%	23-25	6.2-8.4	7.2-7.4	228-243	-
	50%	23-26	6.0-9.0	7.2-7.4	276-308	63
	100%	23-25	6.2-7.7	7.2-7.4	430-471	61
	018	22-25	6.3-8.0	7.2-7.7	254-298	70-78
	014	23-26	6.0-8.2	7.2-7.7	217-228	50
	013	23-26	5.9-6.8	7.2-7.7	206-238	53
3	Control	22-25	6.5-7.9	7.3-7.4	151-156	-
	6.25%	23-25	6.1-7.3	7.3-7.4	170-173	-
	12.5%	23-25	6.3-7.8	7.3-7.4	191-195	-
	25%	23-24	6.2-7.2	7.2-7.3	228-233	-
	50%	23-24	6.2-7.9	7.1-7.4	287-300	-
	100%	24	7.2	-	-	-
	018	23-25	6.1-7.4	7.3-7.5	255-265	-
	014	22-26	6.1-8.0	7.4-7.5	217-227	-
	013	23-25	6.4-8.3	7.4-7.5	205-235	-

(continued)

APPENDIX B-2. Continued

Test	Treatment	Temperature	Dissolved Oxygen	pH	Conductivity	Alkalinity
4	Control	21-24	6.5-7.7	7.2-7.5	144-155	47
	6.25%	22-24	6.5-7.8	7.2-7.6	163-173	-
	12.5%	21-23	6.9-7.7	7.2-7.4	194-210	-
	25%	21-24	6.2-7.8	7.1-7.4	218-280	-
	50%	21-24	6.5-7.1	7.1-7.3	280-308	-
	100%	21-24	6.9-7.2	7.0-7.4	431-442	70
	018	21-25	6.1-7.8	7.3-7.4	255-276	-
	014	20-24	6.3-7.8	7.3-7.4	226-240	-
	013	21-24	6.7-7.6	7.3-7.4	226-238	-
5	Control	21-24	6.2-7.4	7.2-7.4	149-158	40
	6.25%	22-25	6.2-7.4	7.1-7.4	162-176	-
	12.5%	21-23	6.4-7.4	7.0-7.4	184-195	-
	25%	22-24	6.2-7.2	7.0-7.5	228-233	-
	50%	21-23	6.5-7.7	7.0-7.4	270-304	64
	100%	-	7.7	-	431	-
	018	21-24	6.0-7.8	7.2-7.6	254-222	59
	014	22-24	6.3-7.8	7.2-7.6	222-238	-
	013	21-25	6.5-8.0	7.1-7.5	219-234	-
6	Rec Control[1]	22-25	5.8-6.6	7.1-7.5	330-367	69
	Control	22-25	6.3-7.8	7.2-7.8	120-155	47
	6.25%	22-22	6.8-6.9	7.0-7.6	166-177	-
	12.5%	22-24	6.3-7.9	7.0-7.9	188-199	-
	25%	22-23	6.7-7.8	7.0-7.7	221-230	47
	50%	23-23	6.6-8.2	7.0-7.5	280-294	-
	100%	23-24	6.3-8.3	7.1-7.5	395-430	69
	018	22-24	6.3-8.1	7.2-7.5	248-276	80
	014	22-24	6.6-7.8	7.1-7.5	223-234	-
	013	21-24	6.2-8.0	7.0-7.6	227-244	59
7	Rec Control	22-25	5.9-7.0	7.2-7.6	360-446	90
	Control	22-25	6.0-8.5	7.2-7.6	141-161	45
	6.25%	23-25	5.9-7.7	7.4-7.7	177-190	-
	12.5%	22-24	6.4-7.5	7.3-7.7	185-206	-
	25%	22-24	6.5-8.2	7.3-7.7	223-229	38
	50%	23-25	6.2-7.7	7.3-7.5	287-308	-
	100%	22-24	6.3-7.6	7.2-7.5	420-452	85
	018	22-24	6.4-7.5	7.3-7.6	225-282	-
	014	23-23	6.4-7.5	7.4-7.7	220-236	56
	013	22-24	6.3-7.8	7.3-7.6	231-254	-

(continued)

APPENDIX B-2. Continued

Test	Treatment	Temperature	Dissolved Oxygen	pH	Conductivity	Alkalinity
8	Control	23-25	6.2-7.8	7.2-7.4	151-163	52
	6.25%	23-25	6.3-7.9	7.2-7.7	168-177	-
	12.5%	23-25	6.1-7.9	7.2-7.5	190-195	-
	25%	23-25	6.4-8.0	7.3-7.5	217-239	-
	50%	24-25	6.1-8.1	7.0-7.4	297-323	60
	100%	23-25	6.4-8.0	7.0-7.3	407-431	70
	018	23-24	6.2-8.0	7.1-7.5	277-287	-
	014	22-25	6.2-8.0	7.1-7.5	234-244	54
	013	22-25	6.3-8.1	7.1-7.4	227-241	-
9[2]	Control	19-24	6.4-8.9	7.2-7.8	154-164	45-49
	6.25%	19-24	7.4-8.9	7.2-7.9	170-181	-
	12.5%	19-25	6.4-8.9	7.2-7.8	180-198	-
	25%	19-24	6.1-8.9	7.2-7.7	227-235	-
	50%	19-25	6.2-8.8	7.1-7.7	292-303	-
	100%	19-24	6.4-8.7	7.1-7.6	423-443	69-69
	018	19-24	6.6-8.8	7.2-7.7	260-276	84
	014	19-24	6.4-8.7	7.1-7.7	233-238	-
	013	19-25	6.1-8.5	7.2-7.7	229-242	-

Note 1. Reconstituted water, 80-90 µg/l $CaCO_3$.

Note 2. All temperatures ranged 23-25°C, except during last 24 hours.

APPENDIX C. WATER AND SEDIMENT METAL DATA

APPENDIX C-1. TOTAL RECOVERABLE (T.R.) AND DISSOLVED (DIS) METAL CONCENTRATIONS (µg/l)
PRICKLY PEAR CREEK STATION 011, SEPTEMBER 30 THROUGH OCTOBER 9, 1983

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
09-30-83	11	2.5	0.1	13.4*	17.2	183	69	14.5*	34.8	<.2*	2.0	1.9	<1.0
	12												
	13												
10-01-83	39	3.2	0.5	6.1*	7.3	100	27	<6.0*	23.1	0.2*	0.3	<1.0*	3.3
	40	1.8	1.2	7.0	7.0	87	11	6.1*	19.1	<.2*	0.2	<1.0*	2.5
	41	3.9	0.6	7.8*	50.8	56*	58	<6.0*	40.7	<.2*	8.2	<1.0	1.7
10-02-83	84	1.6	0.5	13.6	2.6	106	34	<6.0	<6.0	<.2	<.2	2.3	1.0
	85	1.4	0.2	8.4	1.6	127	30	<6.0	<6.0	<.2	<.2	2.7	1.6
	86	1.3*	2.0	7.4	3.3	114	29	8.0	<6.0	0.2	<.2	1.3*	1.5
10-03-83	135	1.1*	7.2	37.6*	89.0	80*	222	20.8*	176.0	0.9	<.2	1.4	<1.0
	136	1.7	0.2	5.9	0.7	33	24	7.0*	11.1	<.2	<.2	<1.0	<1.0
	137	0.4	0.4	5.7*	12.4	65	36	12.0*	31.7	<.2*	0.3	<1.0	<1.0
10-04-83	199	2.1	2.0	19.0	<1.0	77	46	13.0	<6.0	0.7	<.2	<1.0	<1.0
	200												
	201												
10-05-83	214	1.1*	2.6	17.8	<1.0	110	48	<6.0*	6.1	1.9	<.2	2.7	1.2
	215	1.0		7.6		54		<6.0		0.4		<1.0	
	216	1.1		15.4		49		7.6		0.3			
10-06-83	241	1.9	0.2	22.3	<1.0	70	45	8.8	<6.0	<.2	<.2	<1.0	<1.0
	242												
	243												

(continued)

APPENDIX C-1. (Continued)

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
10-07-83	299 300 301	1.5*	4.4	10.1	<1.0	160	96	13.1	<6	0.4	<.2	11.0	7.1
10-08-83	350 351 352	5.1*	5.8	8.3	4.5	113	27	20	<6	<.2*	0.2	<1.0*	1.1
10-09-83	404	0.6*	9.3	8.9	1.7	75	24	<6	<6	0.3	<.2	1.6*	1.7
	305	2.3	2.0	4.3	3.3	66	36	16	<6	<.2	<.2	1.0	1.0
	306	0.6*	12.5	2.3*	3.3	44	37	<6	<6	<.2	<.2	1.0	<1.0

*Data were not used because total recoverable concentration was less than dissolved concentration.

APPENDIX C-2. TOTAL RECOVERABLE (T.R.) AND DISSOLVED (DIS) METAL CONCENTRATIONS (µg/l)
SPRING CREEK, SEPTEMBER 30 THROUGH OCTOBER 9, 1983

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
09-30-83	26	7.6	5.2	48.1	6	2590	1880	91.3	23.6	2.3	0.2	20.4	3.2
	27												
	28												
10-01-83	66	8.1	5.9		66.7		2480	220.0	60.6	1.9	0.2	86.7	5.3
	67	8.8	7.5	236.2	23.4	3600	3000	224.0	96.0		0.1		2.7
	68	8.8	8.1	243.2	45.2	3650	3170		119.0	2.4	0.1	81.6	4.5
10-02-83	99		4.7	29.1	9.0	1760	1470	66.8	26.4		<.2		4.5
	100	5.4	4.6	50.2	6.0	1820	1490	85.3	25.4	0.5	0.2	13.5	3.6
	101	7.1	5.0	38.3	14.0	1850	1480	55.4	33.6	0.8	0.2	15.7	2.2
10-03-83	162	8.5	5.6	16.2	2.1	2010	1690	66.4	8.0	0.4	<.2	18.4	3.2
	163												
	164												
10-04-83	184	8.3	3.9	106.9	2.0	1770		59.4	<6.0	1.4	<.2	26.7	1.8
	185	4.3		88.7	8.6	1527	1183	51.6	19.4	0.7	<.2		
	186	4.2		100.7	7.0	1626	1107	57.0	14.7	0.7	<.2		
10-05-83	229	10.8	3.0	118.5	<1.0	2750	1280	126.0	<6.0	6.8	<.2	37.5	1.6
	230	15.0		128.1		2561		114.8		1.7			
	231	9.6		120.3		2613		111.8		1.7			
10-06-83	256	13.0	3.9	29.4	1.8	1560	1510	51.1	15.1	1.0	<.2	13.4	3.8
	257	7.5	3.7	33.8	3.6	1708	1111	58	18.9	0.3	<.2	14.6	2.2
	258	5.1	5.3	30.0	4.0	1732	1096	57	13.1	0.3	<.2	13.9	1.5

(continued)

APPENDIX C-2. (Continued)

Date	Sample No.	Cadmium		Lead		Zinc		Copper		Silver		Arsenic	
		T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.
10-07-83	314 315 316	4.0	7.8	23.4	2.1	1260	1030	37.0	<6.0	1.0	<.2	12.2	2.3
10-08-83	365 366 367	6.2	4.9	37.4	5.0	1940	1200	61.8	<6.0	0.1	<.2	22.0	2.8
10-09-83	419	9.0	7.6	58.6	12.3	1990	1680	69.3	28.2	1.0	<.2	17.0	4.8
	420	5.6*	8.4	41.9	6.7	2068	1164	64	23.8	0.6	<.2	16.4	2.7
	421	5.0*	5.5	40.9	10.7	2020	1066	70	27.2	0.5	<.2	15.6	3.7

APPENDIX C-3. TOTAL RECOVERABLE (T.R.) AND DISSOLVED (DIS) METAL CONCENTRATIONS (µg/l)
PRICKLY PEAR CREEK STATION 013, SEPTEMBER 30 THROUGH OCTOBER 9, 1983

Date	Sample No.	Cadmium		Lead		Zinc		Copper		Silver		Arsenic	
		T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.
09-30-83	29 30 31	4.0	1.6	29.6	2.7	672	443	24.4	7.6	.4	<.2	8.3	0.7
10-01-83	57	3.7	2.2	28.7	4.6	677	481	23.5	12.6	.2	<.2	5.5	<1.0
	58	4.4	2.6	20.7	3.9	659	503	19.0	15.7	.2	<.2	5.8	2.5
	59	3.2	1.9	23.5	17.0	633	528	19.4*	44.5	<.2*	0.4	6.6	1.5
10-02-83	108	2.3	1.7	48.4	5.3	683	426	65.0	9.5	0.9	<.2	10.7	1.6
	109	3.1	1.8	40.2	5.5	592	443	33.4	11.6	0.4	<.2	10.6	1.0
	110	2.0	1.7	44.8	7.4	670	430	42.3	10.1	0.4	<.2	10.0	1.4
10-03-83	153 154 155	1.8	1.5	54.4	<1.0	531	378	27.2	6.8	0.7	<.2	5.8	1.3
10-04-83	202 203 204	5.9	1.6	31.0	<1.0	565	371	29.7	<6.0	0.8	<.2	6.4	1.7
10-05-83	238	3.3	1.3	41.3	4.0	641	402	32.2	<6.0	<.2*	0.2	7.4	1.5
	239	3.2		29.9		632		27.0		1.1			
	240	19.8		30.6		641		34.0		1.4			
10-06-83	262 263 264	9.4	1.5	23.2	7.2	517	375	39.6	<6.0	11.2	<.2	7.1	2.4

(continued)

APPENDIX C-3. (Continued)

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
10-07-83	323 324 325	3.9	1.5	20.0	8.0	567	361	22.5	<6.0	<.2	<.2	3.7	2.4
10-08-83	368 369 370	4.1	2.7	21.0	2.4	531	397	21.4	<6.0	<.2	<.2	5.4	2.0
10-09-83	422 423 424	7.6	5.6	11.7	1.3	481	390	12.0	<6.0	<.2	<.2	3.2	2.3

APPENDIX C-4. TOTAL RECOVERABLE (T.R.) AND DISSOLVED (DIS) METAL CONCENTRATIONS (µg/l)
PRICKLY PEAR CREEK STATION 014, SEPTEMBER 30 THROUGH OCTOBER 9, 1983

Date	Sample No.	Cadmium		Lead		Zinc		Copper		Silver		Arsenic	
		T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.
09-30-83	32	1.8*	2.4	10.7	5.4	341	266	11.4*	19.1	.3	.2	3.3	1.9
	33												
	34												
10-01-83	60	11.0	1.2	27.1*	43.2	383	286	33.1*	96.8	0.6*	3.9	4.2	1.5
	61	1.7*	28.0	12.8*	33.3	363*	393	10.5*	73.3	<.2*	3.5	4.4	2.6
	62	1.3	1.0	11.4	6.0	370	274	11.4*	25.2	<.2*	0.2	9.4	2.9
10-02-83	105	1.2	0.8	19.7	<1.0	356	251	12.2	<6.0	<.2	<.2	3.7	1.3
	106	1.2	0.8	41.7	<1.0	349	239	11.2	<6.0	0.2	<.2	4.0	1.1
	107	1.2*	4.9	12.4	1.7		253	13.8	6.8	<.2	<.2	2.7	1.1
10-03-83	156	1.1	0.9	22.9	<1.0	261	202	22.1	6.7	0.3	<.2	3.3	2.1
	157												
	158												
10-04-83	205	1.4	1.3	22.5	<1.0	301	218	17.5	<6.0	0.3	<.2	4.2	2.3
	206												
	207												
10-05-83	235	11.8	1.2	31.3	4.4	358	258	8.6	<6.0	0.3	0.2	3.6	1.9
	236	1.8		14.2		354		8.0		0.6			
	237	1.5		12.3		309		6.0		0.6			
10-06-83	265	4.9	2.1	26.5	6.4	315	249	14.5	<6.0	0.5	<.2	7.0	3.3
	266												
	267												

(continued)

APPENDIX C-4. (Continued)

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
10-07-83	320	4.2	3.4	11.5	6.0	347	262	14.6	<6.0	<.2	<.2	4.4	2.3
	321												
	322												
10-08-83	371	9.5	7.4	14.9	3.6	341	253	15.8	<6.0	<.2	<.2	4.0	2.0
	372												
	737												
10-09-83	425	3.2*	3.6	11.4	1.2	298	235	<6.0	<6.0	0.2	<.2	2.6*	2.8
	426												
	427												

APPENDIX C-5. TOTAL RECOVERABLE (T.R.) AND DISSOLVED (DIS) METAL CONCENTRATIONS (µg/l)
PRICKLY PEAR CREEK STATION 018, SEPTEMBER 30 THROUGH OCTOBER 9, 1983

Date	Sample No.	Cadmium T.R.	Cadmium DIS.	Lead T.R.	Lead DIS.	Zinc T.R.	Zinc DIS.	Copper T.R.	Copper DIS.	Silver T.R.	Silver DIS.	Arsenic T.R.	Arsenic DIS.
09-30-83	35	1.9	0.8	4.9*	37.1	177	159	<6.0*	127	0.2*	1.7	7.4*	3.0
	36												
	37												
10-01-83	63	2.5	0.6	13.1*	40.0	197	147	7.5	6.0	<.2*	2.3	9.3	1.1
	64	1.7	0.5	8.1	<1.0	204	135	8.8*	103.0	<.2	<.2	8.8	6.6
	65	1.3*	2.4	13.4*	14.8	299	169	21.4*	88.8	<.2*	0.6	9.3	6.1
10-02-83	102	8.2	1.1	25.2	2.4	207	130	9.8	<6.0	<.2	<.2	9.0	<1.0
	103	3.5	0.7	35.7	1.7	205	133	7.8	<6.0	<.2	<.2	10.0	<1.0
	104	2.0	2.0	23.1	4.4	229	128	26.8	<6.0	1.3	<.2	8.6	6.5
10-03-83	159	1.4*	2.0	16.3	<1.0	193	129	15.4	6.7	<.2	<.2	9.4	6.0
	160												
	161												
10-04-83	208	8.7	0.5	11.6	<1.0	187	98	13.9	<6.0	0.2	<.2	10.3	6.2
	209												
	210												
10-05-83	232	1.7	1.4	11.2	8.0	192	122	14.7	<6.0	0.3	0.2	10.0	6.8
	233	1.7		12.6		157		7		0.3			
	234	2.1		11.7		158		11		0.7			
10-06-83	368	1.6	1.1	9.6	<1.0	187	149	10.2	<6.0	<.2	<.2	11.9	6.9
	369												
	270												

(continued)

APPENDIX C-5. (Continued)

		Cadmium		Lead		Zinc		Copper		Silver		Arsenic	
Date	Sample No.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.	T.R.	DIS.
10-07-83	317 318 319	3.1	1.4	14.8	4.6	215	144	12.7	<6.0	0.2	<.2	11.0	6.7
10-08-83	374 375 376	2.8	1.5	13.5	1.8	232	122	11.1	<6.0	0.2	<.2	8.7	6.2
10-09-83	428 429 430	3.9	2.4	15.7	4.6	226	128	9.5	<6.0	0.2	<.2	7.8	6.5

APPENDIX C-6. REPLICATE SEDIMENT METAL CONCENTRATIONS IN SPRING CREEK AND PRICKLY PEAR CREEK, MONTANA, SEPTEMBER 27-29, 1983

	Sediment Metal concentration mg/kg				
Station	Cadmium	Lead	Zinc	Copper	Silver
001	3	110	380	100	1
	3	145	550	145	1
	4	150	575	155	2
Spring Creek	31	4020	4965	1110	47
	27	3315	4985	1145	22
	30	3500	4975	1170	40
013	28	3010	4940	970	32
	31	3470	4935	1000	35
	30	3240	4935	930	35
014	14	1220	2890	380	11
	14	1220	2770	360	12
	14	1290	2635	375	13
018	9	655	1950	200	6
	9	700	1620	215	7
	8	650	1470	190	6

APPENDIX D. HYDROLOGICAL DATA

APPENDIX D-1. STREAM STAGE HEIGHT AT PRICKLY PEAR CREEK STATIONS 011, 1983

Date	Time	Gage Height (cm)	Date	Time	Gage Height (cm)
09-21-83	1600	21.0	10-01-83	0840	20.5
09-22-83	1030	21.0	10-01-83	2000	20.5
09-22-83	1400	23.0	10-02-83	0830	21.0
09-22-83	2400	23.0	10-02-83	1600	21.0
09-23-83	0400	22.0	10-03-83	0745	21.0
09-23-83	0700	22.0	10-03-83	1430	20.0
09-23-83	1200	21.0	10-04-83	1600	20.0
09-23-83	1800	21.5	10-05-83	0830	20.0
09-23-83	2200	21.5	10-05-83	1300	20.0
09-24-83	1230	21.5	10-05-83	2100	20.0
09-25-83	0800	21.0	10-06-83	0800	20.0
09-25-83	2000	21.0	10-06-83	1900	20.0
09-26-83	1100	21.0	10-07-83	0815	20.0
09-26-83	2000	21.0	10-08-83	0745	20.5
09-27-83	1200	21.0	10-09-83	0830	20.0
09-27-83	1600	21.0	10-10-83	0820	20.0
09-28-83	0900	21.0	10-11-83	0820	19.5
09-28-83	1600	21.0	10-12-83	0800	19.5
09-29-83	0830	20.5	10-13-83	0930	19.5
09-30-83	1100	21.0	10-14-83	1000	20.5
			10-15-83	0800	21.0

APPENDIX D-2. STREAM STAGE HEIGHT AT SPRING CREEK STATION, 1983

Date	Time	Gage Height (cm)	Date	Time	Gage Height (cm)
09-21-83	1300	11.0	10-01-83	0840	11.0
09-21-83	1630	10.5	10-01-83	2000	11.0
09-22-83	1000	10.5	10-02-83	0800	11.0
09-22-83	1400	10.5	10-02-83	1600	11.0
09-22-83	2400	10.5	10-03-83	0745	11.0
09-23-83	0400	10.5	10-03-83	1430	11.0
09-23-83	0700	10.5	10-04-83	0745	11.0
09-23-83	1200	10.5	10-04-83	1400	10.5
09-23-83	1800	10.0	10-04-83	1700	10.5
09-24-83	1230	10.5	10-05-83	0745	11.0
09-25-83	0800	10.5	10-05-83	2100	11.0
09-25-83	2000	10.5	10-06-83	0745	11.0
09-26-83	1100	10.5	10-06-83	1900	10.5
09-26-83	2000	10.5	10-07-83	0745	11.0
09-27-83	1200	11.0	10-08-83	0830	10.5
09-27-83	1600	11.0	10-09-83	0830	11.0
09-28-83	0900	11.0	10-10-83	0800	10.5
09-28-83	1600	11.0	10-11-83	0800	10.5
09-29-83	0830	11.0	10-12-83	0730	10.5
09-29-83	1930	11.5	10-13-83	1100	12.5
09-30-83	0730	12.0	10-14-83	1000	11.0
09-30-83	1100	11.0	10-15-83	0745	11.0

APPENDIX D-3. STREAM STAGE HEIGHT AT PRICKLY PEAR CREEK 5m DOWNSTREAM FROM THE SPRING CREEK CONFLUENCE

Date	Time	Gage Height (cm)	Date	Time	Gage Height (cm)
09-21-83	1300	37.0	10-01-83	0840	36.0
09-21-83	1630	37.0	10-01-83	2000	36.0
09-22-83	1000	37.0	10-02-83	0830	36.0
09-22-83	1400	37.0	10-02-83	1600	36.0
09-22-83	2400	37.5	10-03-83	0745	36.0
09-23-83	0400	38.5	10-03-83	1430	35.5
09-23-83	0700	38.0	10-04-83	1600	35.0
09-23-83	1200	37.0	10-05-83	0800	35.0
09-23-83	1800	37.0	10-05-83	2100	35.0
09-23-83	2200	37.5	10-06-83	1430	37.0
09-24-83	1230	37.0	10-06-83	1900	37.0
09-25-83	0830	37.0	10-07-83	0830	37.0
09-25-83	2000	37.0	10-08-83	0845	37.0
09-26-83	1100	37.0	10-09-83	0800	37.0
09-26-83	2000	37.0	10-10-83	0810	38.5
09-27-83	1200	37.0	10-11-83	1000	37.0
09-27-83	1600	37.0	10-12-83	1100	37.0
09-28-83	0900	37.0	10-13-83	1100	37.0
09-28-83	1600	37.0	10-14-83	1000	39.0
09-29-83	0830	36.0	10-15-83	0830	40.0
09-30-83	1100	36.0			