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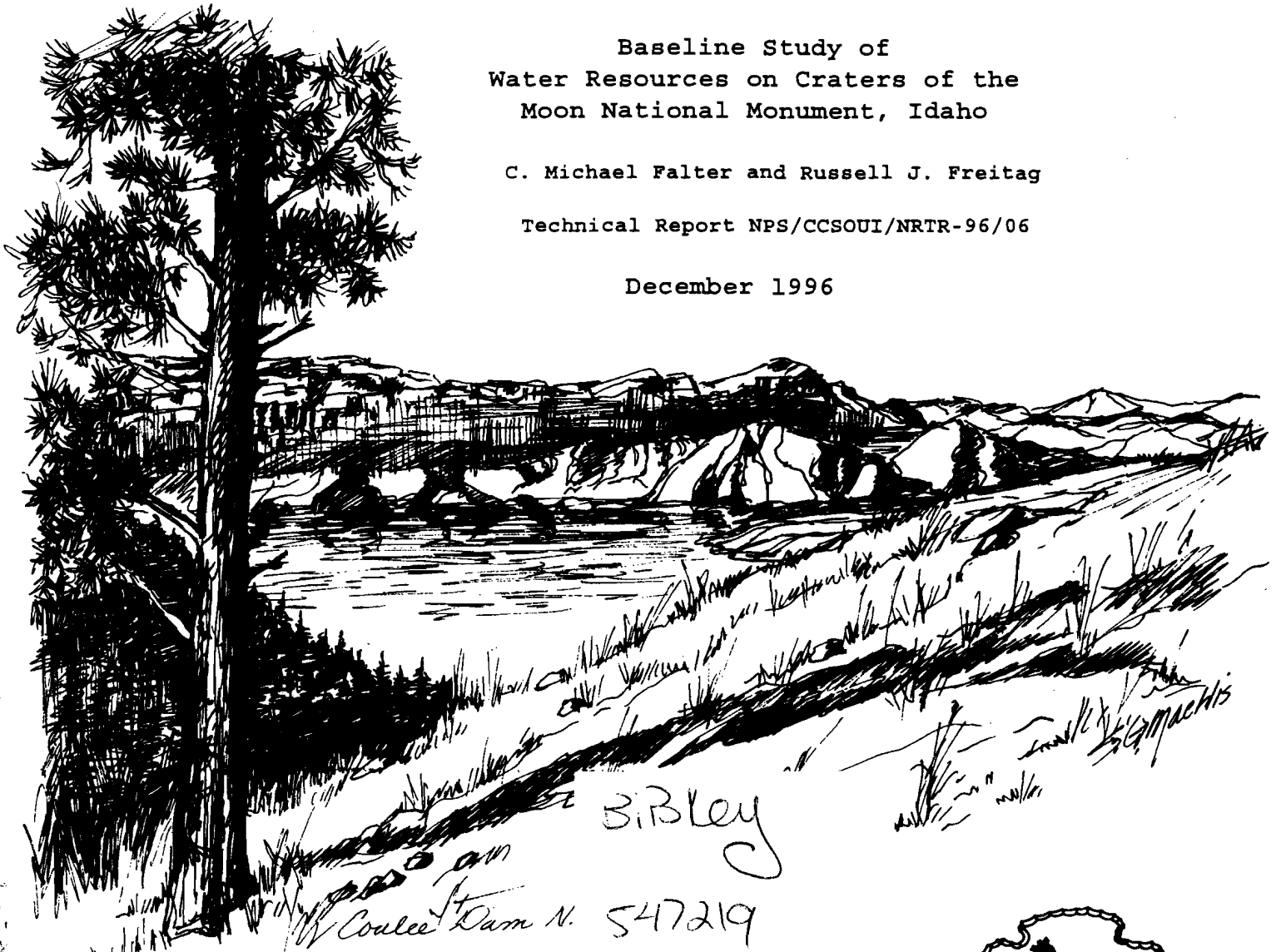
UNIVERSITY OF IDAHO

Baseline Study of Water Resources on Craters of the Moon National Monument, Idaho

C. Michael Falter and Russell J. Freitag

Technical Report NPS/CCSOUI/NRTR-96/06

December 1996



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College of Forestry,
Wildlife and Range Sciences
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ABSTRACT

In the summer - fall of 1992 and 1993, the University of Idaho conducted an assessment of surface aquatic resources on the Craters of the Moon National Monument in south-central Idaho. The study covered Leech and Little Cottonwood Creeks on the north end of the Monument and Big Cottonwood Creek outside of the Monument's northwestern boundary.

Stream water quality was high, with no obvious violations of Idaho State Standards of temperature, dissolved oxygen (indicating low external organic loading), and turbidity. Total dissolved solids content of the water as indicated by electrical conductivity was moderate to low. Stream waters are carbonate-based, of moderately low alkalinity and CO_2 , and neutral to slightly basic pH. Stream water nutrient concentrations of total phosphorus were moderately high with nitrogen limitation indicated. Stream water concentrations of $\text{NH}_3\text{-N}$ are high. High quality streambanks suggests wildlife use of riparian zones, not cattle, as the source of this $\text{NH}_3\text{-N}$. Low to moderate levels of Fecal Coliform with high Fecal Streptococcus bacteria in streams suggests animal (cattle and/or wildlife influence), rather than human influence to the streams. Attached algae production in the streams was moderately high. Stream insect associations are balanced with the exception of the middle reach of Little Cottonwood Creek where Dipteran dominance suggests metals impacts from Martin Mine although chemical measurements of heavy metals were not unusually high. Streambank and channel stability is good with little indication of eroding or collapsing banks. Cave water quality is relatively enriched with the melt water of some caves showing effects of human visitation and contamination. Cave water and water for cave ice formation seems to be from surface, rather than underground sources.

INTRODUCTION

Craters of the Moon National Monument was created in central Idaho in 1924 by President Coolidge (Sterns 1928). The 217 km² expanse of the Craters of the Moon National Monument is situated at the northern edge of the Snake River Plain and on the southern edge of the Pioneer Mountains in south central Idaho (Figure 1). The site is 30 km southwest of Arco, Idaho. Since most of the Monument is geologically recent (*i.e.* < 4,000 years) and consisting of lava flows, cinder cones, and pumice fields, nearly 60% of the area is devoid of soil and therefore, of significant plant cover. Approximately 30% of the site is vegetated with sagebrush-dominated communities (Blakesley and Wright 1988).

Water resources in the Monument are scarce, being concentrated in the short stream valleys of Leech Creek and Little Cottonwood Creek near the northwestern corner of the Monument. Other surface waters on the Monument are in the form of a few isolated water holes or as ice and melt water in perennial cave ices.

Livestock grazed the Craters of the Moon before its establishment as a National Monument. Since lands fell under the jurisdiction of National Park Service, grazing has been restricted, but continuing sporadic grazing has undoubtedly still occurred from trespassing livestock (Blakesley and Wright 1988). Since grazing is restricted on the Monument, Leech and Little Cottonwood Creeks, representative of relatively ungrazed conditions, will be compared to Big Cottonwood Creek adjacent to, but off and northwest of the Monument.

Approximately 6 miles to the northwest of the Monument lies the drainage of Big Cottonwood Creek, managed by the Bureau of Land Management and actively grazed. Big Cottonwood Creek will serve as our comparison site when comparing grazed and lightly-grazed streams.

All three streams are very similar in geology consisting of sagebrush-covered hillsides in short stream valleys of sand- and clay-type surface soils. Little Cottonwood Creek ranges from 5,960 ft to 6,900 ft in elevation while Big Cottonwood Creek is slightly higher in elevation ranging from 5,880 ft to 7,200 ft. Big Cottonwood and Little Cottonwood Creeks have both had deep shaft mining activity in their drainages. The mining activity in the area was associated with the silver boom in south-central Idaho from 1880 to 1902 (Blakesley and Wright 1988).

The Martin Mine located on Little Cottonwood Creek transferred ownership to the Monument in 1963 and most of the structures associated with the mine have since been removed. The Paymaster mine located on Big Cottonwood Creek still has some outbuildings in place and is closer to operational mining status.

In June 1992, the University of Idaho was commissioned by the National Park Service to conduct a survey of aquatic resources as a baseline data set for future evaluation of water resources on the Craters of the Moon National Monument.

PROJECT OBJECTIVES

1. Develop a baseline of stream water and cave ice quantity and quality in 1992 and 1993;
2. Provide a baseline description of biological resources of surface waters on the Monument, including a) attached benthic algae, b) aquatic insects, and c) riparian and stream channel analysis; and,
3. To establish a monitoring system for water and ice quality and quantity to be implemented in the future by NPS personnel.

MATERIALS AND METHODS

Leech, Little Cottonwood, and Big Cottonwood Creeks were surveyed for a range of water quality parameters. Each creek was surveyed monthly from May-October in 1992 and 1993 at stations established on upper, mid, and lower reaches of each stream. At low flows, lower sites on Leech and Little Cottonwood Creeks were dry.

Water quality samples were split into two groups; those that could be obtained in the field with the use of meters or field chemistry kits, and those to be frozen for further analysis at the University of Idaho Analytical Lab.

Study Stations

Leech Creek -- Upper Site:

Immediately downstream of the Monument's upper boundary on Leech Creek at an elevation of 6,420 ft.

Leech Creek -- Lower Site:

South of and adjacent to the research camp at an elevation of 6,000 ft.

Little Cottonwood Creek -- Upper Site:

On the upstream side of the culvert that Little Cottonwood Creek passes through. This site has a V-notch flow box installed in the creek and is at an elevation of 6,720 ft.

Little Cottonwood Creek -- Below Martin Mine:

This station is located on the east side of the road and is located downstream of the Martin Mine. It is at an elevation of 6,220 ft.

Little Cottonwood Creek -- Lower Site:

This station is located in the large meadow at the bottom of the drainage and is located just upstream of the well sites. It is at an elevation of 6,040 ft.

Big Cottonwood Creek -- Below Paymaster Mine:

Below the mixing zone from tailings drainage into BCC at an elevation of 6,840 ft.

Big Cottonwood Creek -- Upper Site:

Immediately below the road that leads to the Paymaster Mine at an elevation of 6,640 ft.

Big Cottonwood Creek -- Lower Site:

Upstream of road bridge over BCC at an elevation of 6,010 ft.

Field Analyses

All chemical measurements were conducted according to Standard Methods for the Analysis of Water and Wastewater (APHA 1991). Temperature and dissolved oxygen were determined at each site with a YSI Model 57 Temperature-Dissolved Oxygen Meter. Temperatures were recorded as temperature in °C. The meter was calibrated at each site for 100% saturation as a function of temperature and altitude. The results were reported in mg/l dissolved oxygen.

Electrical conductivity was measured with a YSI Salinity-Conductivity-Temperature Meter. This meter was calibrated daily. Results were reported as μmhos (microsiemens or micromhos)/ cm^2

Measurements of pH were determined with a Orion pH meter calibrated daily against pH 7, pH 10, and pH 4 buffer solutions. The results were reported as pH units on a standardized scale of 1 - 14.

Turbidity of the water was determined with a Hach 2100-A Turbidity meter calibrated daily with the use of Hach standards and reported as NTU's (Nephelometric Turbidity Units).

Alkalinity and Carbon Dioxide (CO_2) both determined by titration (APHA 1991). Alkalinity was determined with a 0.02N sulfuric acid solution and methyl orange indicator and reported as mg/l CaCO_3 . Carbon dioxide was determined with 0.02N sodium hydroxide and phenolphthalein indicator and reported as mg/l CO_2 .

Flow was determined with the use of a Marsh-McBirney solid state velocity meter in conjunction with depth and width measurements to determine water discharge as cubic feet per second.

Laboratory Analyses

All samples taken back to the University of Idaho Analytical lab were collected in triplicate in one-liter acid-washed polyethylene bottles. Each bottle was labeled and fixed with the 2 ml sulfuric acid to prevent decomposition of the sample and frozen within 12 hours of collection. The only samples not fixed with sulfuric acid were soluble reactive phosphorus which were filtered through 0.45 μ membrane filters and frozen within 4 hours of collection. Total phosphorus and soluble reactive phosphorus were determined using the Stannous Chloride method (APHA 1991). A colorimetric method where molybdophosphoric acid is reduced by stannous chloride to a brilliant blue color and reported as mg/l TP or SRP.

Ammonia Nitrogen was determined by the colorimetric process of Nesslerization (APHA 1991) and reported as mg/l NH₃-N. Nitrate Nitrogen was determined with the ultraviolet spectrophotometric screening method which utilized wavelengths of 220 nm and 275 nm to determine mg/l NO₃-N (APHA 1991). Organic Nitrogen was determined using the Kjeldahl method (APHA 1991).

Samples analyzed for metal concentration were sent to the University of Idaho Analytical Laboratory for metals determination by atomic absorption analysis. The lab followed the guidelines of (APHA 1991). Results are reported as mg/l of the specific metal. Metals tested were arsenic, cadmium, copper, lead, molybdenum, silver, and zinc. There were two types of metals tests performed by the lab. First, a metal screening test was performed to determine the concentrations of several different types of metals and second, a separate test was performed to determine concentrations of lead and arsenic. Results for the metal screening test are reported as ppm (parts per million) and lead and arsenic values are reported as ppb (parts per billion).

Biological Resources

Attached Benthic Algae: Five replicated samples of periphyton growth on natural rock substrate were scraped off the rocks with a stiff brush, filtered through GFC filters on site, and frozen for chlorophyll *a* and ABA biomass analysis at the UI Limnology Laboratory (APHA 1991). Results are reported as mg chlorophyll *a*/m² of substrate.

Benthic Macroinvertebrates (aquatic insects): Five replicated one-ft² samples of stream substrate and benthic macroinvertebrates were taken for determination of

macroinvertebrate density, species composition, and community diversity. Samples were taken at times of high and low flow at each stream site and distributed randomly within the stream channel at each site for a representative estimate of the insect community. Rocks and gravel contained within a 170 μ screen from the specific sample area were scrubbed by hand and stirred thoroughly to dislodge insects. Samples were transferred to jars and preserved in a solution of 70% ethanol.

All samples taken were identified with Merritt and Cummins (1988), Wiggins (1977), and Pennak (1978) and numbers of each taxa recorded. When possible, taxa were taken to the generic level.

Stream Channel & Riparian Habitat Assessment

Stream channel and riparian habitat assessment analyses were conducted during the summer of 1992 at many sites along the creeks. Starting at the headwaters, an assessment of habitat was completed at one-quarter mile intervals until the streams disappeared into lava sinks. The assessment followed that of the United States Department of Agriculture's stream reach inventory and channel stability evaluation (Pfankuch 1978).

At each site, the following measurements were made:

1. Streambank slope
2. Streambank and channel stability
3. Stream depth profile
4. Riparian cover

Streambanks and Channel Measurements

Streambank slope (degrees) was visually estimated individually for right and left banks. This measurement is based on a vertical plane with 100% slope being a 45° slope and 0% slope being horizontal. Right or left side of bank was standardized for this study as right bank to right side of viewer when facing *upstream* and left bank to left side of viewer when facing *upstream*.

Streambank stability was determined for each site by estimating the percent cover, bank composition, and slope of both right and left streambanks. Factors such as erodability, type and variety of cover, amount of sand, silt, and clay, and steepness of slope were used in determining

this feature. Each streambank was designated by excellent, good, fair, or poor as a result of these factors.

Channel stability was determined for each site in similar ways but relied on streambed composition, undercut streambanks, and both manmade and natural disturbance as channel stability indicators.

Stream depth-to-width ratios were determined with a metal tape and were taken at left-, right-, and mid-channel locations. Wetted stream width as well as full bankflow width were measured to determine amount of water that could be carried by the channel.

Riparian Cover

Riparian communities were analyzed with the use of a one-meter square quadrat. Ten one-meter quadrats were systematically selected at each of our sites and plant species identified with the use of keys (primarily Hitchcock and Cronquist 1973). Each quadrat was assessed for species composition to characterize the riparian community.

RESULTS AND DISCUSSION

STREAMS

Stream Water Discharge

Water discharge in Little Cottonwood, Leech, and Big Cottonwood Creeks was lower in 1992 than in 1993. All watersheds had discharge curves typical of basin and range geography in the intermountain region with high discharge occurring in late spring and early summer due to snowmelt and low discharge in late summer or early fall. Leech Creek's peak discharge was in October of 1992 at 0.12 ft³/sec at the upper site and 0.13 ft³/sec in May at the lower site. Peak 1993 discharge occurred in May with values of 0.68 ft³/sec at the upper site and a peak discharge of 0.89 ft³/sec at the lower site in May (Figures 2 and 3). Mean discharge through the summer-fall in Leech Creek in 1992 was 0.07 ft³/sec at the upper site and 0.13 ft³/sec at the lower site. Mean discharge through the summer-fall, 1993 was 0.30 ft³/sec and 0.55 ft³/sec at upper and lower sites, respectively.

In Little Cottonwood Creek, 1992 peak discharge occurred in October at both sites with a discharge of 0.09 ft³/sec at the upper site and peak discharge below the Martin Mine in October, 1992 of 0.11 ft³/sec (Figures 4 and 5). Mean discharge rates in Little Cottonwood Creek for 1992 were 0.04 ft³/sec for the upper site and 0.10 ft³/sec below the Martin Mine. Peak discharge occurred at the upper site in June of 1993 with a discharge of 0.54 ft³/sec. Peak discharge occurred in June at the site below the Martin mine with a discharge of 1.13 ft³/sec. Mean discharge rates in 1993 were 0.30 ft³/sec at the upper site and 0.52 ft³/sec at the site below the Martin Mine.

In Big Cottonwood Creek, 1992 peak discharge occurred in May at the upper site and in October at the lower site with 0.41 ft³/sec and 0.77 ft³/sec respectively. In 1993, peaks were in June at both sites in with values of 3.31 ft³/sec at the upper site and 4.44 ft³/sec at the lower site (Figures 6 and 7). Mean summer-fall discharge for Big Cottonwood Creek at the upper site was 0.27 ft³/sec in 1992 and 2.14 ft³/sec in 1993. The lower site showed a mean summer-fall discharge of 0.48 ft³/sec in 1992 and 2.17 ft³/sec in 1993. These streams responded to higher

snow pack and precipitation in 1993. The winter of 1991-92 had below-average snowfall and thus smaller water discharge values in 1992 while the 1992-93 winter had average snowfall for the area and is reflected in the higher water discharge rates of 1993.

Water Temperature

Water temperatures ranged from 8.0°C to 15.0°C in Leech Creek with the maximum temperature of 15.0°C reached during August, 1992 at the upper site (Tables 1 and 2 and Figure 8). Temperatures in 1993 were lower than those in 1992. Temperatures in 1993 ranged from 8.5°C to 12.5°C with the highest temperature of 12.5°C reached in September at the lower site (Tables 3 and 4 and Figure 9).

Water temperatures ranged from 8.0°C to 15.0°C in Little Cottonwood Creek in 1992 (Tables 5 and 6 and Figure 10) and from 8.0°C to 15.0°C in 1993 (Tables 7 and 8 and Figure 11). At the lower site on Little Cottonwood Creek, we found water only during the months of May and June in 1993 (Table 9). Peak water temperature of 15.0°C occurred both in August, 1992 at the upper site and in July, 1993 at the station below the Martin Mine.

Water temperatures in Big Cottonwood Creek ranged from 10.0°C to 29.0°C (Tables 10-12 and Figures 12-14) during the 1992 season with a summer-fall mean of 18.2°C. The high of 29.0°C was reached at the site below the Paymaster Mine during June. Temperatures in 1993 were slightly lower. Temperatures ranged from 8.0°C to 16.5°C (Tables 13-15 and Figures 12-14) with a summer mean of 10.9°C being reached. The high reading of 16.5°C was again seen in July at the site below the Paymaster mine.

Dissolved Oxygen

Dissolved oxygen levels in Leech Creek ranged from 7.6 mg/l to 13.0 mg/l during the 1992 sampling season with a summer mean of 8.3 mg/l (Tables 1-2 and Figures 15-16). In 1993, levels ranged from 7.5 mg/l to 10.0 mg/l with a summer mean of 8.9 mg/l (Tables 3-4 and Figures 15-16). Leech Creek oxygen percent saturation ranged from 72% to 105% in 1992 and from 68% to 86% in 1993.

Little Cottonwood Creek had dissolved oxygen levels ranging from 6.6 mg/l to 10.3 mg/l in 1992 with a summer mean of 7.2 mg/l (Tables 5-6 and Figures 17-18) and from 5.4 mg/l to 9.6 mg/l in 1993 with a summer mean of 7.8 mg/l (Tables 7-8 and Figures 17-18). In

1993, levels fell below the state and federal standard of 6.0 mg/l only in August at the upper site where a reading of 5.4 mg/l was observed. Oxygen percent saturation in Little Cottonwood Creek ranged from 64% to 91% in 1992 and from 48% to 87% in 1993.

Dissolved oxygen levels in Big Cottonwood Creek ranged from 5.1 mg/l to 11.0 mg/l in 1992 with a summer mean of 7.4 (Tables 10-12 and Figures 19-21). The low of 5.1 was below the state and federal standard of 6.0 mg/l but only occurred during the month of June at the site below the Paymaster Mine (largely because of high water temperature at that site). Dissolved oxygen levels increased slightly in 1993 at all three sites. Levels ranged from 7.4 mg/l to 11.2 mg/l with the low occurring in June at the site below the Paymaster Mine (Tables 13-15 and Figures 19-21). The mean summer dissolved oxygen level for 1993 was 8.3 mg/l.

Oxygen percent saturation in Big Cottonwood Creek ranged from 64% to 100% in 1992 and from 68% to 94% in 1993.

Electrical Conductivity

Total dissolved solids as measured by the electrical conductivity were typical for the geology of the area (Harenberg, et. al. 1987). Conductivity ranged from 90 to 197 μ mhos in the Leech Creek during 1992 (Tables 1-2 and Figures 22-23) (1992 mean = 148 μ mhos) and ranged from 180 to 225 μ mhos during 1993 (Tables 3-4 and Figures 22-23) (1993 mean = 203 μ mhos).

Conductivity ranged from 150 to 900 μ mhos during 1992 in Little Cottonwood Creek (Tables 5-6 and Figures 24-25) (1992 mean = 209 μ mhos) and ranged from 95 to 240 μ mhos during 1993 (Tables 7-9 and Figures 24-25) (1993 mean = 170 μ mhos). The high reading of 900 μ mhos occurred in October, 1992 below the Martin Mine after three months of no surface water discharge in the stream channel at this site (Figure 25). First discharge following the three-month dry period apparently carried a high concentration of dissolved minerals below the Martin Mine.

Electrical conductivity levels in Big Cottonwood Creek ranged from 80 to 455 μ mhos in 1992 (Tables 10-12 and Figures 26-28) (1992 mean = 139.2 μ mhos). In 1993 conductance was lower with a range of 46 to 270 μ mhos (Tables 13-15 and Figures 26-28) with a 1993 mean of 92.4 μ mhos. The lower levels of conductivity in 1993 can be attributed to dilution with higher water runoff from the watershed into the stream.

Alkalinity, Carbon Dioxide, and pH

Alkalinity was moderate and ranged from 136 to 177 mg/l in Leech Creek during 1992 (Tables 1-2 and Figures 29-30) with a mean of 152 mg/l and from 147 to 210 mg/l with a mean of 173 mg/l in 1993 (Tables 3-4 and Figures 29-30). Alkalinity in Little Cottonwood Creek was somewhat lower with levels ranging from 94 to 170 mg/l with a mean of 128 mg/l in 1992 (Tables 5-6 and Figures 31-33) and levels ranged from 84 to 172 mg/l with a mean of 130 mg/l in 1993 (Tables 7-9 and figures 31-33). Alkalinity in Big Cottonwood Creek was also in the moderate range. Levels ranged from 16 to 77 mg/l in 1992 (Tables 10-12 and Figures 34-36) with a mean of 51 mg/l. Big Cottonwood Creek showed similar characteristics in 1993 with levels ranging from 20.6 to 63.6 mg/l (Tables 13-15 and Figures 34-36) with a mean of 47 mg/l. These figures were consistent with the findings of Omernik and Griffith 1986. They found lower alkalinity readings associated with higher elevation streams in alpine meadows or flowing from mountain peaks.

Carbon dioxide levels were relatively low for all three watersheds with a low of 0 mg/l in August of 1993, at the lower site on Leech Creek and a high of 16 mg/l in October of 1992, in Little Cottonwood Creek below Martin Mine (Groundwater influence is obvious at that latter site). The mean annual level of CO₂ in Leech Creek for 1992 was 10 mg/l (Tables 1-2 and Figures 37-38) and 7 mg/l in 1993 (Tables 3-4 and figures 37-38). The mean annual CO₂ level CO_{2i} in Little Cottonwood Creek was 9 mg/l in 1992 (Tables 6-7 and figures 39-40) and 7.6 mg/l in 1993 (Tables 7-9 and Figures 39-40). The mean annual level of CO₂ in Big Cottonwood Creek in 1992 was 5.3 mg/l (Tables 10-12 and figures 41-43) and 4.3 mg/l in 1993 (Tables 13-15 and figures 41-43). The low amount of CO₂ in most surface stream sites on COM suggests minimal groundwater influence except for the apparent groundwater flow influences below the Martin Mine.

The waters of all three creeks showed slightly acid to slightly basic qualities most of the time (Figures 44-50) with the pH ranging from 5.80 to 8.66 (Tables 1-15). Leech Creek had a mean pH in 1992 and 1993 combined of 8.11; Little Cottonwood Creek had a mean pH of 7.81; and Big Cottonwood Creek had a mean pH 7.67. All means were true means *i.e.* calculated on antilogs of pH readings taken on site and monthly readings combined to determine true site means of pH.

Turbidity

Turbidity readings were relatively low with most less than 3.0 NTU (Nephelometric Turbidity Units). Levels in Leech Creek ranged from 1.1 to 8.5 NTU in 1992 (Tables 1-2 and Figures 51-52) with a mean of 2.1 NTU and ranged from 1.1 to 5.0 NTU in 1993 (Tables 3-4 and Figures 51-52) with a mean of 2.3. Levels in Little Cottonwood Creek were somewhat lower with values ranging from 1.3 to 3.4 NTU in 1992 (Tables 5-6 and figures 53-54) with a mean of 1.9 NTU and from 0.7 NTU to 2.3 NTU in 1993 (Tables 7-9 and Figures 53-54) with a mean of 1.6 NTU. Turbidity in Big Cottonwood Creek was similar to the other drainages. Levels ranged from 1.0 to 5.5 NTU in 1992 (Tables 10-12 and Figures 55-57) with a mean of 1.8 NTU. Levels in 1993 were slightly higher and ranged from 1.4 to 7.0 NTU (Tables 13-15 and Figures 55-57) with a mean annual reading of 2.8 NTU. There were a few readings that were higher than 3.0 NTU but these occurred during or after rainstorms which would increase the amount of suspended sediments, thereby discoloring the water. The higher readings occurred in Leech Creek at the lower site during June of 1992 with a reading of 8.5 NTU. This reading is most likely due to large amounts of sediments and terrestrial organic debris suspended in the water column at the time of sampling.

Nutrients

Nitrate-nitrogen ($\text{NO}_3\text{-N}$) levels were quite low in all three of the streams studied. None of the streams had levels exceeding 0.036 mg/l (Tables 15-16) either year of the study. $\text{NO}_3\text{-N}$ levels for Leech Creek ranged from 0 mg/l to 0.036 mg/l in 1992 (mean = 0.007 mg/l $\text{NO}_3\text{-N}$) and ranged from 0 mg/l to 0.002 mg/l in 1993 (mean = 0.002 mg/l $\text{NO}_3\text{-N}$). Levels in Little Cottonwood Creek ranged from 0.001 mg/l to 0.010 mg/l for 1992 (mean = 0.003 mg/l $\text{NO}_3\text{-N}$) and ranged from 0 mg/l to 0.002 mg/l $\text{NO}_3\text{-N}$ in 1993 (mean = 0.001 mg/l $\text{NO}_3\text{-N}$). Levels in Big Cottonwood Creek ranged from 0.001 mg/l to 0.010 mg/l $\text{NO}_3\text{-N}$ in 1992 (mean = 0.003 mg/l $\text{NO}_3\text{-N}$) and levels ranged from 0.002 mg/l to 0.006 mg/l $\text{NO}_3\text{-N}$ in 1993 (mean = 0.004 mg/l $\text{NO}_3\text{-N}$). These very low levels of $\text{NO}_3\text{-N}$ suggest that these streams are relatively unpolluted because they fall in the bottom end of the ultra-oligotrophic range of 0 - 0.200 mg/l $\text{NO}_3\text{-N}$ (Wetzel 1983).

Ammonia nitrogen ($\text{NH}_3\text{-N}$) levels for Little Cottonwood, Leech, and Big Cottonwood Creeks ranged from 0.02 to 1.67 mg/l $\text{NH}_3\text{-N}$ during the course of the study (Tables 15-16).

Ammonia levels in Leech Creek ranged from 0.09 to 0.35 mg/l in 1992 (mean = 0.19 mg/l $\text{NH}_3\text{-N}$) and ranged from 0.04 to 0.18 mg/l in 1993 (mean = 0.11 mg/l $\text{NH}_3\text{-N}$). Levels in Little Cottonwood Creek ranged from 0.08 to 0.26 mg/l $\text{NH}_3\text{-N}$ in 1992 (mean = 0.17 mg/l $\text{NH}_3\text{-N}$) and ranged from 0.08 to 1.66 mg/l in 1993 (mean = 0.32 mg/l $\text{NH}_3\text{-N}$). Levels in Big Cottonwood Creek ranged from 0.10 to 0.61 mg/l $\text{NH}_3\text{-N}$ in 1992 (mean = 0.19 mg/l $\text{NH}_3\text{-N}$) and ranged from 0.10 to 1.50 mg/l $\text{NH}_3\text{-N}$ in 1993 (mean = 0.19 mg/l $\text{NH}_3\text{-N}$). Increased levels of either $\text{NO}_3\text{-N}$ or $\text{NH}_3\text{-N}$ were not seen in Big Cottonwood Creek, the stream receiving most grazing of the three study streams. Ammonia, the parameter most responsive to cattle grazing, was little different between the three streams.

Total phosphorus (TP) levels were moderate in all streams (Tables 15-16). Phosphorus levels in Leech Creek ranged from 0.012 mg/l to 0.100 TP mg/l in 1992 (mean = 0.050 mg/l TP) and levels ranged from 0.025 mg/l to 0.124 mg/l in 1993 (mean = 0.047 mg/l TP). Total phosphorus levels in Little Cottonwood Creek were similar to those found in Leech Creek. Levels ranged from 0.010 mg/l to 0.158 mg/l in 1992 (mean = 0.065 mg/l TP) and ranged from 0.013 mg/l to 0.071 mg/l TP in 1993 (mean = 0.041 mg/l TP). Total phosphorus levels in Big Cottonwood Creek were similar to those found in the other two streams. Levels ranged from 0.020 mg/l to 0.150 mg/l TP in 1992 (mean = 0.050 mg/l TP) and levels ranged from 0.006 mg/l to 0.070 mg/l TP in 1993 (mean = 0.033 mg/l TP).

Although most unpolluted surface water streams have total phosphorus levels of 0.010 - 0.050 mg/l TP and phosphorus levels are generally lower in mountain streams compared to lowland streams (Wetzel 1983), the values we observed on COM streams are not as low, relatively speaking, as are the nitrogen levels. The following table summarizes annual levels of NO_3 , NH_3 , and TIN (Total inorganic nitrogen) over the two study years, then compares TIN to TP values and ratios for both annual and two-year trends. TIN:TP ratios < 8 indicate nitrogen-limited waters; the very low ratios observed in this COM study (3.2 - 5.2) indicate nitrogen-limited stream waters. Nitrate-nitrogen is very low in all streams with the unusual situation of almost all TIN contributed by ammonia, but the low ratios are most likely a manifestation of relatively high $\text{NH}_3\text{-N}$ and moderate TP concentrations. The stream watersheds are all

geochemically diverse (as indicated by the mining activity) mixes of igneous, basaltic, and metamorphic rock types, conditions generally yielding higher TP concentrations in runoff water. No unusual man-caused sources of phosphorus to the streams were seen.

	1992			1993		
	NO3	NH3	TIN	NO3	NH3	TIN
Leech Creek	0.007	0.19	0.197	0.002	0.11	0.112
Little Cottonwood Cr.	0.003	0.17	0.173	0.001	0.32	0.321
Big Cottonwood Cr.	0.003	0.19	0.193	0.004	0.19	0.194

	1992			1993			Study
	TIN	TP	N:P	TIN	TP	N:P	Mean N:P
Leech Creek	0.197	0.050	3.940	0.112	0.047	2.383	3.2
Little Cottonwood Cr.	0.173	0.065	2.662	0.321	0.041	7.829	5.2
Big Cottonwood Cr.	0.193	0.050	3.860	0.194	0.033	5.879	4.9

Nutrient concentrations from the three springs on Little Cottonwood Creek were assessed four time in 1992 and six times in 1993 (Table 17). Concentrations were similar to stream values

and the three springs were similar to each other except for moderately high concentrations of $\text{NH}_3\text{-N}$ found in Spring 1. Spring 1 $\text{NH}_3\text{-N}$ values were always higher than Springs 2 and 3, reaching concentrations of 1.17 mg/l. Organic contamination is the probable source of high NH_3 .

Bacteria

Fecal coliform concentrations were relatively low with all samples falling below 100 colonies per 100 ml of water (Table 18). Although these numbers seem low, they often did not meet the Idaho State Water Standard of <1 fecal coliform/100 ml for drinking water (Idaho Division of Environmental Quality 1992). Fecal coliform concentrations in Leech Creek generally did not meet drinking water standards in 1992 and not at all in 1993 (ranging from 22 to 60 colonies/100 ml). Fecal coliform levels in Little Cottonwood Creek were all less than 100 in 1992 and ranged from less than 1 to 10 in 1993. Fecal Coliform concentrations in Big Cottonwood Creek were 100 colonies or less for 1992 and ranged from less than 1 to 8 colonies per 100 ml. in 1993. When high values were present, they were in lower Leech Creek or Big Cottonwood Creek.

Fecal streptococcus samples were fairly high during the 1992 season and fell off drastically during the 1993 season. Concentrations in Leech Creek ranged from 200 - 700 colonies/100 ml in 1992 and from 3 - 25 colonies/100 ml in 1993. Fecal streptococcus levels in Little Cottonwood Creek ranged from 200 - 1,300 colonies/100 ml in 1992 and from less than 1 - 37/100 ml in 1993. Fecal streptococcus concentrations for Big Cottonwood Creek ranged from 100 - 600 colonies /100 ml in 1992 and from 1 - 9/100 ml in 1993. A fecal coliform to fecal streptococcus ratio of less than 4.0 usually indicates that domestic livestock and other animals are the predominant source of bacterial loading to the water (Gary et. al 1983). Our FC:FS ratios in this study were always very low, indicating livestock or wildlife contamination of the streams. The higher bacteria counts found in Little Cottonwood Creek and Leech Creek might be attributed to higher riparian wildlife use of area where the public is denied access. Wildlife favor these riparian zones for refuge and resting (Stuart et al. 1971).

Metals

Dissolved metals analyses (EPA 200.7 screening tests to determine presence or absence of twenty different species of metals) was conducted at high and low flows in both Leech and Little Cottonwood Creeks. Results of this testing are shown in Tables 19 and 20.

It appears the Martin Mine is minimally influencing the metals content of Little Cottonwood Creek. Sampling in October, 1992 does show concentrations of lead and arsenic that were slightly above detection limits (Table 20). Arsenic reached a level of 6.8 ppb (parts per billion) and lead reached a level of 2 ppb. During the 1993 season, lead fell below the detection limits of the test but arsenic still showed up with levels reaching 4.2 ppb. These levels are still well below EPA's criteria for domestic and irrigation water supplies (arsenic = 36 ppb and lead = 140 ppb). No samples from Big Cottonwood Creek were analyzed for metal concentrations.

Attached Benthic Algae

Attached benthic algae (ABA) levels were assessed by the indicator chlorophyll *a* concentrations in the biofilm scraped from stream substrate rocks. Leech, Little Cottonwood, and Big Cottonwood Creeks were all analyzed at both high and low stream flows. ABA chlorophyll *a* values were slightly higher in 1992, the lower flow year, than in 1993. Concentrations in Leech Creek ranged from 0.3 mg/ m² to 18.9 mg/m² in 1992 and from 0.3 mg/m² to 1.7 mg/m² in 1993. Levels in Little and Big Cottonwood Creeks ranged from 0.7 mg/m² to 7.7 mg/m² in 1992 and from 0.4 mg/m² to 3.8 mg/m² in 1993. This decrease in chlorophyll *a* concentrations from 1992 to 1993 is most likely due to increased water discharge between the two study years, resulting in diluted or lower nutrient concentrations in 1993. Levels of chlorophyll *a* in both 1992 and 1993 were not high enough to be considered "nuisance levels" (100-150 mg/ m²) as described by Welch et al. 1986. Attached benthic algae chlorophyll *a* levels are in line with the NH₃ and TP concentrations suggesting that these are relatively rich streams.

Insects

Insect communities in the three drainages showed differences in community composition reflecting subtle water quality differences between the streams. Leech Creek, the smallest of the three streams, showed a relatively even balance of Ephemeropterans (mayflies), Dipterans (two-winged flies), and Plecopterans (stoneflies). In Leech Creek, Plecopterans comprised 30.8% of the community, Dipterans 21.7% of the community, and Ephemeropterans comprised 20.2% of the community. The rest of the community structure consist of Trichopterans (caddisflies), Coleopterans (beetles), Oligochaetes (freshwater earthworms), and Planarians (flatworms).

Little Cottonwood Creek showed a slightly different pattern of insect community composition. The community structure of Little Cottonwood Creek was dominated by Dipteran larva at 64.7% of the insects found in this stream. Dipterans are generally more tolerant of metals concentrations than are the other groups. Plecopterans comprised 11.7% of the population with other groups poorly represented. The remainder of the Little Cottonwood Creek community structure consisted of Ephemeroptera, Trichoptera, Coleoptera, Hemiptera, Oligochaetes, and Planarians.

Big Cottonwood Creek had an insect community more similar to Leech Creek than to Little Cottonwood Creek. In Big Cottonwood Creek, the insect community was predominantly Dipterans, Ephemeropterans, and Plecopterans. Dipterans comprised 40.9% of the community, Ephemeropterans 35.7%, Plecopterans 14.7%, and the remainder of the community comprised of Trichopterans, Coleopterans, Oligochaetes, and Planarians.

Often insects are used as indicators when assessing stream condition for fish (mostly salmonids) habitat. For the stream to be assessed as good habitat, the EPT (Ephemeroptera: Plecoptera:Tricoptera) component should be high compared to the rest of the community. Another use for the EPT ratio is to characterize the streambed. An insect population comprised mostly of Dipterans *i.e.* with a low EPT ratio, would indicate a streambed dominated by sand or silt or a stream possibly receiving metals inputs. Streams with a high EPT ratio would indicate larger substrate composition.

ICE CAVES

During the two-year study, ice caves containing ice and water of sufficient quantity were sampled each year in August. Caves that were studied were Bear's Den Waterhole, Little Prairie Waterhole, Moonshine Cave, and Boy Scout Cave. All other caves were visited and determined not to have sufficient ice or water for sampling.

Bear's Den Cave

Bear's Den Cave, located in the wilderness area of the Monument, was one of the caves sampled during both years of the study. This cave is unique to the Monument due to the fact that it has a large slab of ice near the back of the cave with an ice slide that drops about six feet in elevation. It is the only cave on the Monument with this feature. Water quality parameters were taken from the large pool near the entrance to the cave. Water temperature was 4.2°C in August, 1992 and 4.5°C in August, 1993. Dissolved oxygen in the water pool of the cave was 7.4 mg/l in 1992 and 8.0 mg/l in 1993. Electrical conductivity declined from 75 µmhos in 1992 to 30 µmhos in 1993, suggesting that the higher snowpack of the preceding 1992-93 winter diluted surface runoff in 1993, resulting in a lower conductivity compared to 1992. The pH reading

for both years was in the neutral range with a pH of 7.1 in 1992 and a pH of 7.3 in 1993. Alkalinity and CO₂ in 1992 had means of 17.3 mg/l and 4.3 mg/l, respectively, declining slightly in 1993 with alkalinity and CO₂ means of 14.6 mg/l and 2.3 mg/l, respectively. The low alkalinity and CO₂ levels also suggest, that the water in the cave is from surface water sources (with condensate and snowmelt most likely predominating) and not from groundwater seeps. Far greater values of both parameters would be expected in groundwater. This was further supported by the August, 1993 observation of a large mound of snow still remaining in the cave entrance. It is apparent that snowfall has a dominant influence on the amount of ice that is formed in the caves each year. Measurements were taken on the depth of the ice pack in the rear of the cave and compared between the two sampling years. An increase of 12-14" was observed in the depth of the ice from summer 1992 to summer 1993.

Turbidity was relatively low with means of 1.5 NTU in 1992 and 1.9 NTU in 1993. Nutrient analyses were performed on cave water in 1993. Nutrients measured were NO₃-N, NH₃-N, TKN, and total phosphorus. NH₃-N levels were 0.127 mg/l, NO₃-N levels 0.026 mg/l, and TKN less than detection at 0.02 mg/l. The water in Bear's Den Cave had levels of total phosphorus up to quite high levels of 0.182 mg/l.

Chlorophyll *a* concentrations on submerged rocks in the cave were measured in August, 1992. Levels of chlorophyll *a* in 1992 averaged 9.5 mg/m². These samples were highly variable, probably largely due to variability of shading in the cave, as indicated by 80% confidence intervals of 1.1 to 11.3 mg/m².

Little Prairie Waterhole

Little Prairie Waterhole is located southeast of Bear's Den Cave in the wilderness area of the Monument. Little Prairie Waterhole is not as large as Bear's Den and has more of a vertical entrance and therefore receives direct light. The small amount of ice present in the cave was under four to five feet of water and therefore was not measured or sampled during the study. Water quality parameters were taken and they are similar to that of Bear's Den. Temperature was 4°C in 1992 and 4.5°C in 1993. Dissolved oxygen was 7.4 mg/l in 1992 and 8.4 mg/l in 1993. Conductivity for both years was relatively low with conductivity in 1992 of 40 µmhos and 30 µmhos in 1993. The pH for both years was in the neutral range with a measurement of 7.0 in 1992 and 7.8 in 1993. Total alkalinity was quite low, ranging from a mean of 19 mg/l

in 1992 to a mean of 19.8 mg/l in 1993. CO₂ was also low with a means of 4.0 mg/l in 1992 and 2.4 mg/l in 1993. This again suggests that water in the cave is from surface and not ground water sources. Turbidity of Little Prairie Waterhole water was quite low with means of 1.6 NTU in 1992 and 1.5 NTU in 1993.

Nutrient concentrations of Little Prairie Waterhole water were lower than those found in Bear's Den. Levels of NO₃-N in the Waterhole were 0.012 mg/l, NH₃-N levels were 0.093 mg/l, and TKN levels were less than 0.02 mg/l. Total phosphorus concentrations in Little Prairie Waterhole were 0.050 mg/l. Chlorophyll *a* concentrations of ABA in Little Prairie Waterhole averaged 26.5 mg/m² with 80% confidence intervals of 22.8 to 30.1 mg/m². These were considerably higher than in Bear's Den Cave but still well below the nuisance level of 100 to 150 mg/m² as reported by Welch et al. 1986. This cave is in a remote location and poorly accessible to the public.

Moonshine Cave

Moonshine cave is a small cave located southwest of the spatter cones and contained a small pocket of water with some ice near the back of the cavern. There is a narrow opening through which one must crawl to reach the pocket of water and ice. Water overlying the anchor ice was too deep to permit ice sampling. Water temperature was cold in the cave with a temperature of 4.0°C in 1992 and 5.0°C in 1993. Dissolved oxygen was 8.0 mg/l in 1992 and 10.2 mg/l in 1993. The oxygen reading in 1992 was slightly below saturation but the oxygen of 10.2 mg/l in 1993 was at 100% saturation for that temperature and altitude. Conductivity was fairly low with readings of 60 µmhos in 1992 and 50 µmhos in 1993, suggesting little influence of dissolved solids leached into groundwater. The pH was around the neutral range with values of 6.4 in 1992 and 7.4 in 1993. Total alkalinity was low in both years with means of 36.3 mg/l in 1992 and 30.0 mg/l in 1993. Carbon dioxide concentrations for both years were low with means of 3.6 mg/l in 1992 and 2.6 mg/l in 1993. These low measurements once again suggest water in the cave is from surface and not from groundwater sources. Turbidity in both years was low with means of 1.8 NTU in 1992 and 2.0 NTU in 1993. Nutrient levels in Moonshine Cave were similar to those observed in Bear's Den but higher than those found in Little Prairie Waterhole. Nitrate-nitrogen was 0.016 mg/l, NH₃-N was 0.070 mg/l, TKN levels less than 0.02 mg/l, and TP was 0.105 mg/l.

Boy Scout Cave

Boy Scout Cave is a cave on the public tour and tends to get heavy foot traffic from visitors on the Monument. This cave was sampled during both study years and was found to have no water during the 1992 season when only ice was found in the cave. During the 1993 season, large amounts of water were found near the back of the cave and water quality measurements were taken. Temperature of the water was 4°C. Dissolved oxygen levels were 10.2 mg/l (97% saturated). Conductivity was fairly low at 70 µmhos. The pH of the water was on the basic side in Boy Scout Cave with a reading of 8.2. Total alkalinity and CO₂ were low with means of 30 mg/l and 2.3 mg/l, again suggesting that the water is from surface water sources. Turbidity in the cave was high compared to all of the other caves with a reading of 5.0 NTU. In-cave traffic stirring up dirt and debris was indicated. Boy Scout Cave had the highest level of nutrients of all the caves tested. Ammonia-nitrogen was 0.971 mg/l, NO₃-N was 0.04 mg/l, TKN was 1.20 mg/l, while TP levels in the cave reached 0.200 mg/l. These very high levels of nutrients in this cave are apparently related to visitor activity. It was observed during our 1993 trip that the cave had been recently receiving heavy visitor traffic. In addition, while sampling the cave, we were approached by approximately 30 people in the thirty minutes we were in the cave. With ammonia levels nearing 1.0 mg/l, it is apparent the cave is receiving human wastes.

RIPARIAN HABITAT ANALYSIS

Stream Channel Evaluation

The stream reach inventory and channel stability evaluation was determined using the Pfankuch (1978) method and the results were in the "good" range for all three streams. This analysis takes into account the force of the water necessary to shape the stream channel during times of high flow. Since most of all three creek lengths are in steep canyons, there is little opportunity for high flows to alter stream course. Appendix C lists the criteria used in the habitat analysis. Most stream reaches were in the "good" range with a score of 39-76. Mean score for Leech Creek was 63.5 with a range of 48-74. Mean score for Little Cottonwood Creek was 65.4 with a range of 52-88. Mean score for Big Cottonwood Creek was 60 with scores ranging from 46 to 71. The lower station Six on Little Cottonwood Creek was the only station that did not receive a "good" rating. It was rated only fair due to steep banks, very large rock content, and lack of consolidation of the substrate (*i.e.*, low substrate stability).

Riparian Vegetation

One section of the habitat analysis was to conduct a plant survey for the riparian areas of both streams. Resulting plant lists are in Appendix D. The plant species found are typical of the high mountain desert and dry grasslands environments in the Great Basin. Because the north end of the Monument is the only area with flowing water on it, plants found in riparian zones of this area tend to absent or rare in the rest of the Monument.

During our study at the lower station on Little Cottonwood Creek, water flow was present for only a short time, in early 1993. This station was dry for the entire 1992 sampling season (May-October). The lower station is located west of the well site on Little Cottonwood Creek and flows through a meadow of grasses and sagebrush. This community of perennial plants is more xeric and plant ages indicate that xeric communities have obviously has dominated the area for some time. It is apparent that the springbox diversions reduces the downstream surface and subsurface water volumes at the lower site. However, if water were allowed to flow through this lower section of stream, one should see a change in plant community to a more moist riparian community, similar to communities found higher in the drainage. More water in Little Cottonwood Creek would extend the riparian vegetation further downstream.

During the 1992 sampling season, the middle site on Little Cottonwood Creek was also dry. The middle site is located downstream of the Martin Mine and was dry from July through September, 1992. This middle site held a number of moist species of plants such as seep-spring monkey flower and should be watched carefully in the future to track riparian community change. To maintain a balanced riparian community representative of the area, flow should ideally be kept sufficient in Little Cottonwood Creek to allow flow to reach below the Martin Mine.

CONCLUSIONS

- Stream water quality is high, indicating no obvious violations of Idaho State Standards of temperature, dissolved oxygen (indicating low external organic loading), and turbidity.
- Total dissolved solids content of the water as indicated by electrical conductivity is moderate to low.
- Stream waters are carbonate-based, of moderately low alkalinity and CO_2 , and neutral to slightly basic pH.
- Stream water nutrient concentrations of Total Phosphorus are moderately high with nitrogen limitation indicated.
- Attached algae production in the streams is moderately high.
- Stream water concentrations of $\text{NH}_3\text{-N}$ are high. High quality streambanks suggests wildlife use of riparian zones, not cattle, as the source of this $\text{NH}_3\text{-N}$.
- Low to moderate levels of Fecal Coliform with high Fecal Streptococcus bacteria in streams suggests animal (cattle and/or wildlife influence), rather than human influence to the streams.
- Stream insect associations are balanced with the exception of the middle reach of Little Cottonwood Creek where Dipteran dominance suggests metals impacts from Martin Mine.
- Streambank and channel stability is good with little indication of eroding or collapsing banks.
- Cave water quality is relatively enriched with some caves showing effects of human visitation and contamination. Cave water and water for cave ice formation seems to be from surface sources.

**FUTURE WATER MONITORING
ON THE CRATERS OF THE MOON MONUMENT**

Because of year-to-year variation in water quantity and quality, a regular (perhaps alternate year) water quality survey for physical parameters and nutrient analysis should be implemented. Minimal analyses should be at peak hydrograph (June) and at low flow (August).

Stations at each creek should be established on upper and lower sites on the streams and a middle site on Little Cottonwood Creek to monitor mine drainage. Due to the short length of Leech Creek, two stations would be sufficient.

Leech Creek--Upper Site:

Immediately downstream of the Monument's upper boundary on Leech Creek at an elevation of 6,420 ft.

Leech Creek--Lower Site:

South of and adjacent to the research camp at an elevation of 6,000 ft.

Little Cottonwood Creek --Upper Site:

On the upstream side of the culvert that Little Cottonwood Creek passes through. This site has a V-notch flow box installed in the creek and is at an elevation of 6,720 ft.

Little Cottonwood Creek--Below Martin Mine:

This station is located on the east side of the road and downstream of the Martin Mine. It is found at an elevation of 6,220 ft.

Little Cottonwood Creek--Lower Site:

This station is located in the large meadow at the bottom of the drainage and just upstream of the well sites. It is located at an elevation of 6,040 ft.

Big Cottonwood Creek--Below Paymaster Mine:

Below the mixing zone from tailings drainage into BCC at an elevation of 6,840 ft.

Big Cottonwood Creek--Upper Site:

Immediately below the road that leads to the Paymaster Mine at an elevation of 6,640 ft.

Big Cottonwood Creek--Lower Site:

Upstream of road bridge over BCC at an elevation of 6,010 ft.

Water Discharge

Discharge in Little Cottonwood and Leech Creeks should be monitored monthly during ice-free months. Stations used to determine water discharge should ideally be consistent with those used by the University of Idaho study to facilitate comparisons of year-to-year water flow volumes in each creek and of water yields from these watersheds. This can be accomplished with the use of some type of shallow water velocity meter such as a hand-held Marsh-McBirney meter in conjunction with depth and width measurements to determine discharge. A staff gage is impractical in Little Cottonwood and Leech Creeks due to the small amount of water. The use of a V-notch weir might be useful to concentrate low water flows and permit more accurate measurement of water flows. A V-notch weir has been installed at the upper station on Little Cottonwood Creek. To determine discharge of a stream, some type of shallow water flow meter will need to be obtained. Discharge measures volume (cubic feet of water per second) flowing in the channel at any one time, and is the product of depth, width, and velocity. Discharge (Q) of a stream reach is equal to $\Sigma(W \cdot D \cdot V \cdot r)$ where W is width of a stream segment, D is the depth of the stream segment, V is the velocity of each stream segment, and r is the roughness coefficient, varying from 0.98 for smooth clay to 0.60 for large cobbles.

Physical - Chemical Parameters

Stream water parameters such as temperature, dissolved oxygen, conductivity, pH, alkalinity, CO₂, and turbidity. These measurements can be obtained in a couple of different ways. If cost is a major concern, Hach Inc. (Loveland, CO; 800-227-4224) makes some inexpensive field chemistry kits that allow these parameters to be measured. These kits are inexpensive but do sacrifice some accuracy. Yellow Springs Instrument Co. (Yellow Springs, OH; 800-765-4974) makes a very reliable, field-hardy, and accurate line of meters for temperature,

dissolved oxygen, and conductivity. Solomat Instruments (Norwalk, CT; 800-765-6628) produces a reasonably priced, accurate, and also field-hardy line of instruments for temperature, dissolved oxygen, pH, conductivity, and turbidity. Forestry Suppliers (Jackson, MS; 800-647-5368) distributes all of the above meters in addition to field chemical test kits for all of our measured nutrients, although the field test kits will suffer some sacrifice of accuracy and precision relative to standard methods run in a laboratory.

These parameters should also be collected twice each year at high and low flows (July and August) to track stream response to long term patterns of weather and other environmental conditions on the drainages.

Nutrient Analyses

Nutrient analyses should be run from water samples collected in one-liter cubitainers that are obtained from any IDEQ lab in Idaho. Water samples should be collected in triplicate to establish estimates of variability. Nutrient analysis would measure concentrations of nitrate-nitrogen, ammonia-nitrogen, Kjeldahl-nitrogen, and total phosphorus in the water. Regional IDEQ labs that do these analyses are found in Boise, Twin Falls, Pocatello, or in Idaho Falls. The University of Idaho has used the Boise IDEQ lab commonly with good results. The Boise IDEQ lab (2220 Old Penitentiary Road, Boise, ID: 208-334-2235) is recommended. This lab is capable of doing any nutrient analysis needed by the Monument. Periodic evaluation of these nutrients and of ratios between them will detect subtle changes in watershed health. Along with these nutrient analyses, separate samples should be taken from each of the streams for metals analysis. With the mining activity associated with Little Cottonwood Creek, samples should be taken to monitor potential outflow effects from the Martin Mine.

Insects

Insects should be sampled alternate years at times of low flow (usually August or September) to determine long term trends in insect communities. Insects should be sampled at established stations with the use of Surber or Hess samplers (Wildlife Supply Co., Saginaw, MI). Both are good shallow water samplers for obtaining one-sq. ft. stream bottom samples and are easy to use to provide quantitative analyses of benthic stream insects. To remain consistent with the work done by the University of Idaho, a three-minute sampling procedure should be used. This

method is simply where the sampler is placed in the creek and the substrate in the sampler is agitated for three minutes to collect the insects from the enclosed one-sq. ft. bottom area to document trends in insect community structure, biomass, and diversity.

Ice Caves

Park personnel should implement a water quality monitoring program in caves. This program should consist on nutrient analysis of the water found in the caves as well as bacterial tests for fecal streptococcus and fecal coliform bacteria. Data from this study suggest that recreational use of the caves by the public is having an impact on water quality within the caves. Because of the public health issues, once-per-year samples should be taken from the caves in mid- or late summer to determine water quality. Cave visitors might tend to think of ice melt water as pristine and potable just because it's ice melt and in a remote location. Things to watch for would be an increase of bacteria counts over the heavy use periods as well as increases in ammonia levels. Both would indicate contamination of the caves by human or animal wastes.

Caves that do not have heavy use, such as those found in the wilderness area should also be tested to determine early onset of water quality changes from baseline data.. Cave ice can be directly linked to snowfall on the Monument and will increase or decrease with the amount of precipitation received during the winter months. To monitor cave ice, yearly visits would consist of a visual description of the size of the ice slab as well as information about the ice growing or shrinking. We recommend establishment of photo points and annual photographs of the ice pack to document the condition of the ice pack for long-term reference.

Riparian Habitat Analyses

Riparian analyses should be continued on both Little Cottonwood and Leech Creeks. These would entail survey of plants found in the riparian area of both creeks, as well as documentation of changes in riparian plant communities. Areas of concern would be the lower part of Little Cottonwood Creek where water does not always flow. This survey should be done every five years to determine long term climate patterns on the riparian zones of the streams.

We characterized the riparian area of both Monument creeks at one-quarter mile intervals from the headwaters downstream to the larger grass meadow northwest of Sunset Cone. To determine plant community type, a one-meter square quadrat was utilized. Individual plant stems were not counted but every type of plant in the square was recorded. Along with plant type, a visual percent composition was used to determine abundance of plants.

FIGURES

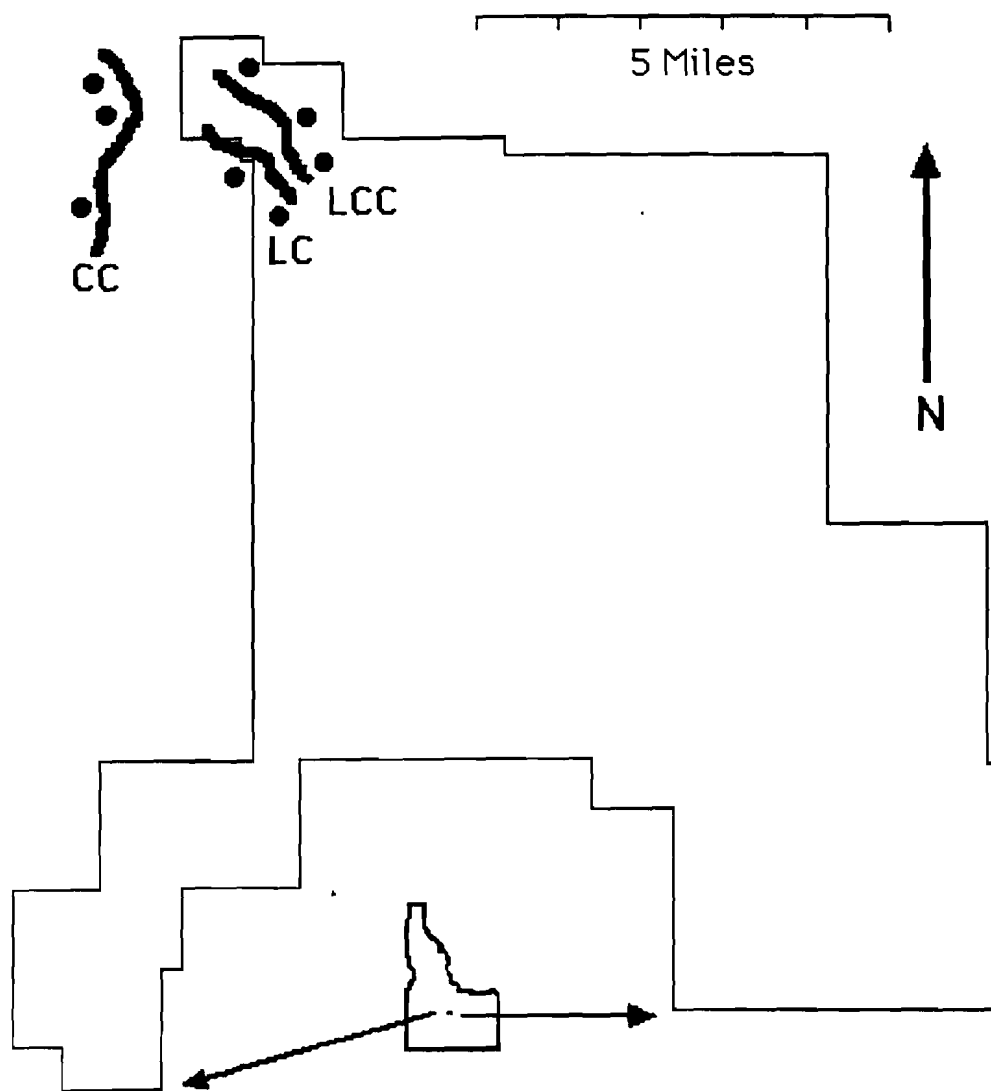


Figure 1. Craters of the Moon National Monument showing placement of the three study streams Cottonwood Creek (CC), Leech Creek (LC), and Little Cottonwood Creek (LCC) and study sites in the 1992 - 93 water resources study.

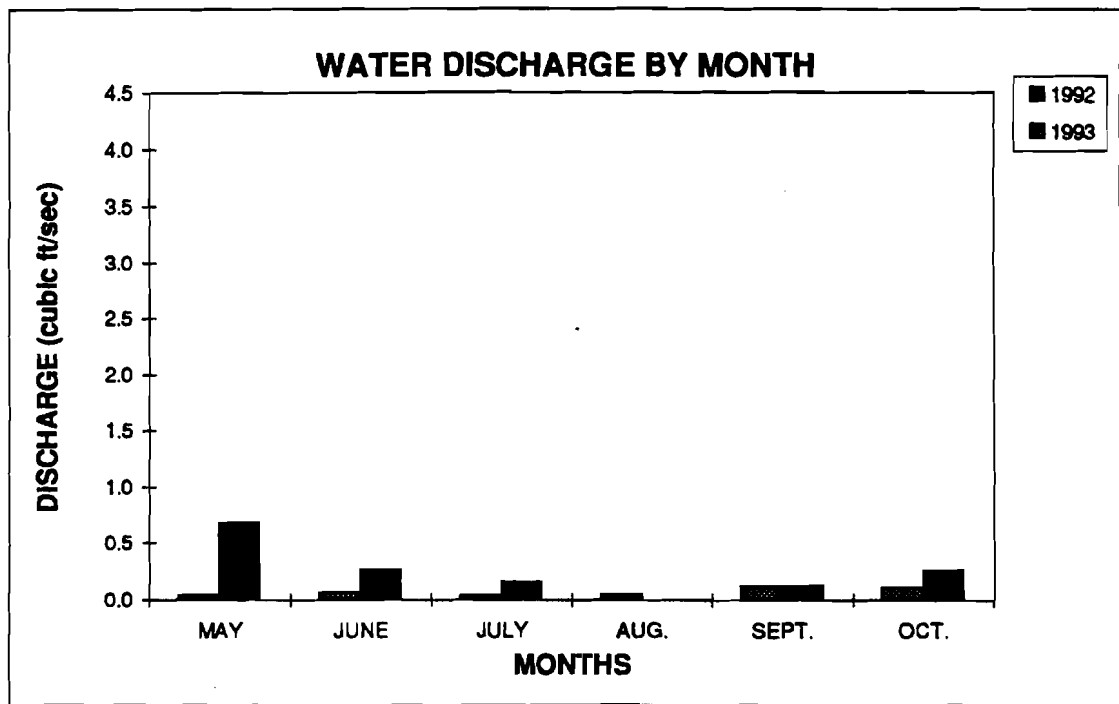


Figure 2. Monthly water discharge at upper site on Leech Creek, May through October, 1992 and 1993.

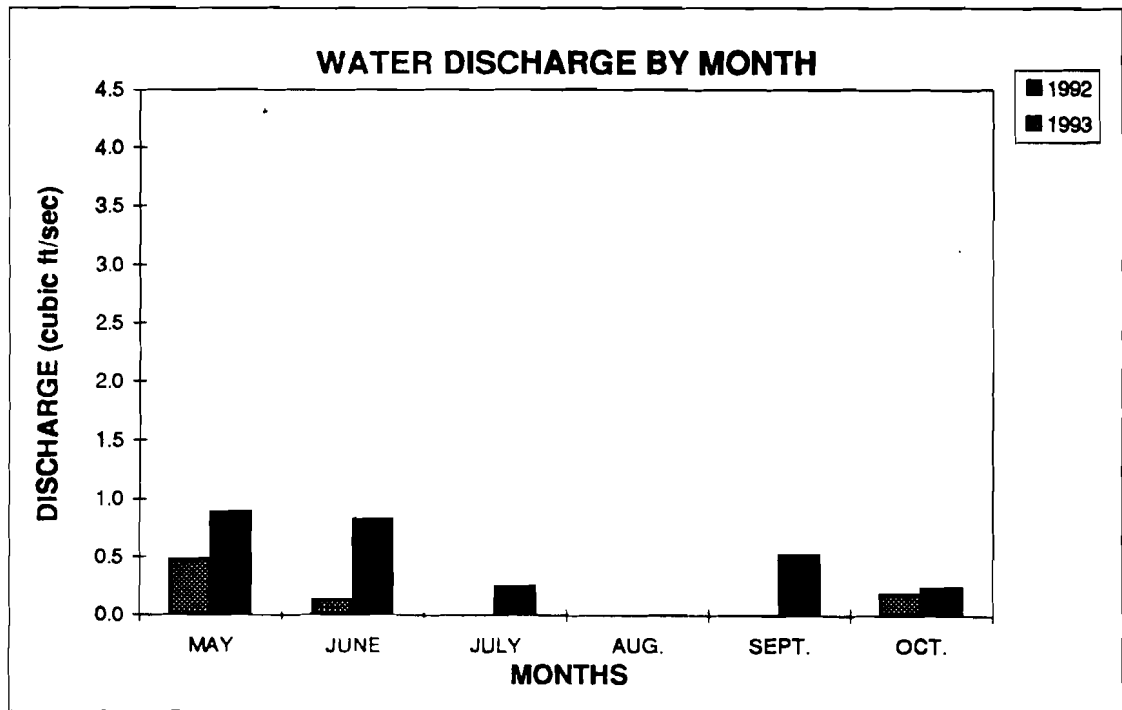


Figure 3. Monthly water discharge at lower site on Leech Creek, May through October, 1992 and 1993.

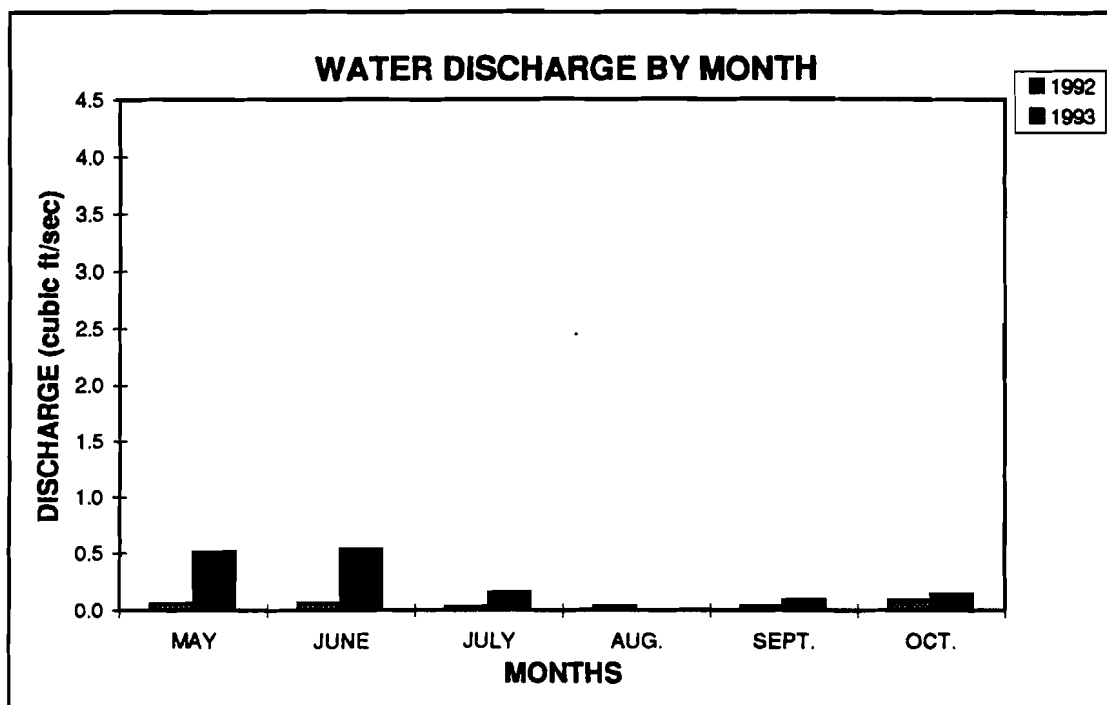


Figure 4. Monthly water discharge at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

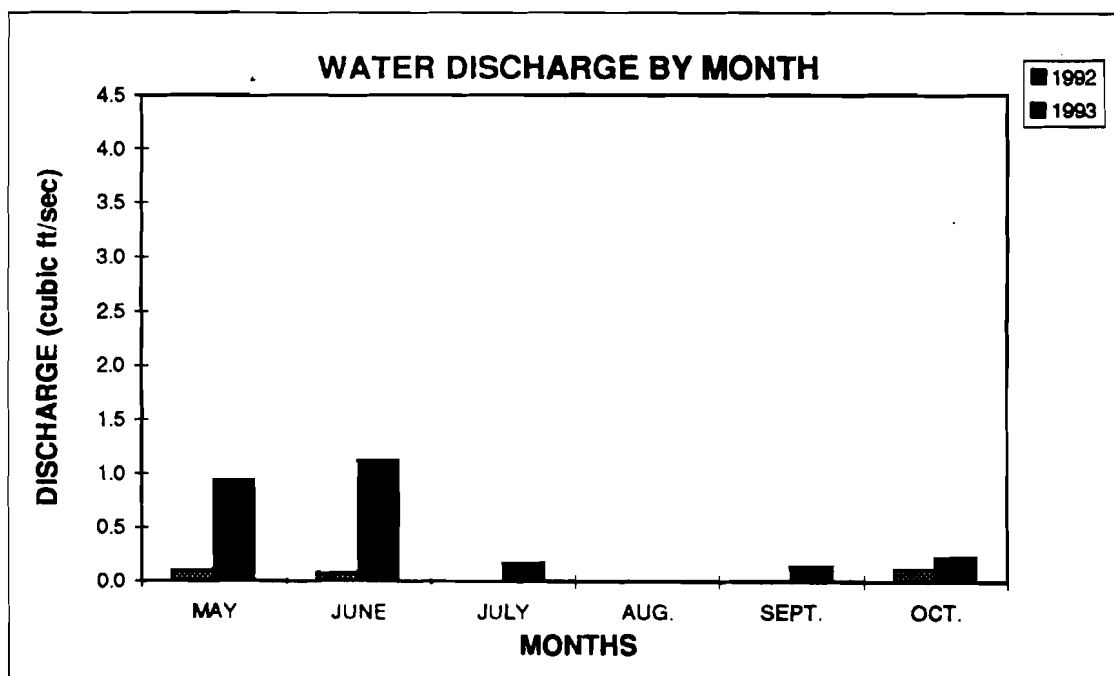


Figure 5. Monthly water discharge at site below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

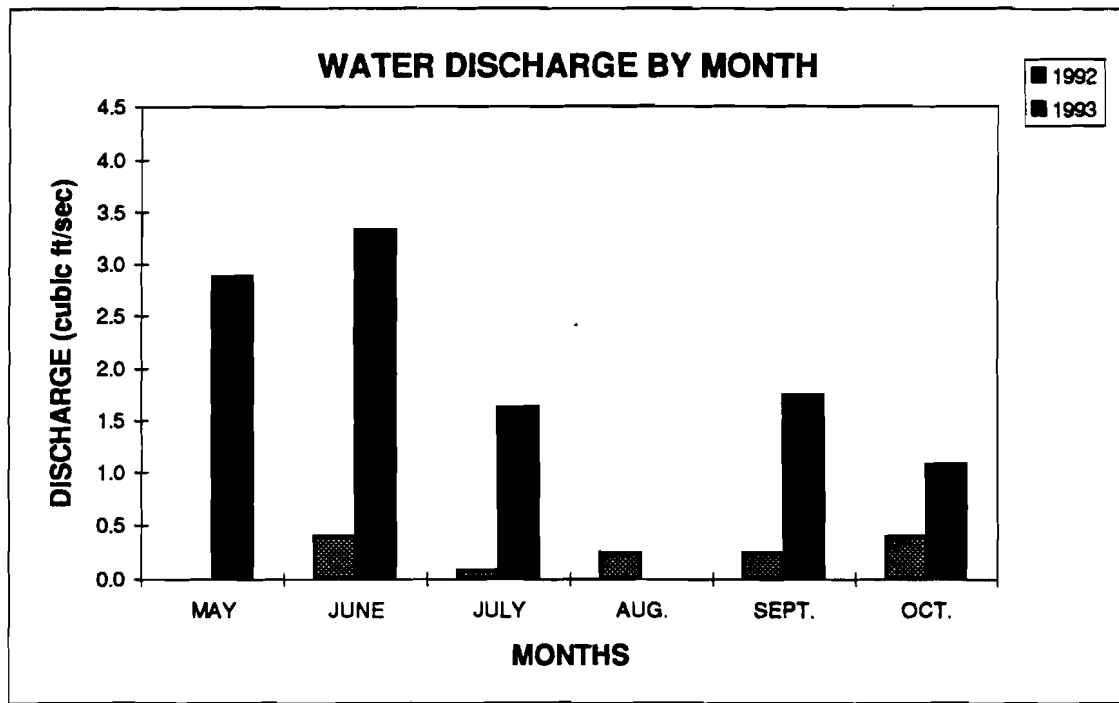


Figure 6. Monthly water temperature at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

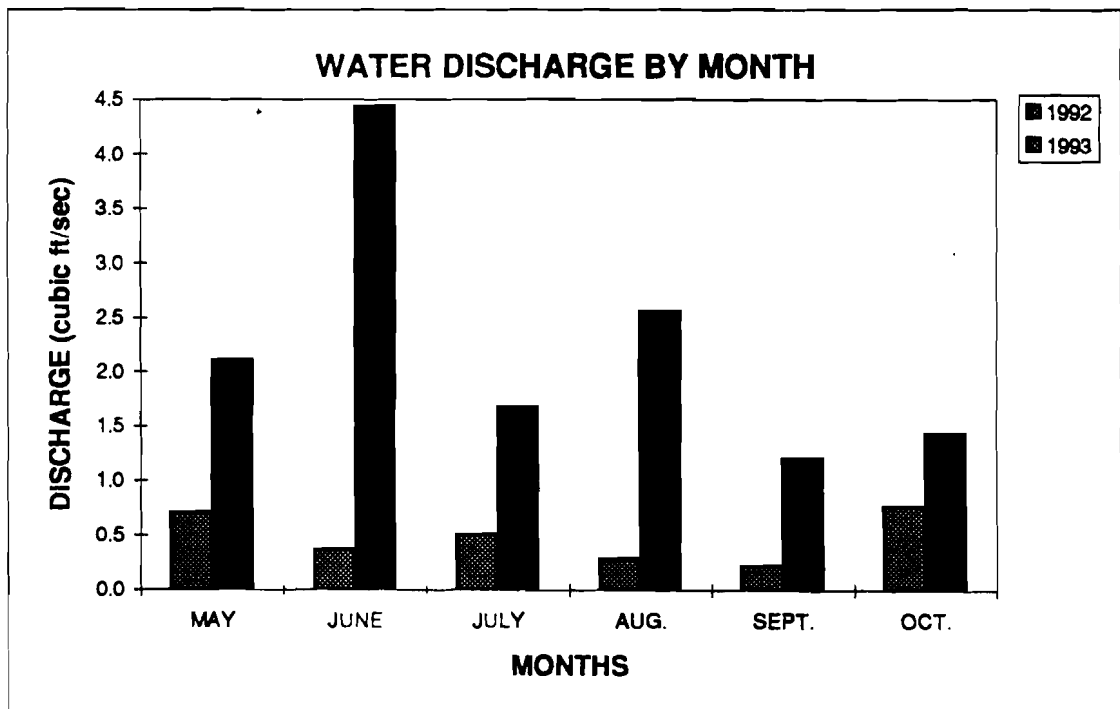


Figure 7. Monthly water discharge at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

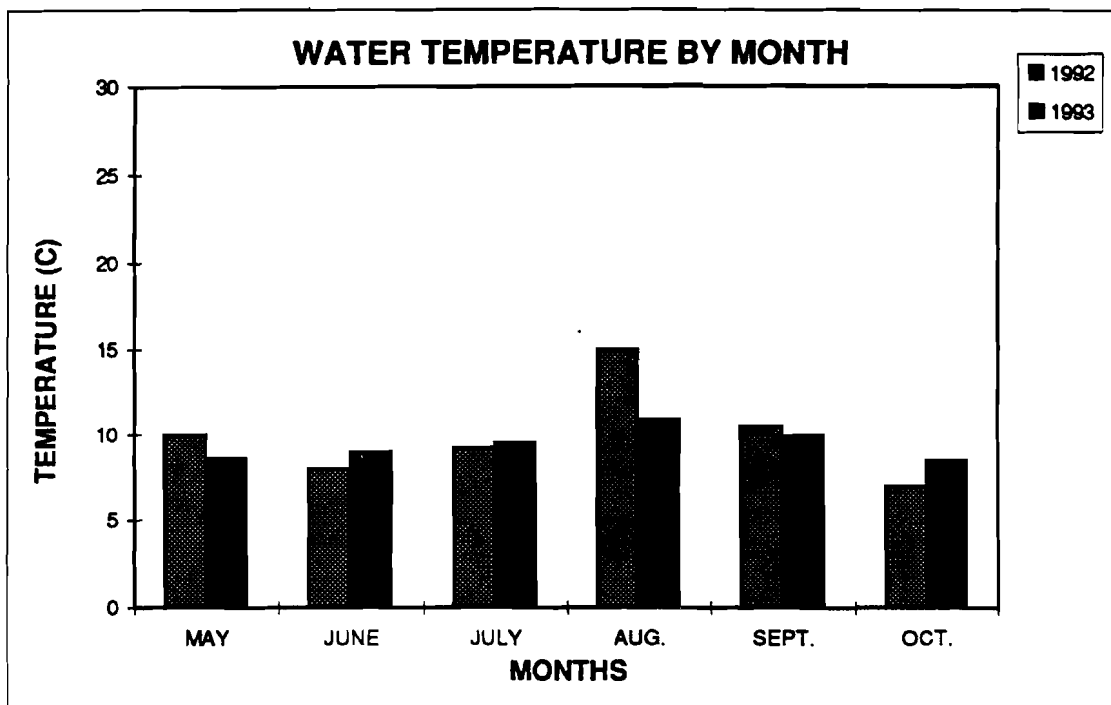


Figure 8. Monthly water temperature at upper site on Leech Creek, May through October, 1992 and 1993.

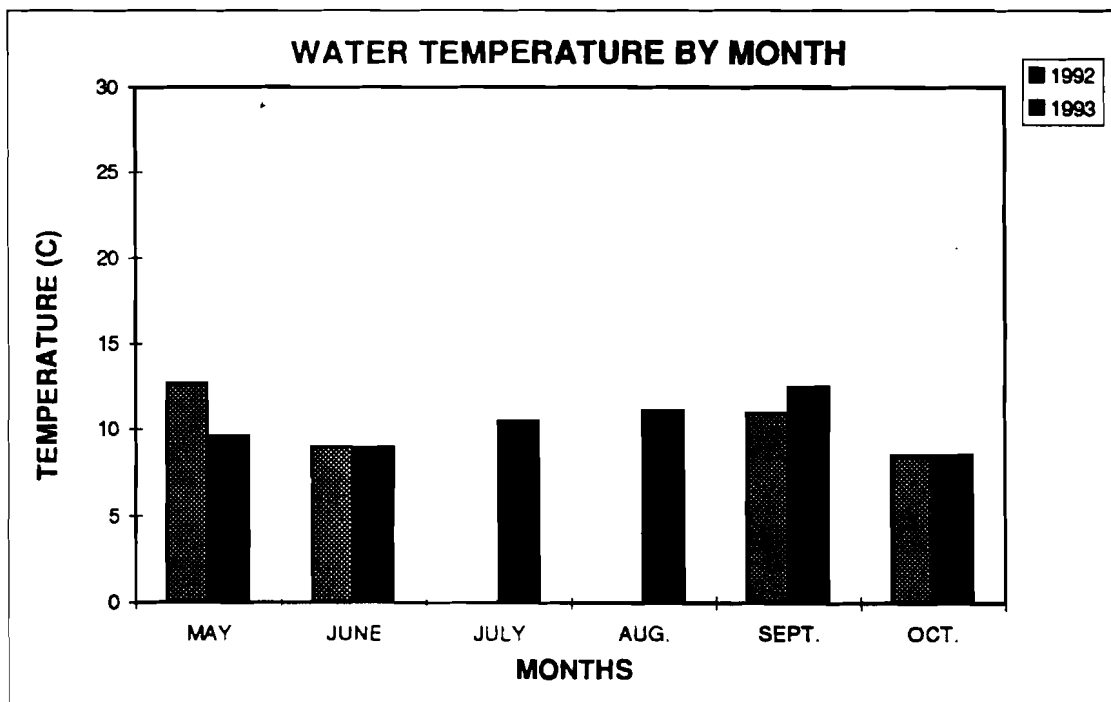


Figure 9. Monthly water temperature at lower site on Leech Creek, May through October, 1992 and 1993.

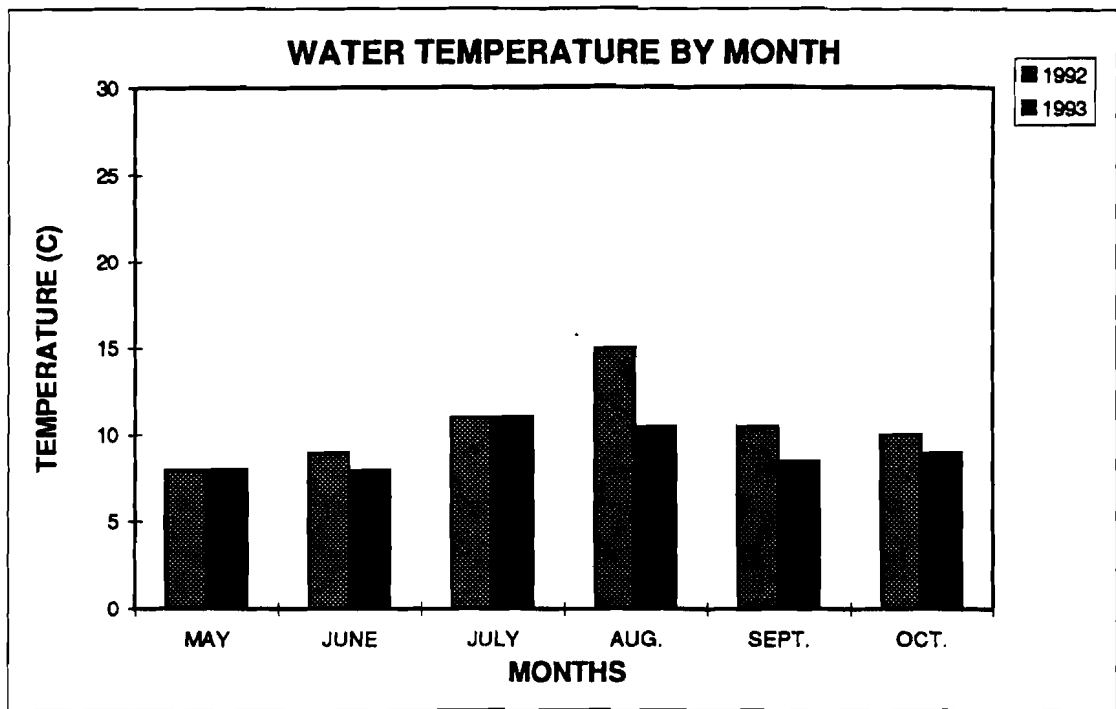


Figure 10. Monthly water temperature at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

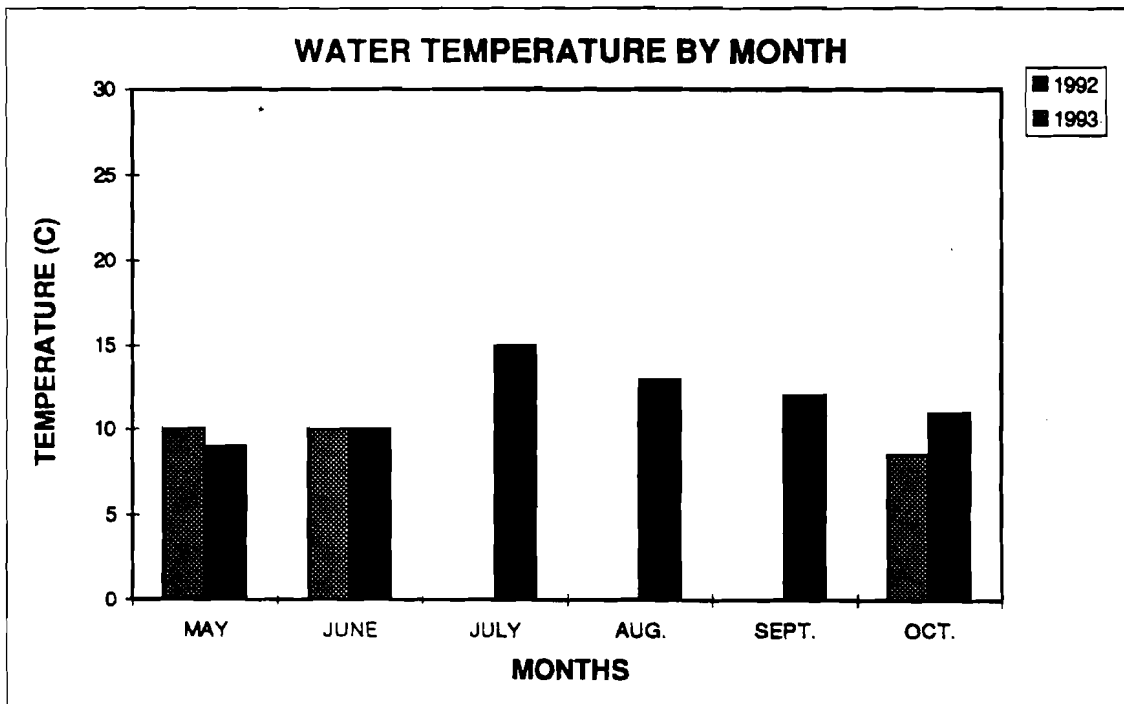


Figure 11. Monthly water temperature below Martin Mine on Little Cottonwood Creek May through October, 1992 and 1993.

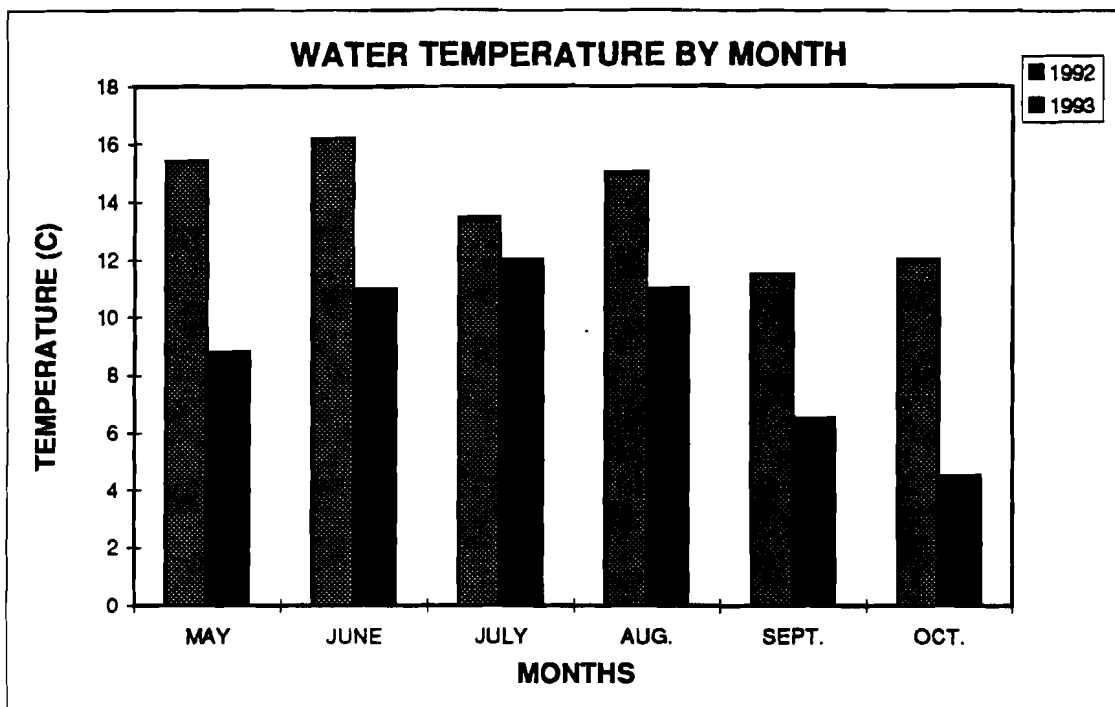


Figure 12. Monthly water temperature at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

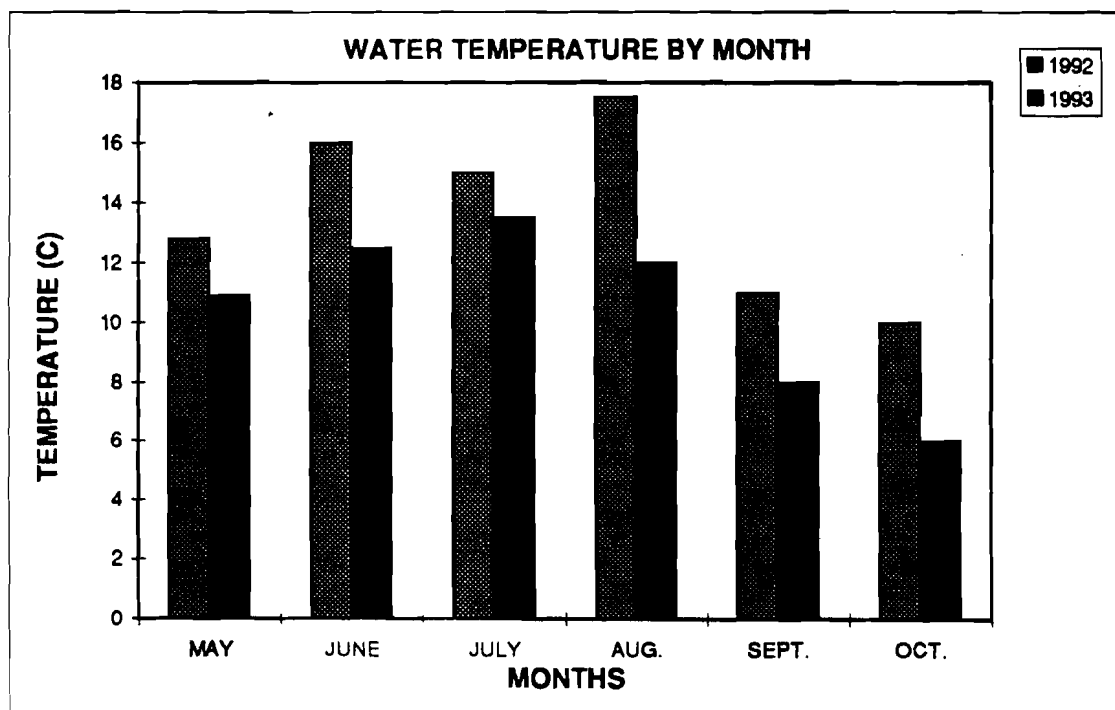


Figure 13. Monthly water temperature at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

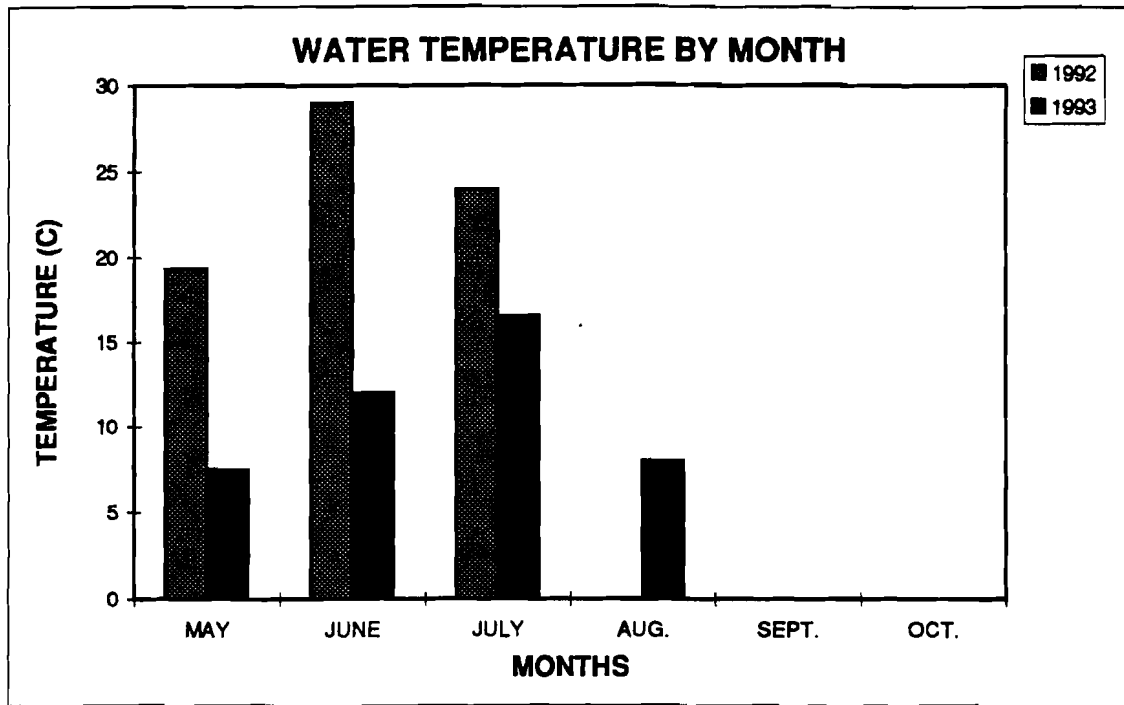


Figure 14. Monthly water temperature below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

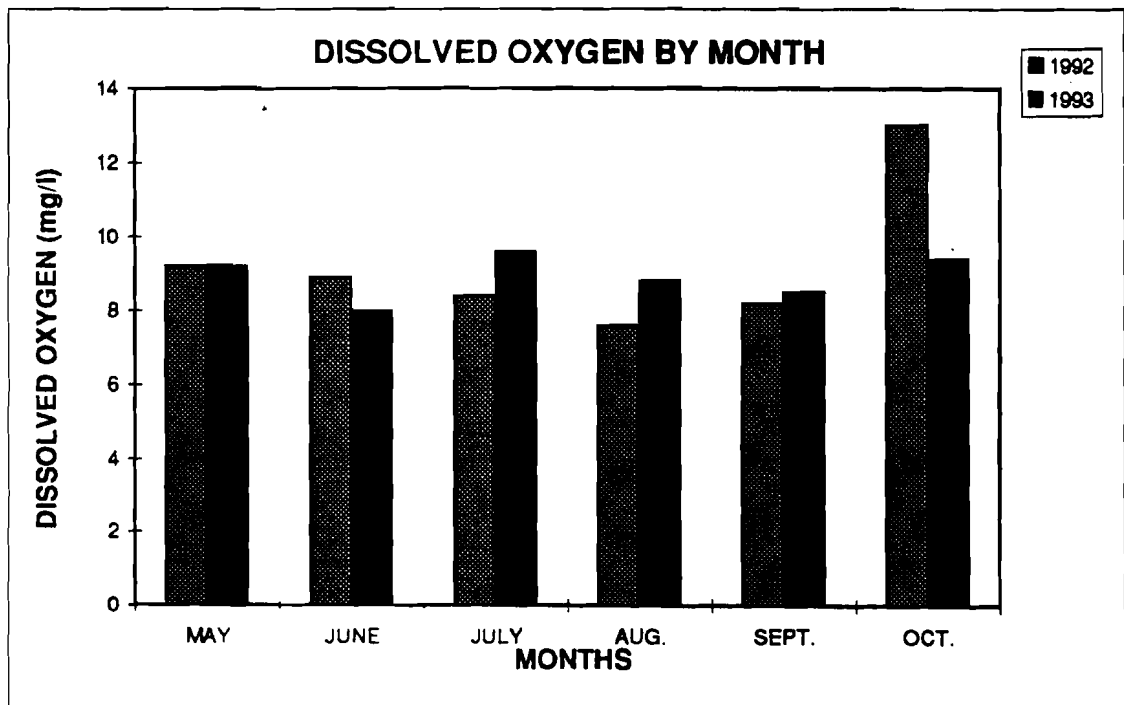


Figure 15. Monthly dissolved oxygen at upper site on Leech Creek, May through October, 1992 and 1993.

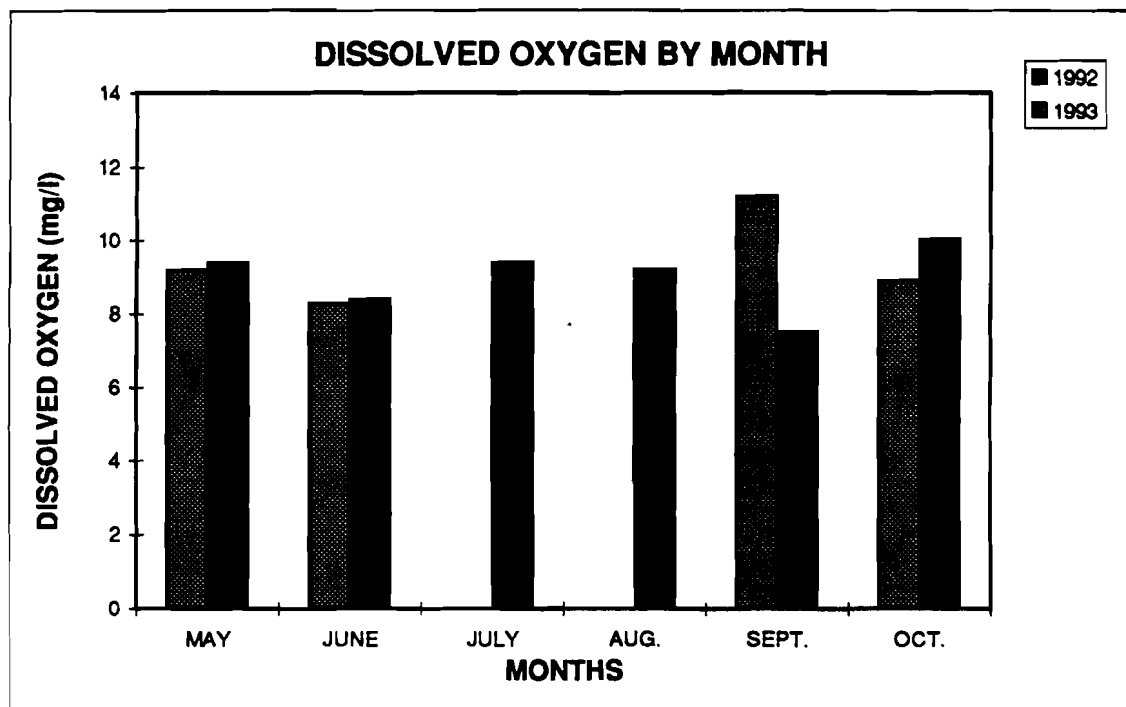


Figure 16. Monthly dissolved oxygen at lower site on Leech Creek, May through October, 1992 and 1993.

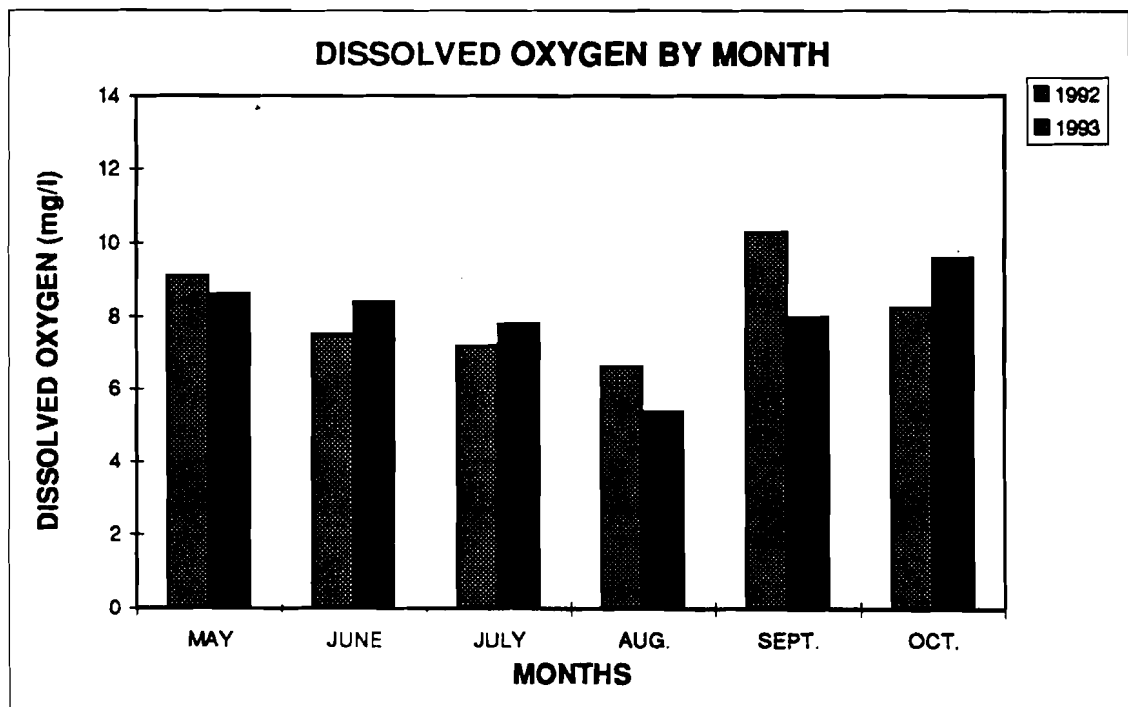


Figure 17. Monthly dissolved oxygen at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

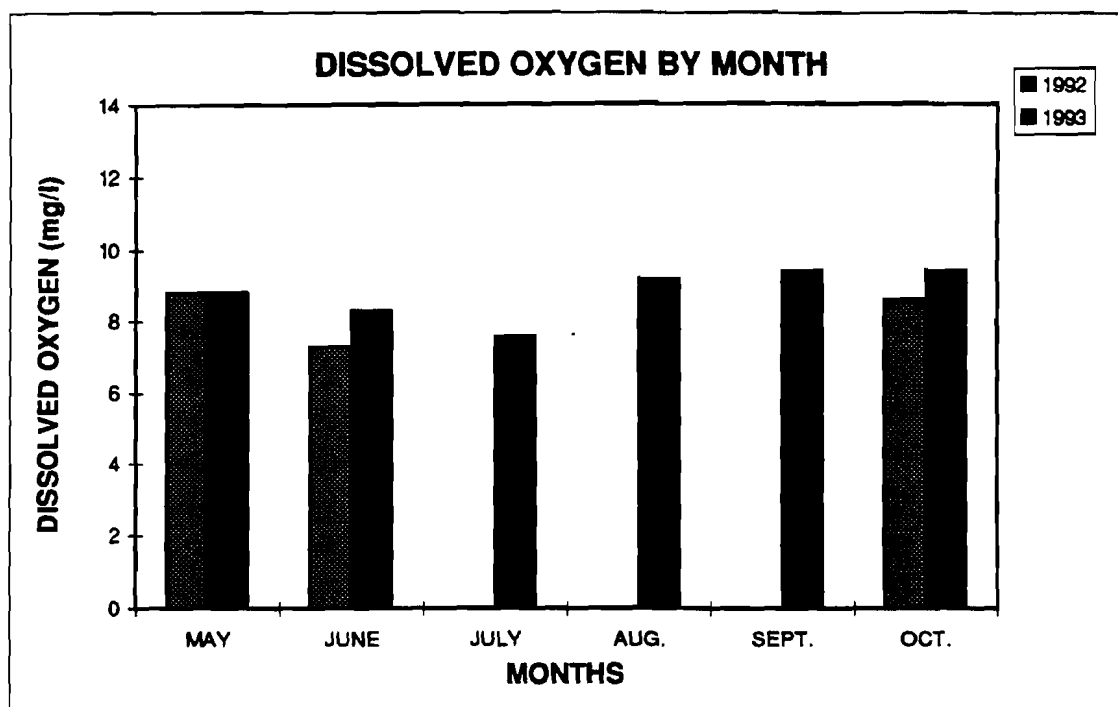


Figure 18. Monthly dissolved oxygen below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993

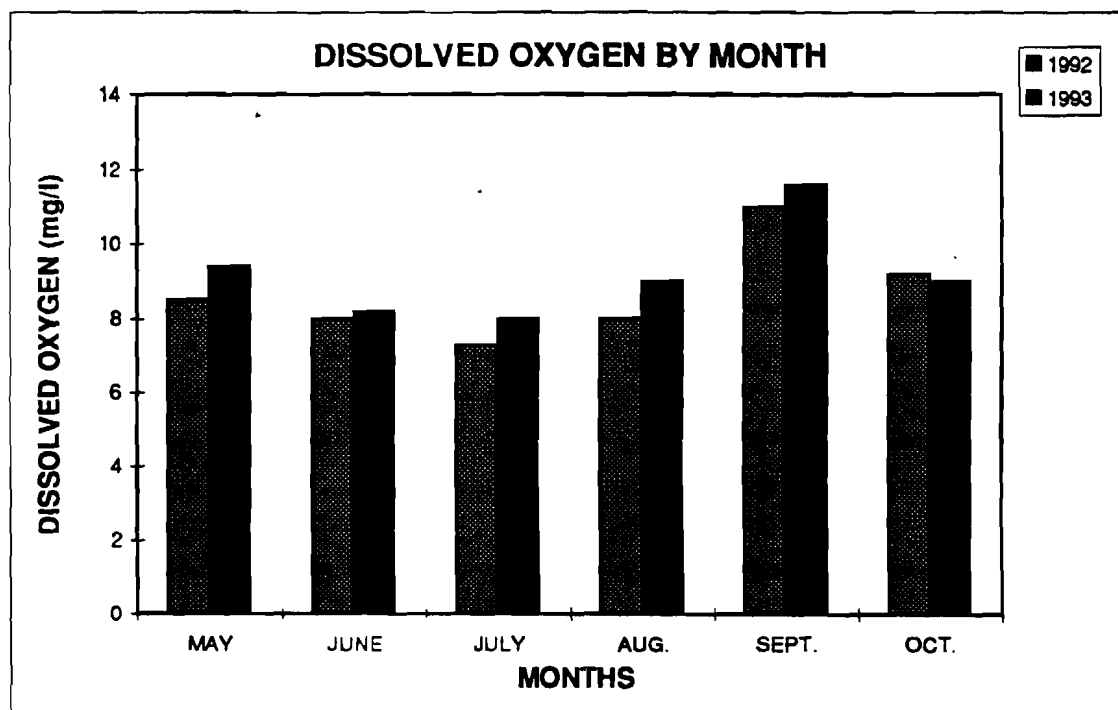


Figure 19. Monthly dissolved oxygen at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

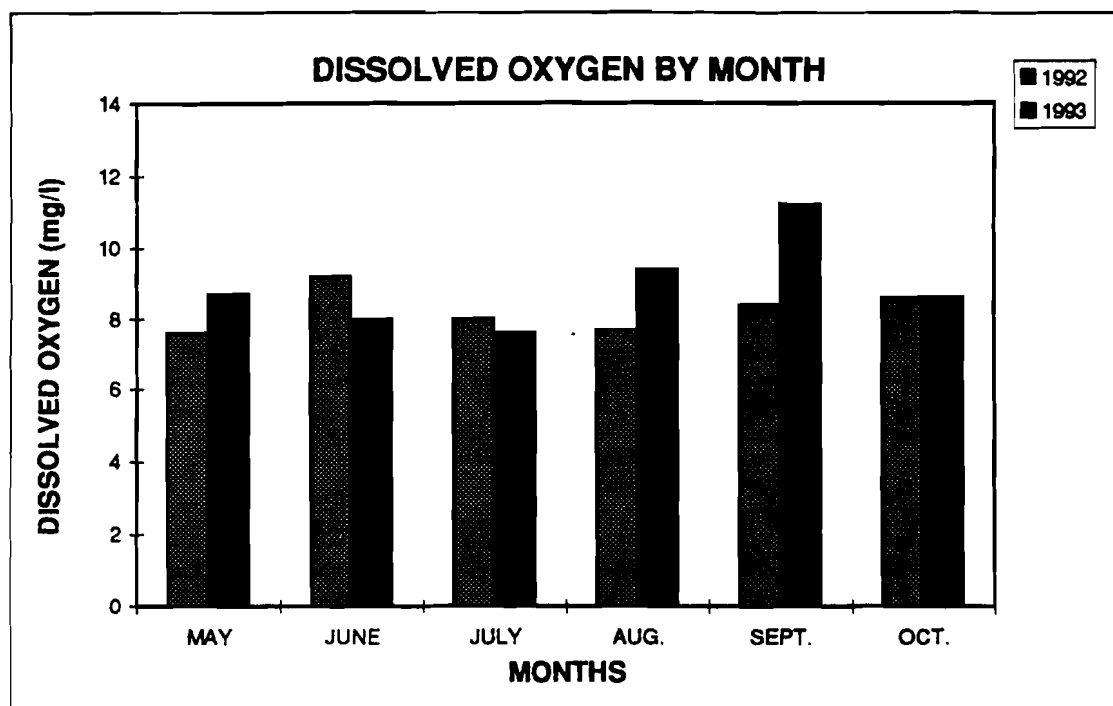


Figure 20. Monthly dissolved oxygen at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

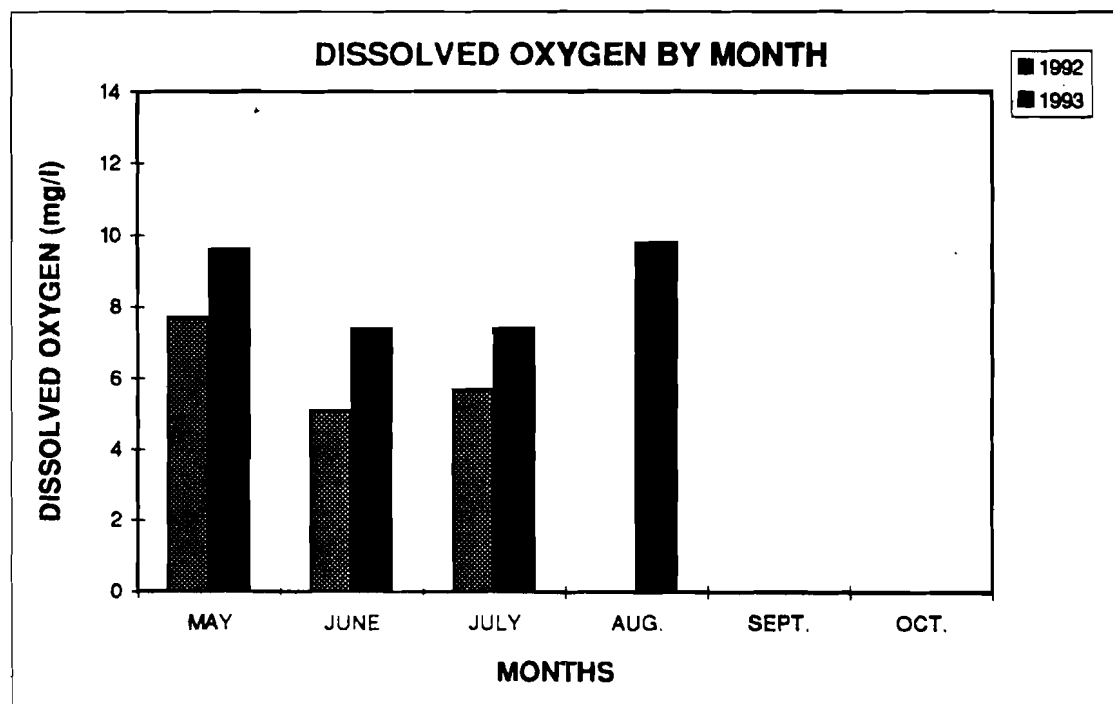


Figure 21. Monthly dissolved oxygen below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

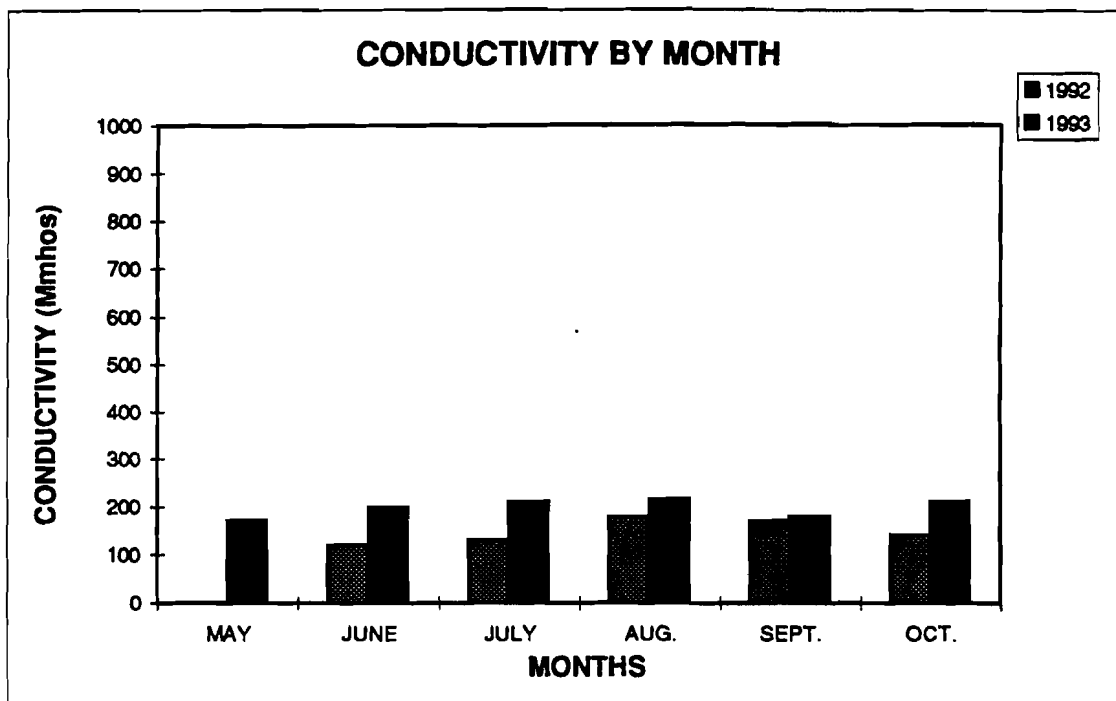


Figure 22. Monthly conductivity at upper site on Leech Creek, May through October, 1992 and 1993.

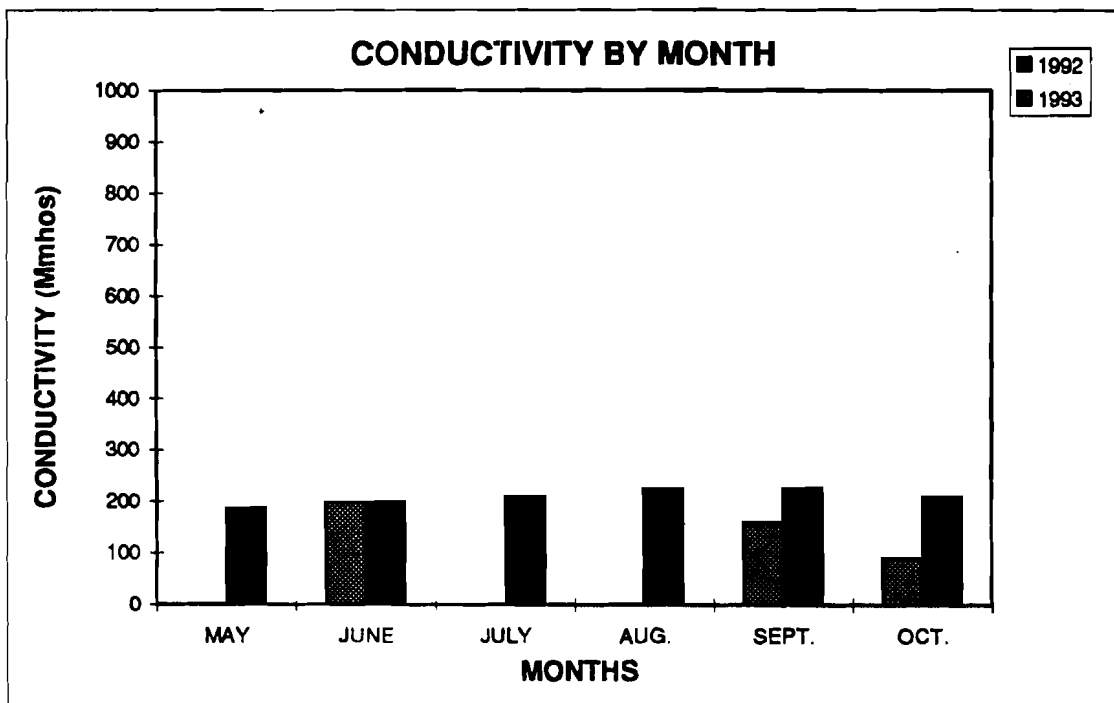


Figure 23. Monthly conductivity at lower site on Leech Creek, May through October 1992 and 1993.

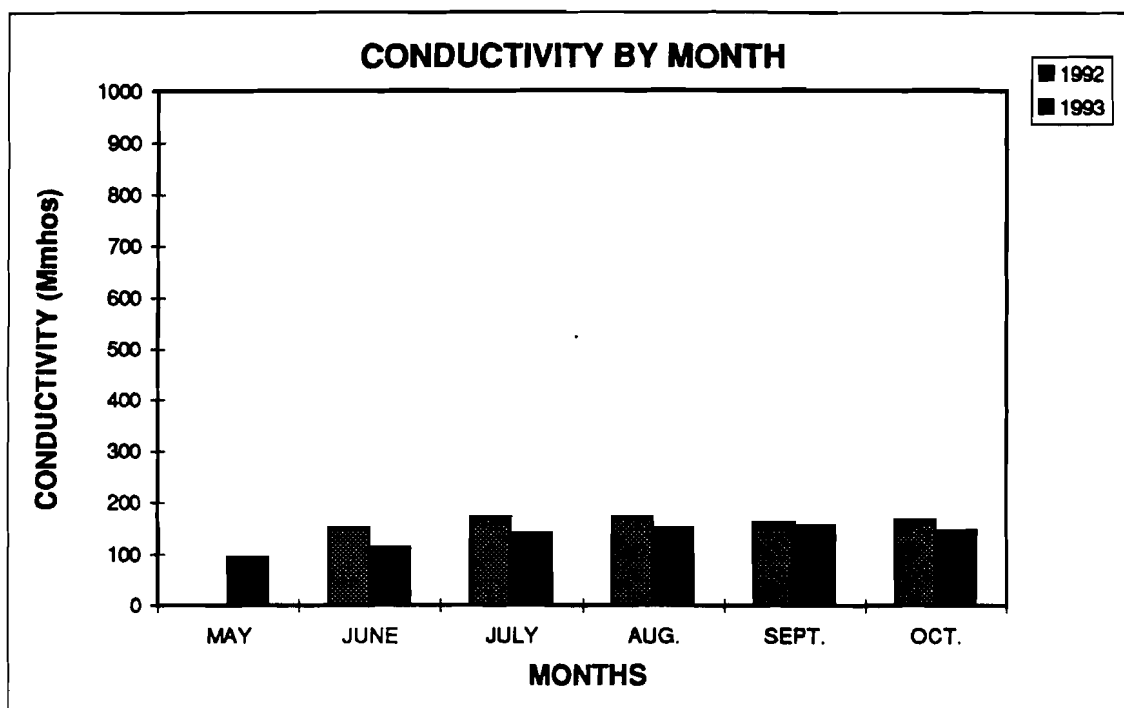


Figure 24. Monthly conductivity at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

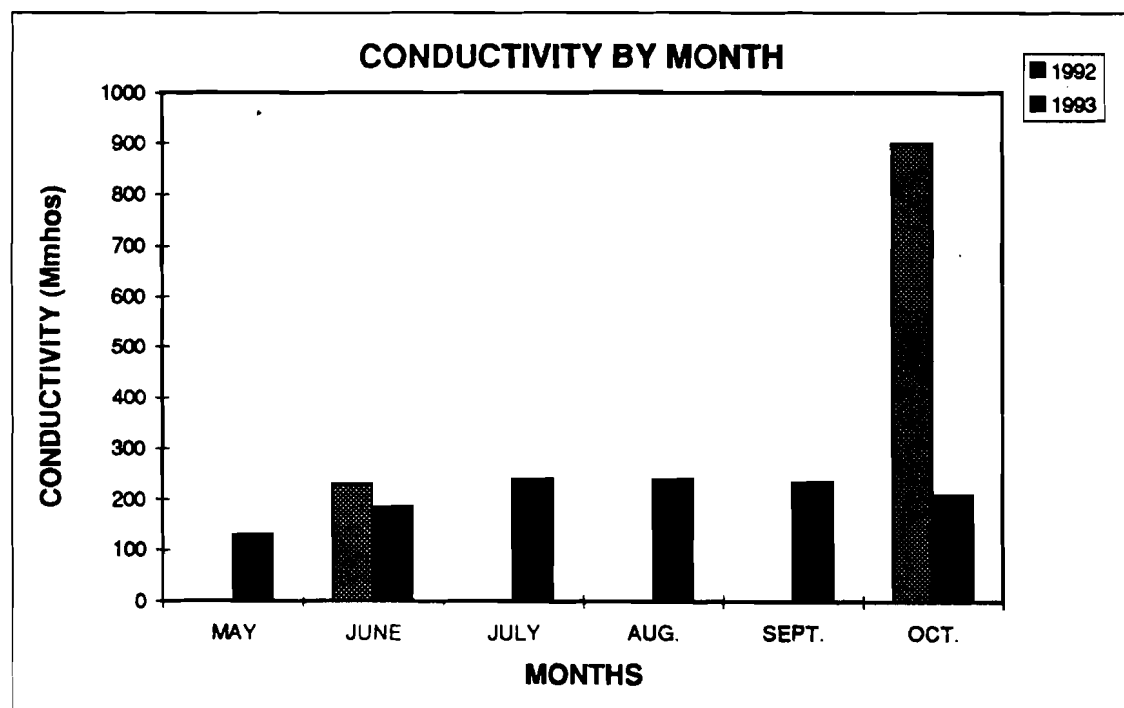


Figure 25. Monthly conductivity below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

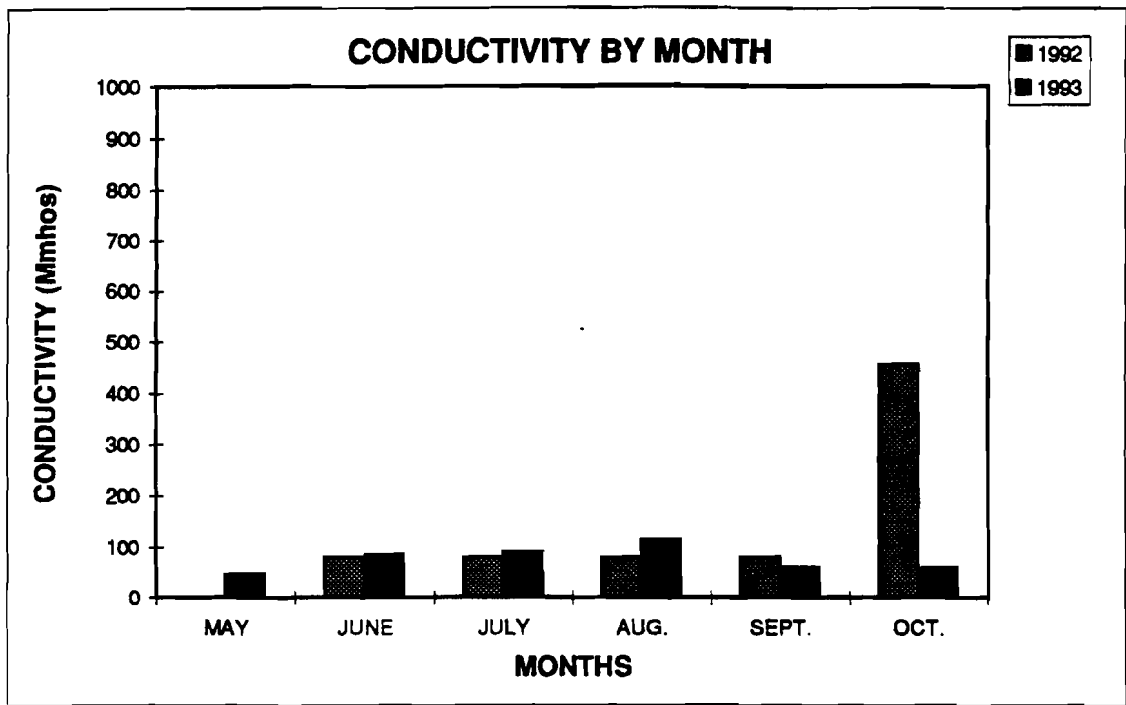


Figure 26. Monthly conductivity at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

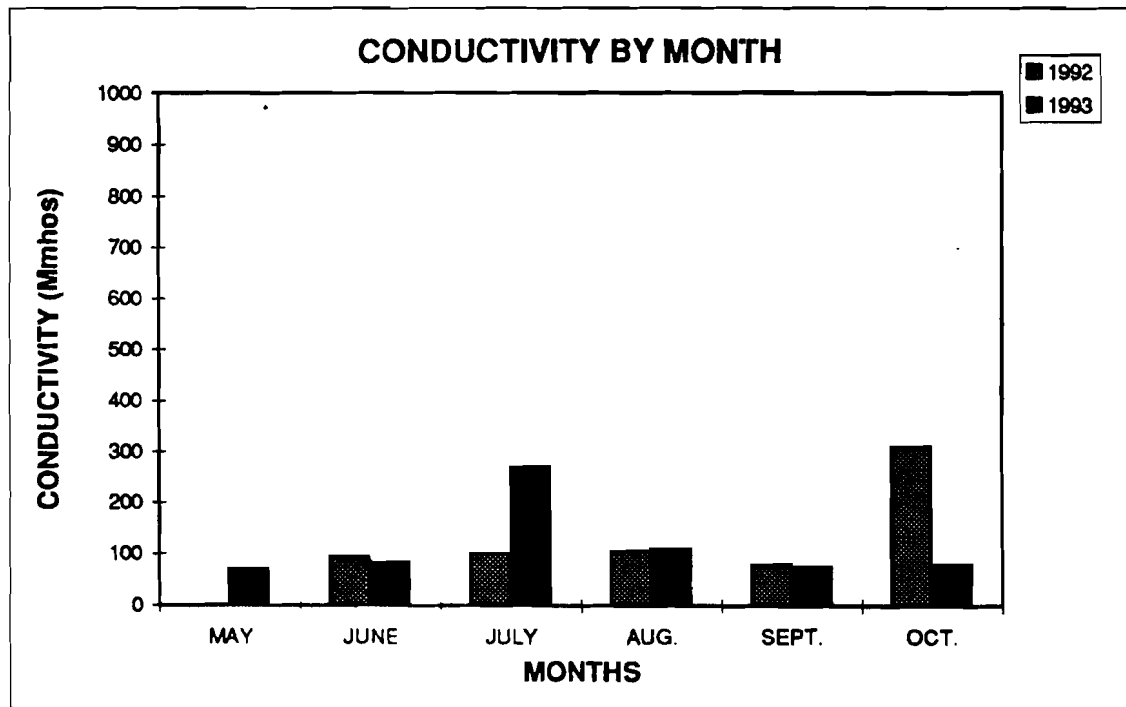


Figure 27. Monthly conductivity at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

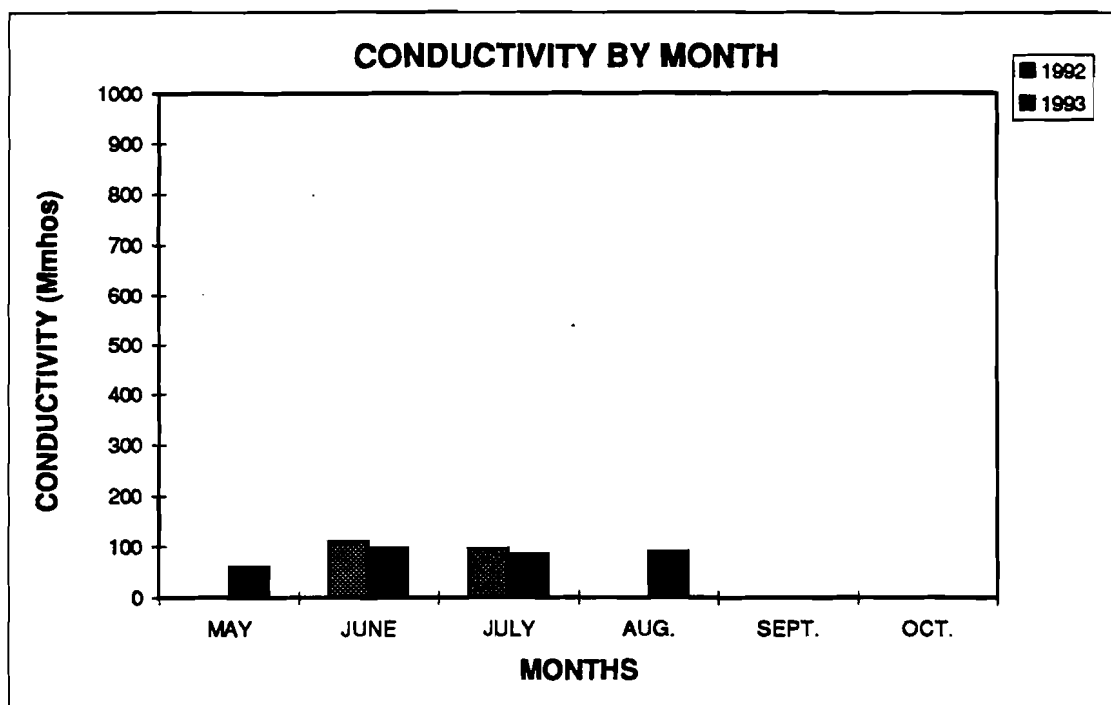


Figure 28. Monthly conductivity below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

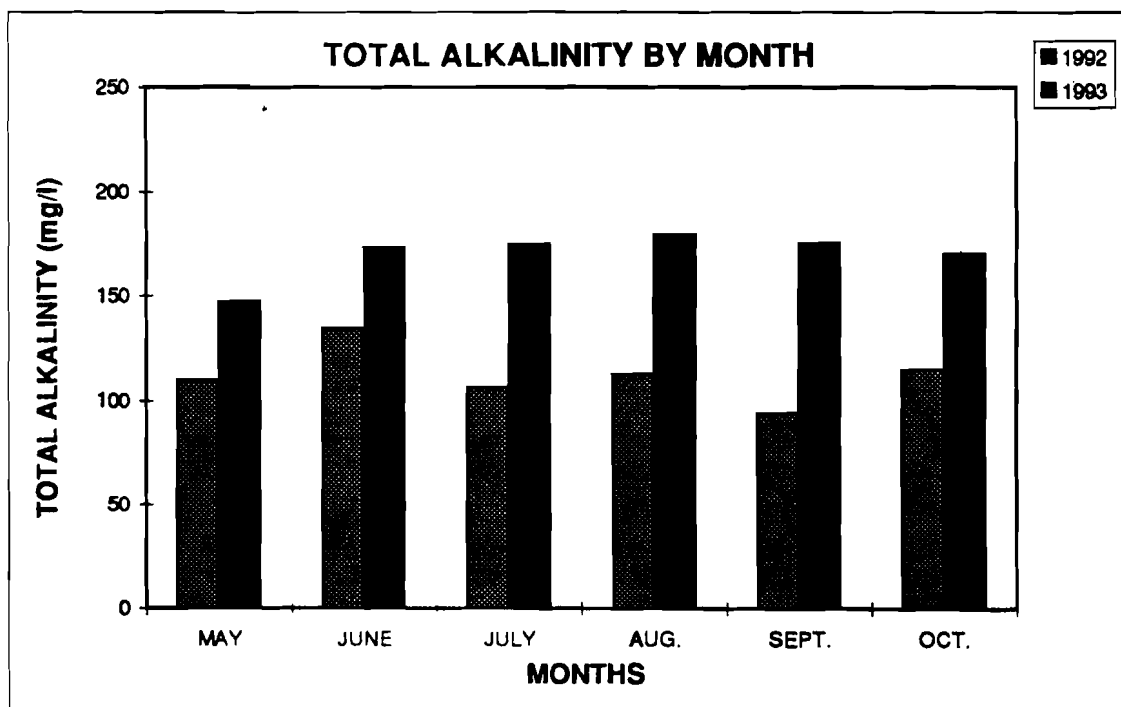


Figure 29. Mean total alkalinity at upper site on Leech Creek, May through October, 1992 and 1993.

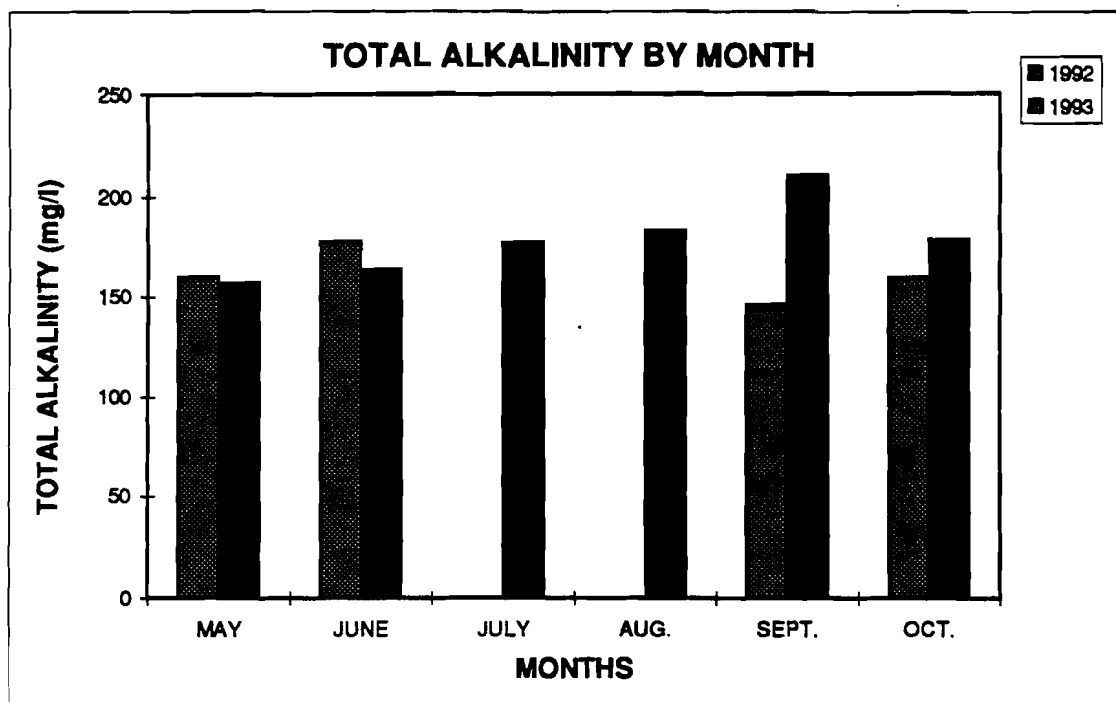


Figure 30. Mean monthly total alkalinity at lower site on Leech Creek, May through October, 1992 and 1993.

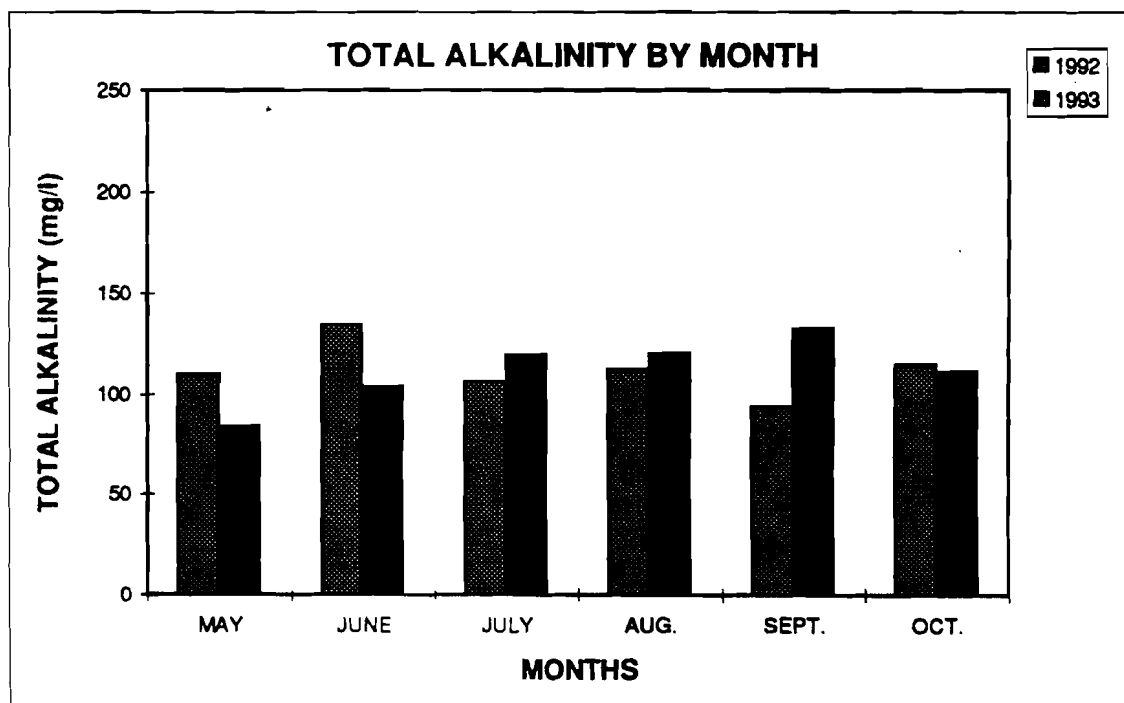


Figure 31. Mean monthly total alkalinity at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

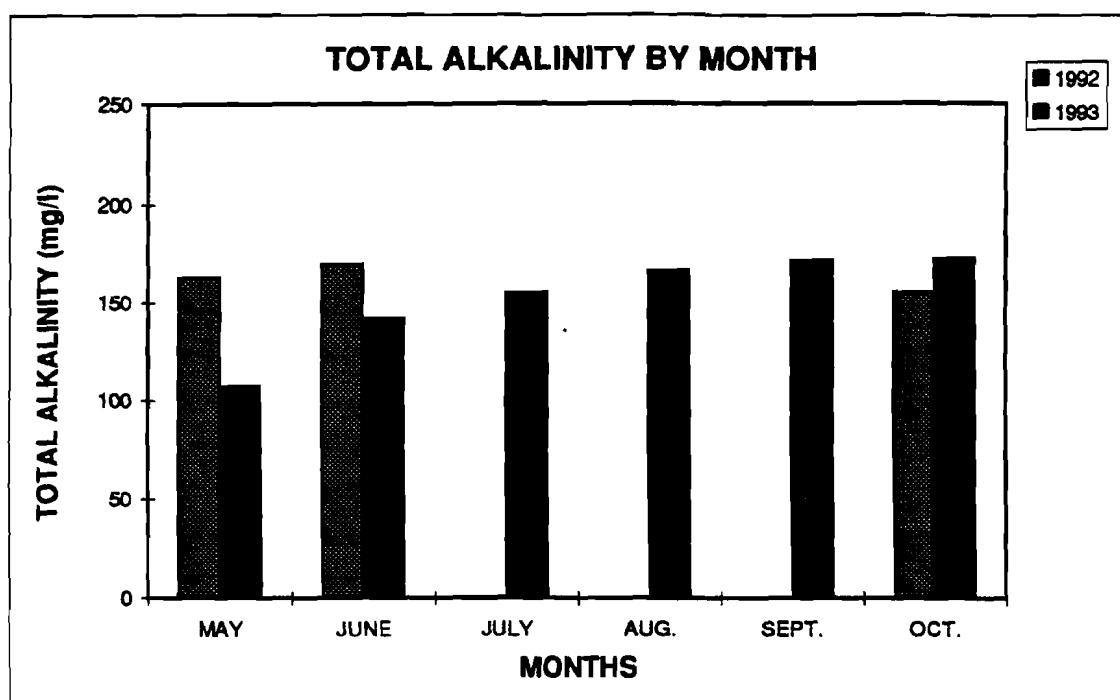


Figure 32. Mean monthly total alkalinity below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

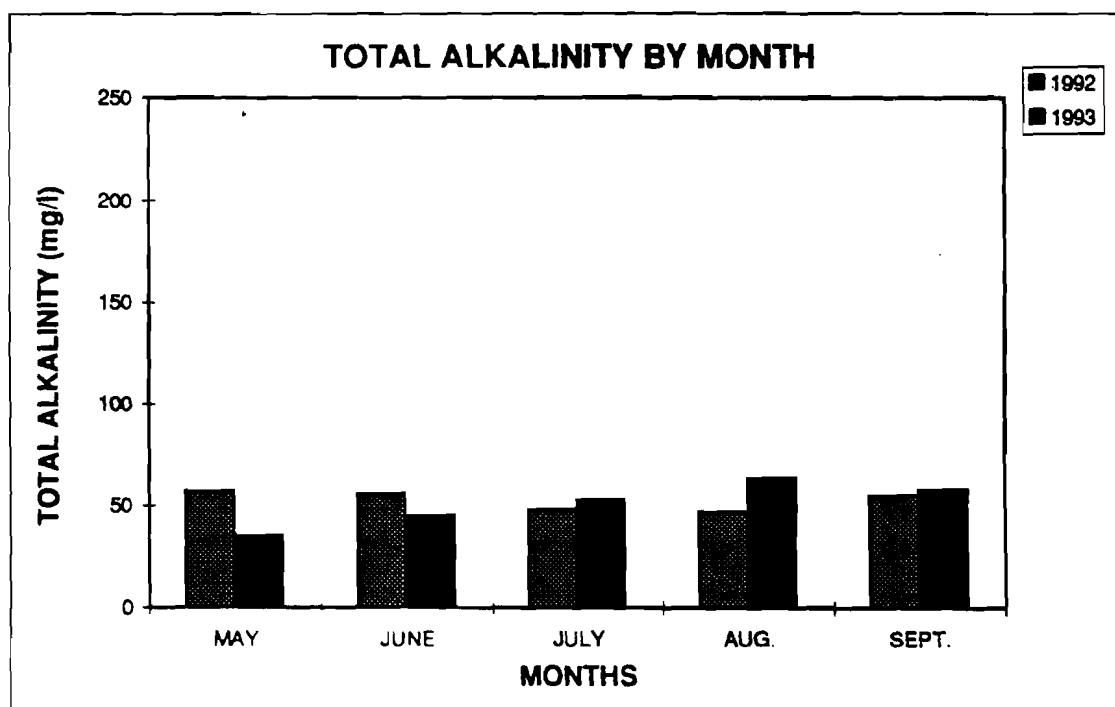


Figure 33. Mean monthly total alkalinity at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

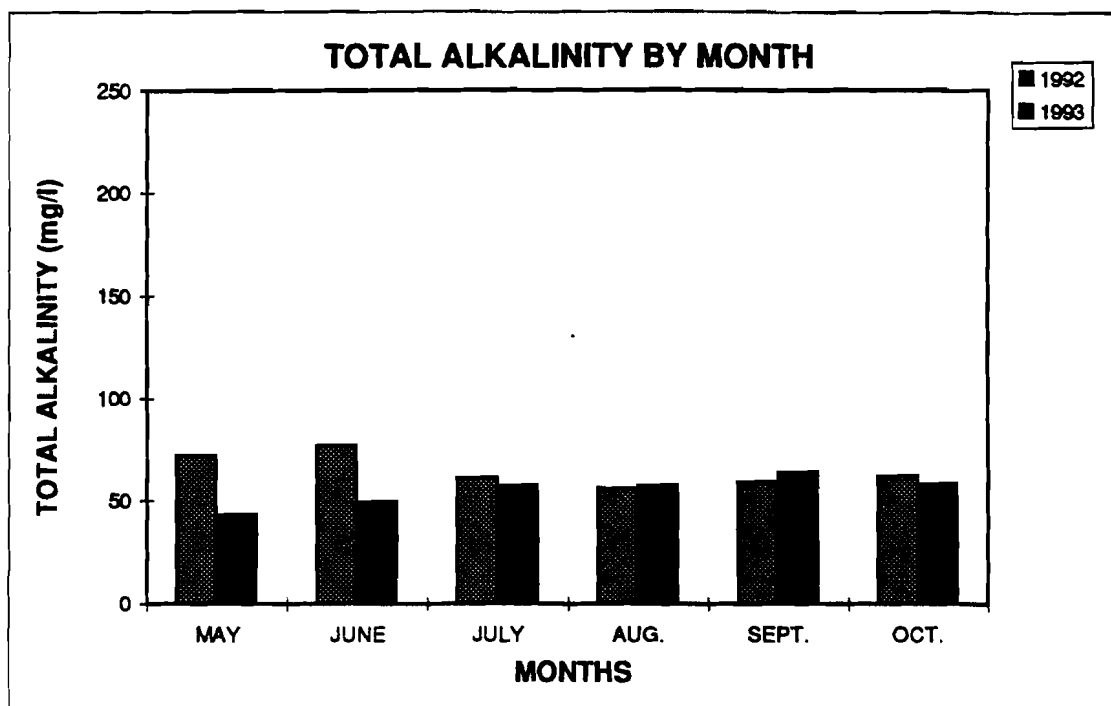


Figure 34. Mean monthly total alkalinity at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

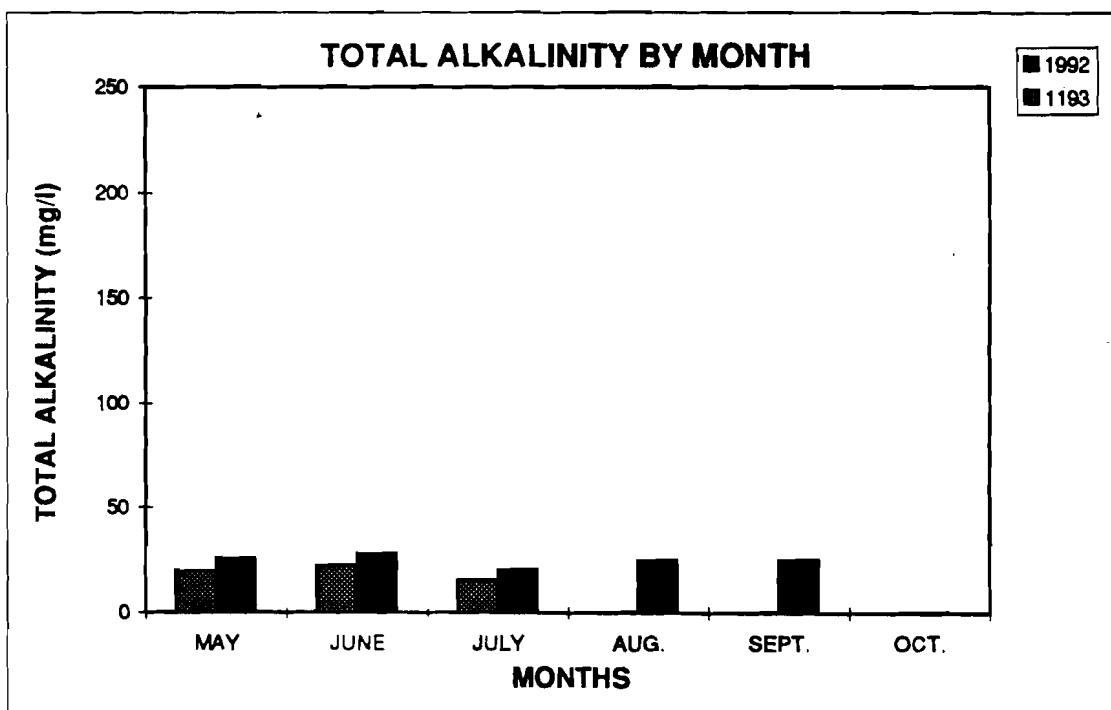


Figure 35. Mean monthly total alkalinity below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

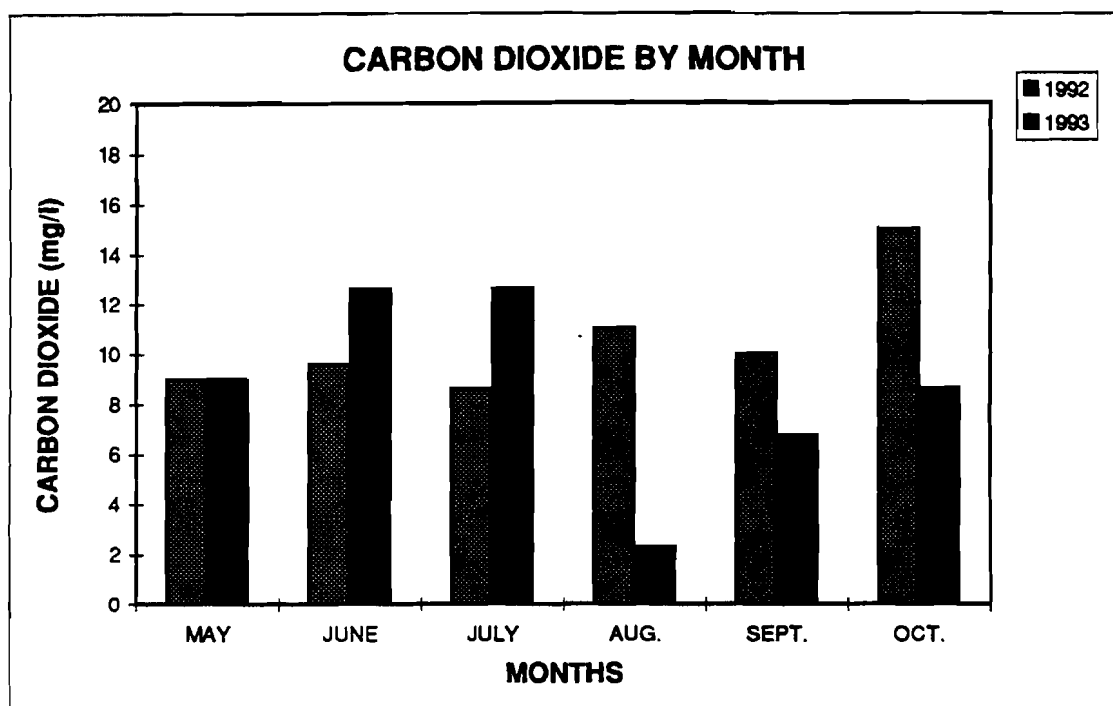


Figure 36. Mean monthly carbon dioxide at upper site on Leech Creek, May through October, 1992 and 1993.

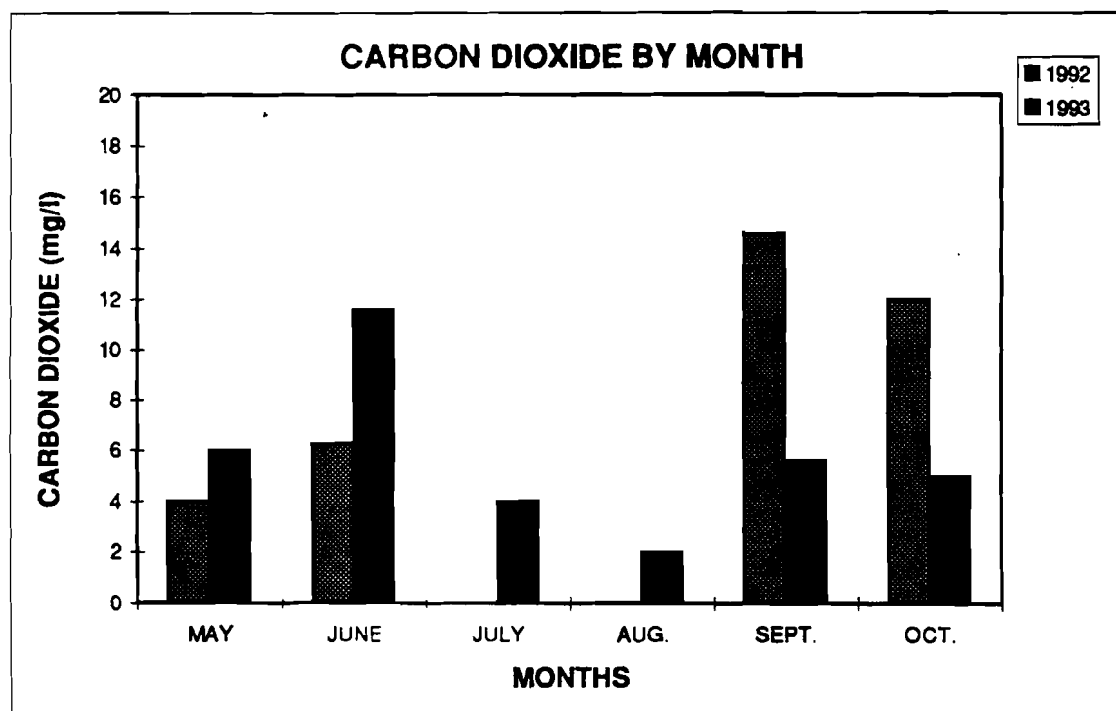


Figure 37. Mean monthly carbon dioxide at lower site on Leech Creek, May through October, 1992 and 1993.

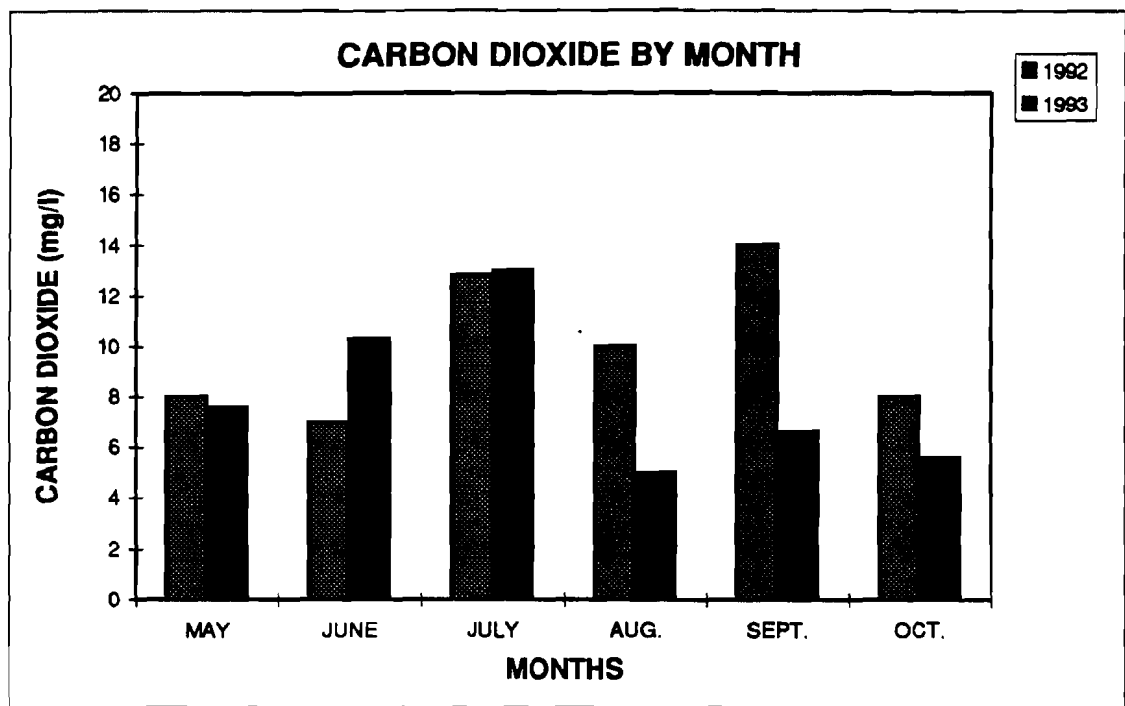


Figure 38. Mean monthly carbon dioxide at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

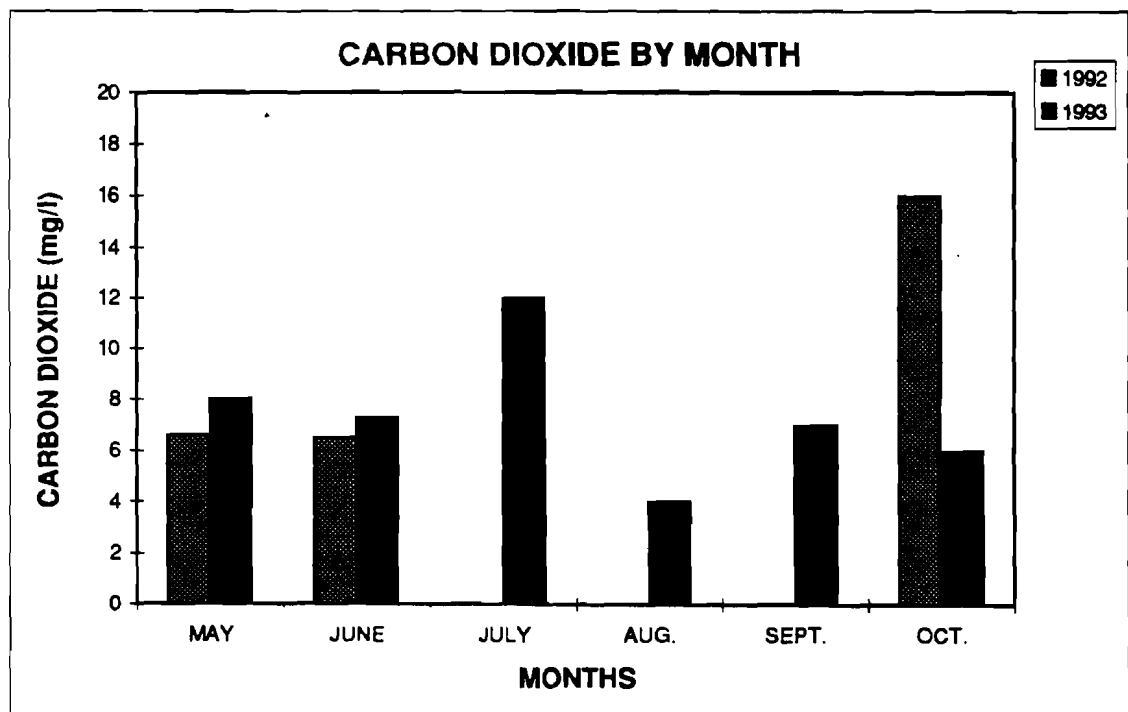


Figure 39. Mean monthly carbon dioxide below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

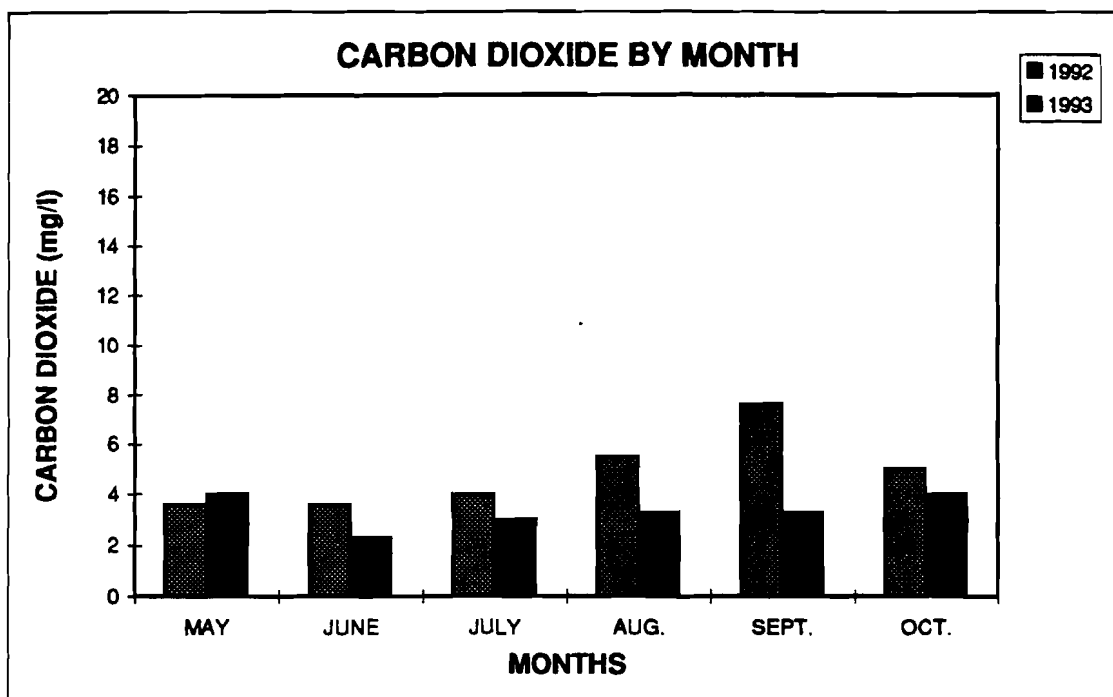


Figure 40. Mean monthly carbon dioxide at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

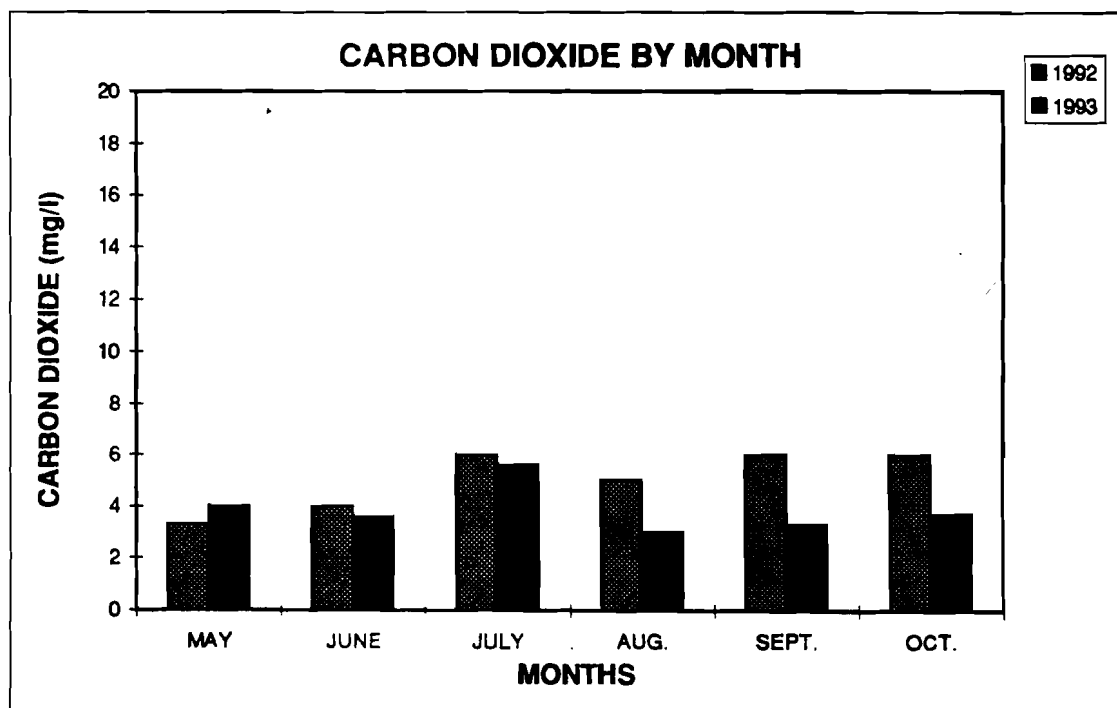


Figure 41. Mean monthly carbon dioxide at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

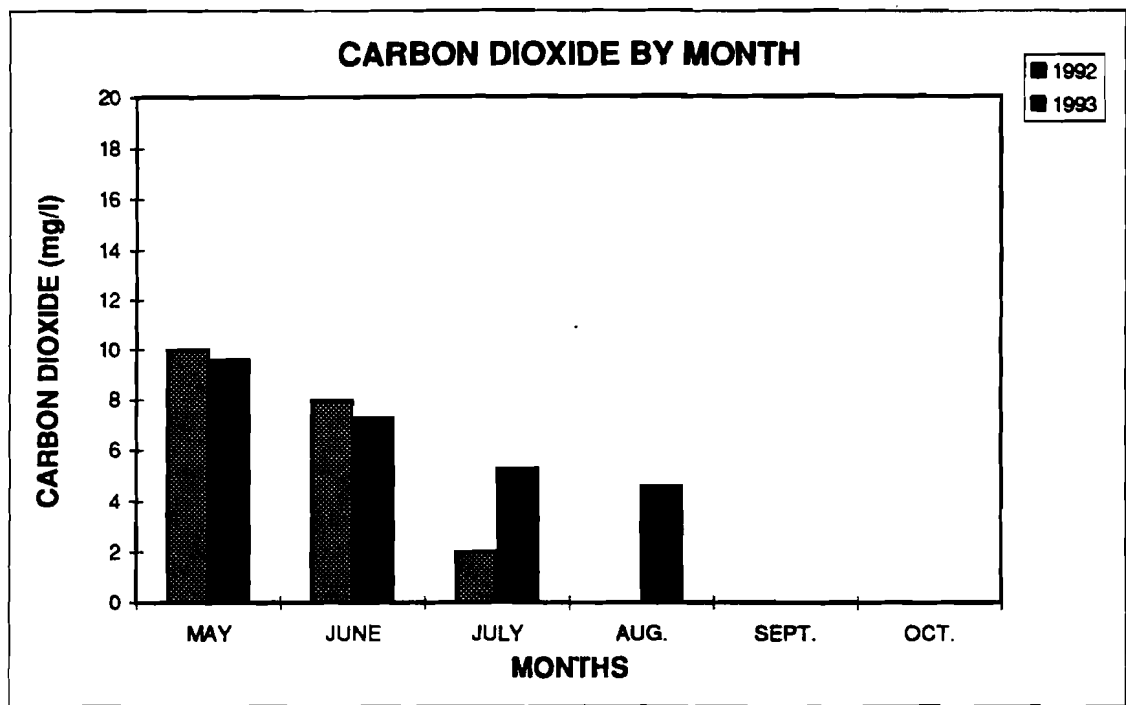


Figure 42. Mean monthly carbon dioxide below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

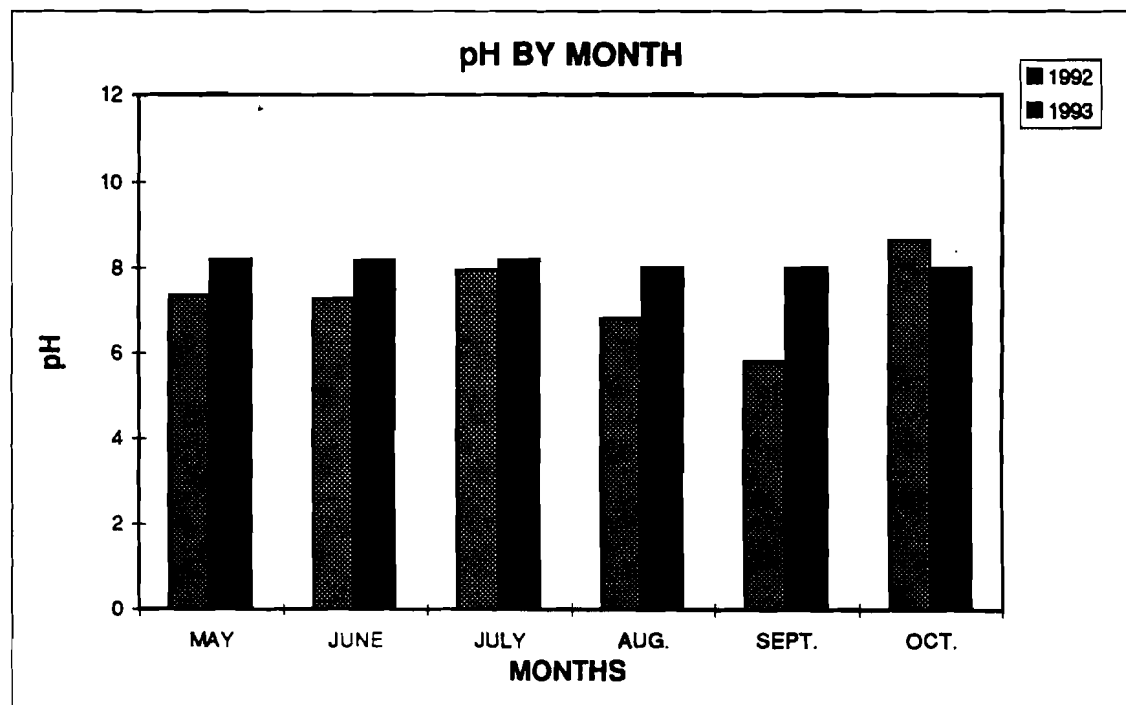


Figure 43. Monthly pH at upper site on Leech Creek, May through October, 1992 and 1993.

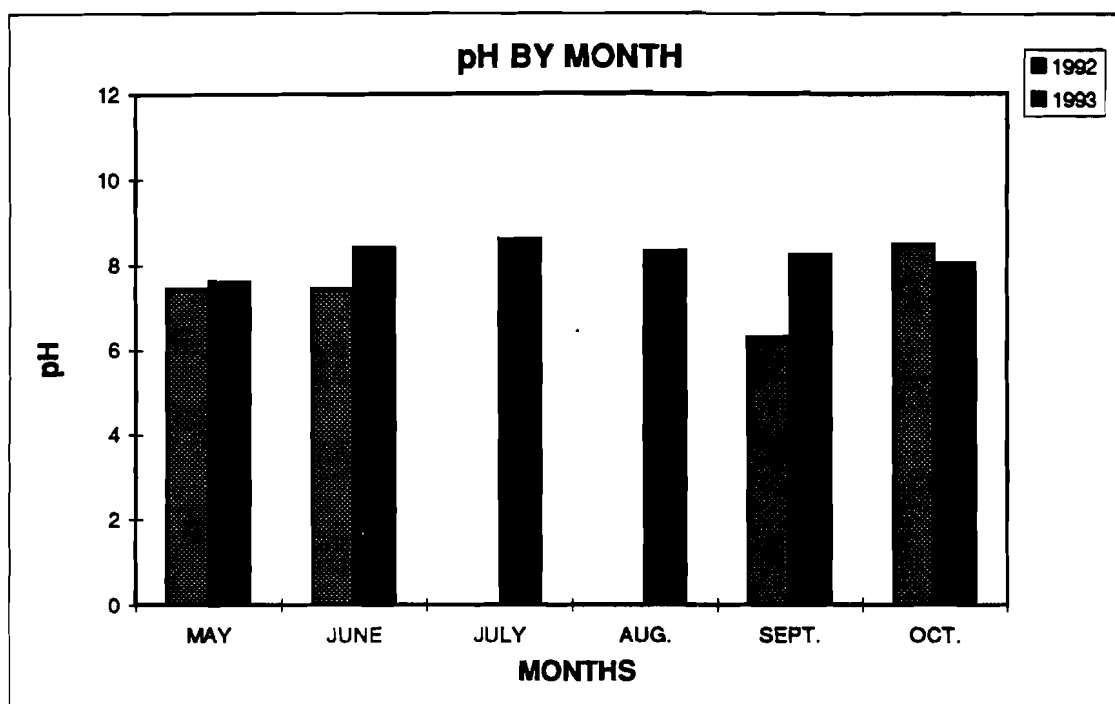


Figure 44. Monthly pH at lower site on Leech Creek, May through October, 1992 and 1993.

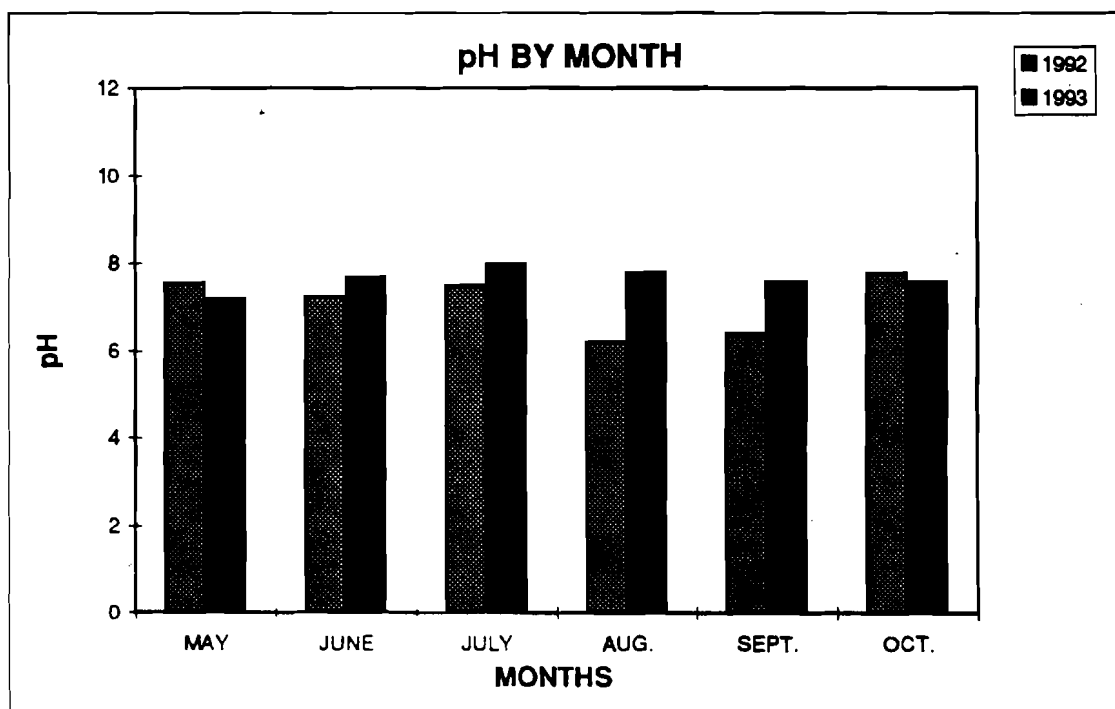


Figure 45. Monthly pH at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

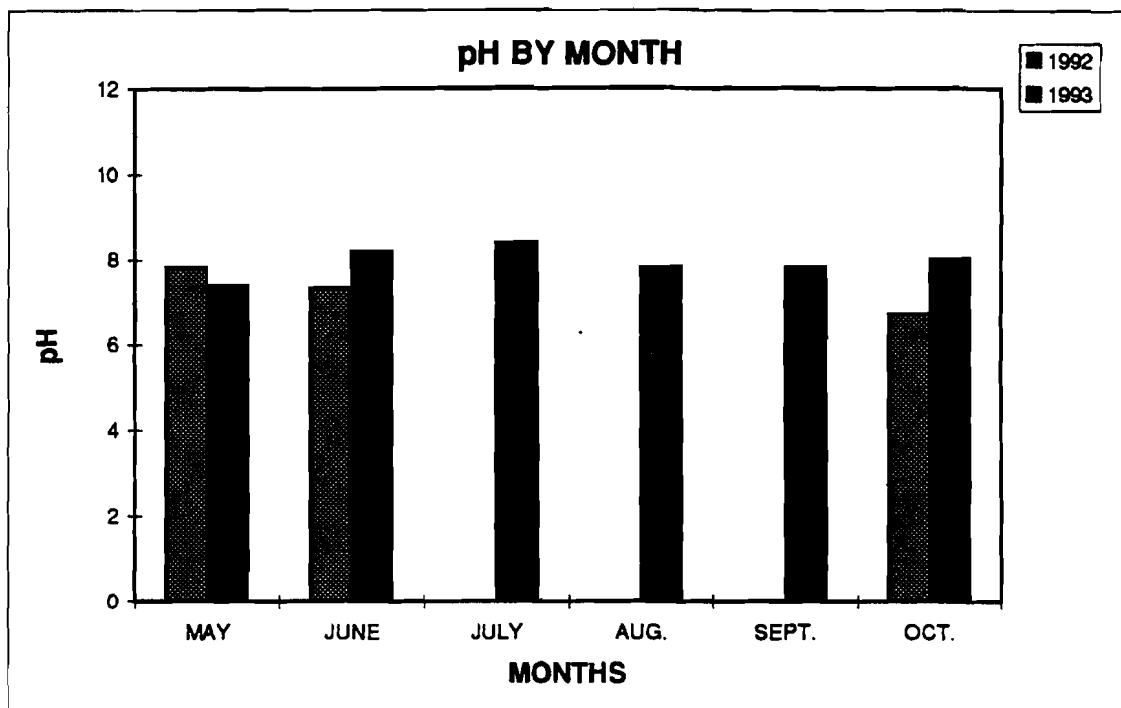


Figure 46. Monthly pH below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

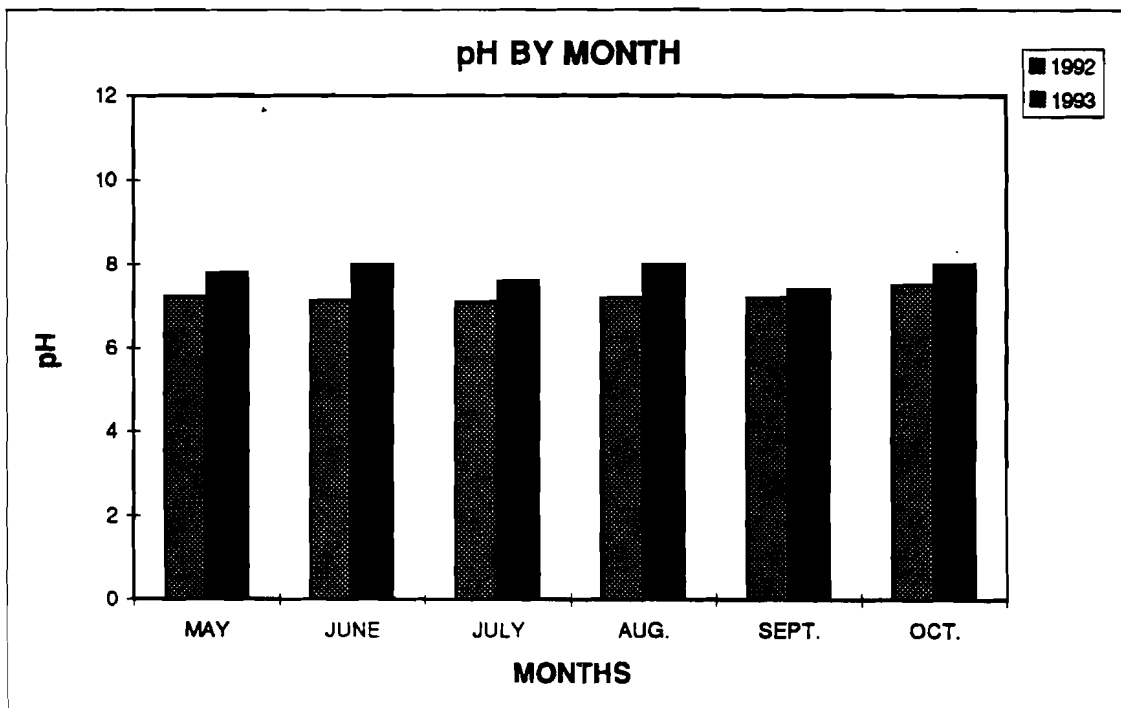


Figure 47. Monthly pH at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

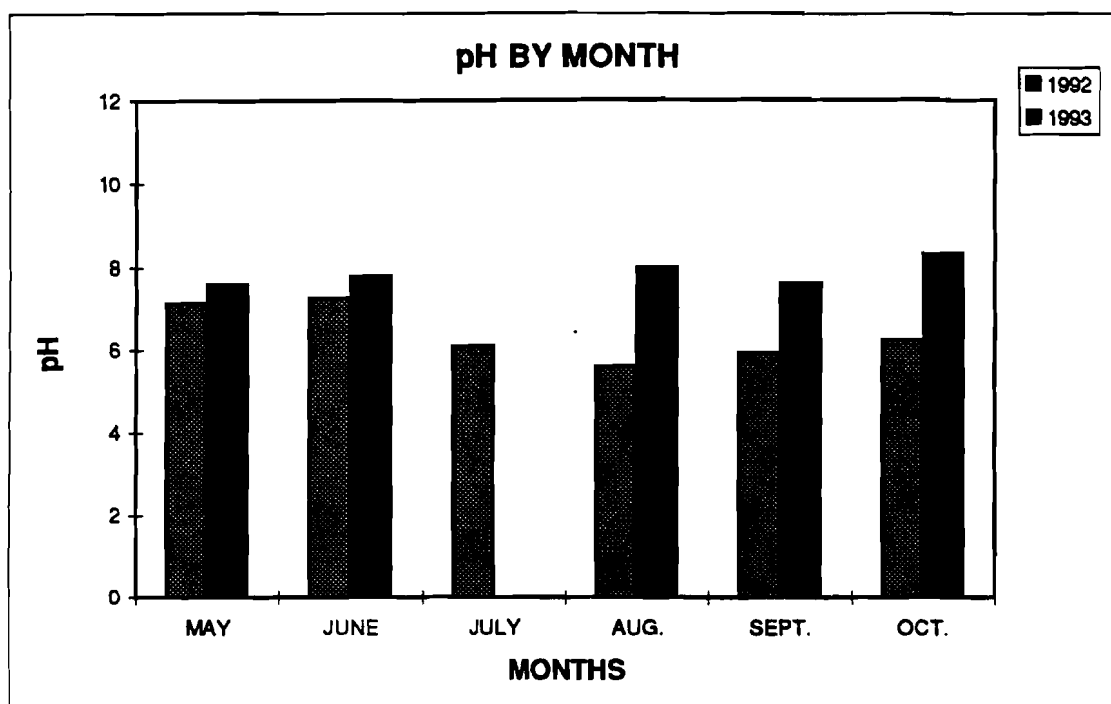


Figure 48. Monthly pH at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

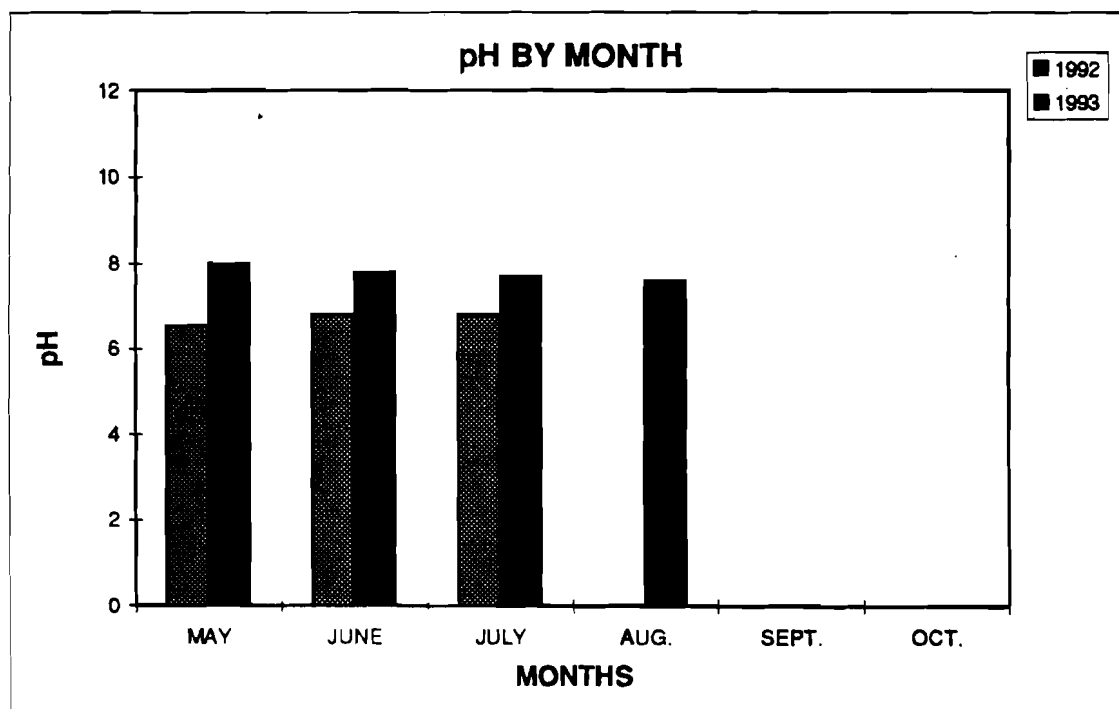


Figure 49. Monthly pH below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

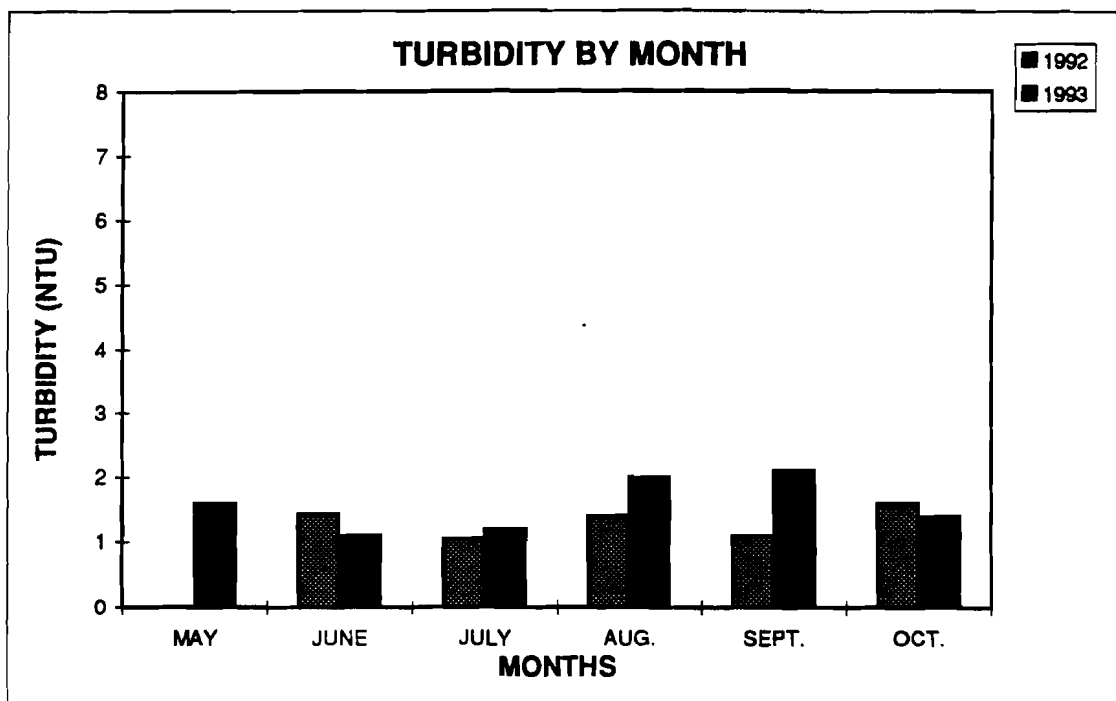


Figure 50. Mean monthly turbidity at upper site on Leech Creek, May through October, 1992 and 1993.

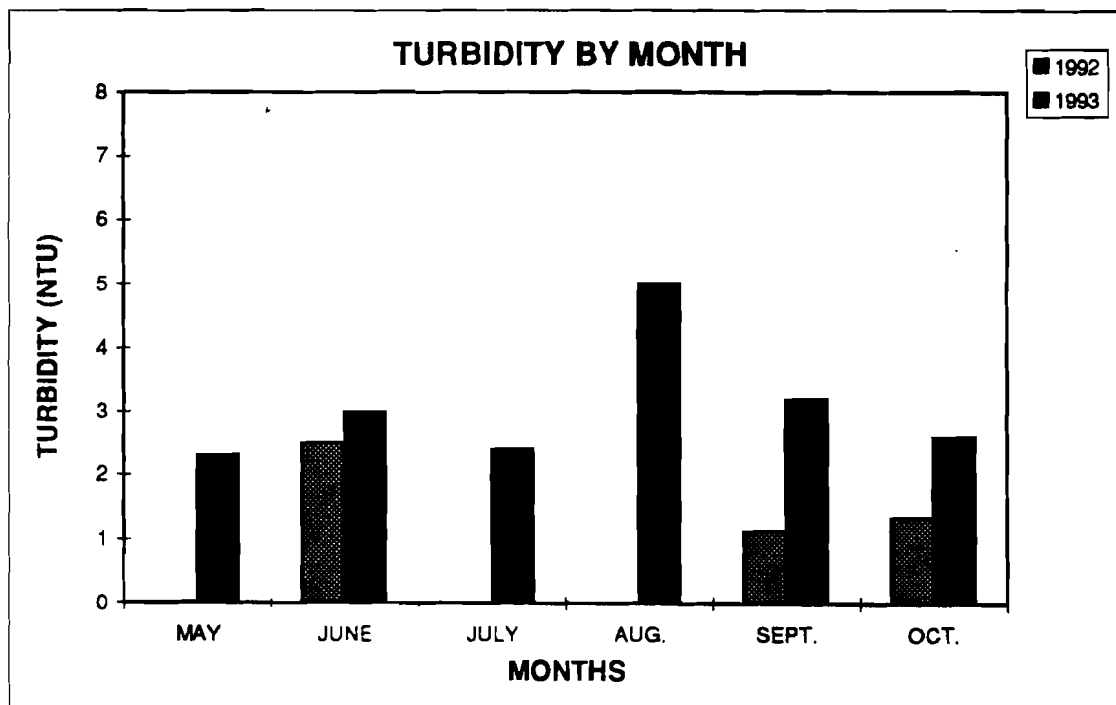


Figure 51. Mean monthly turbidity at lower site on Leech Creek, May through October, 1992 and 1993.

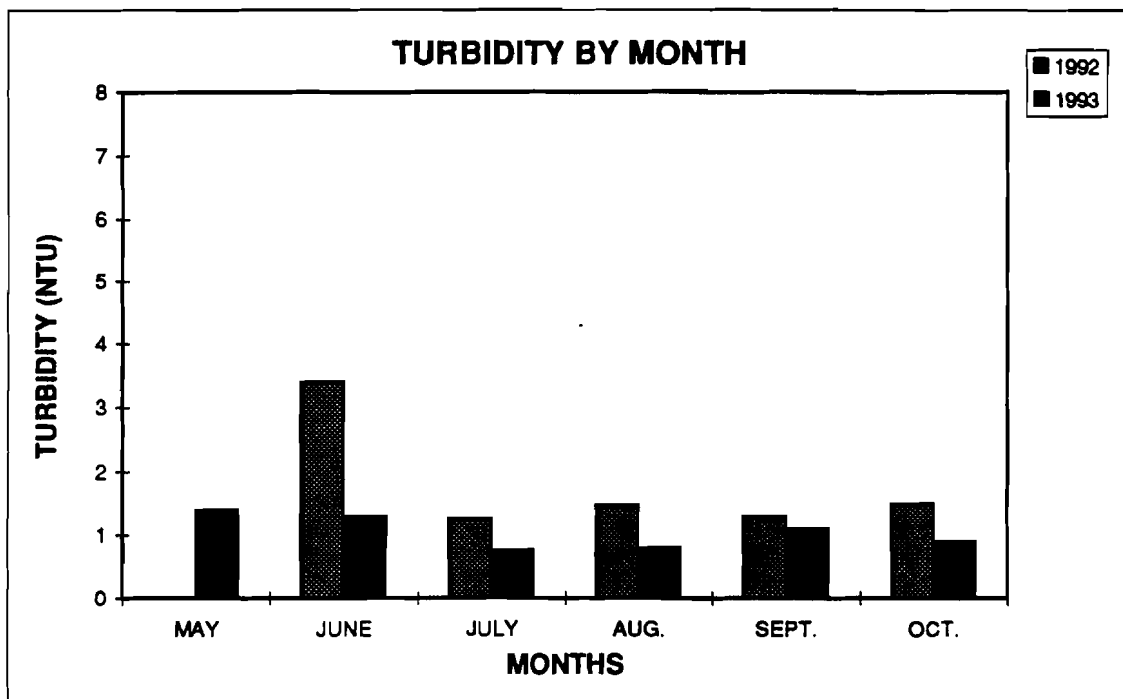


Figure 52. Mean monthly turbidity at upper site on Little Cottonwood Creek, May through October, 1992 and 1993.

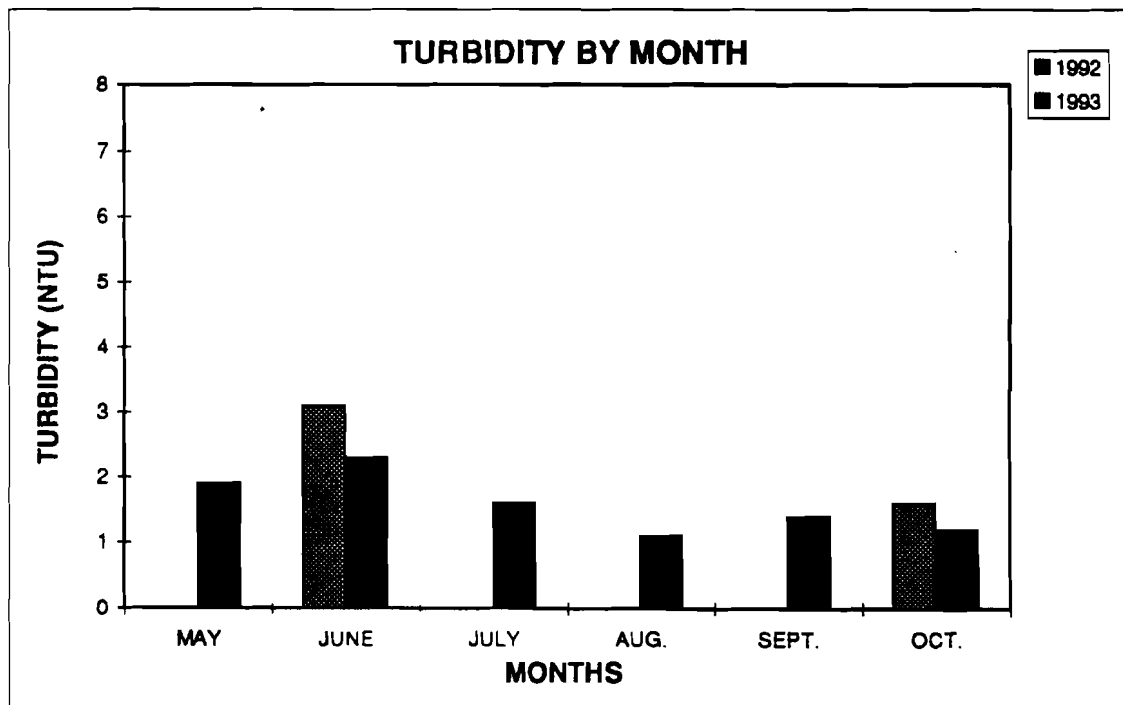


Figure 53. Mean monthly turbidity below Martin Mine on Little Cottonwood Creek, May through October, 1992 and 1993.

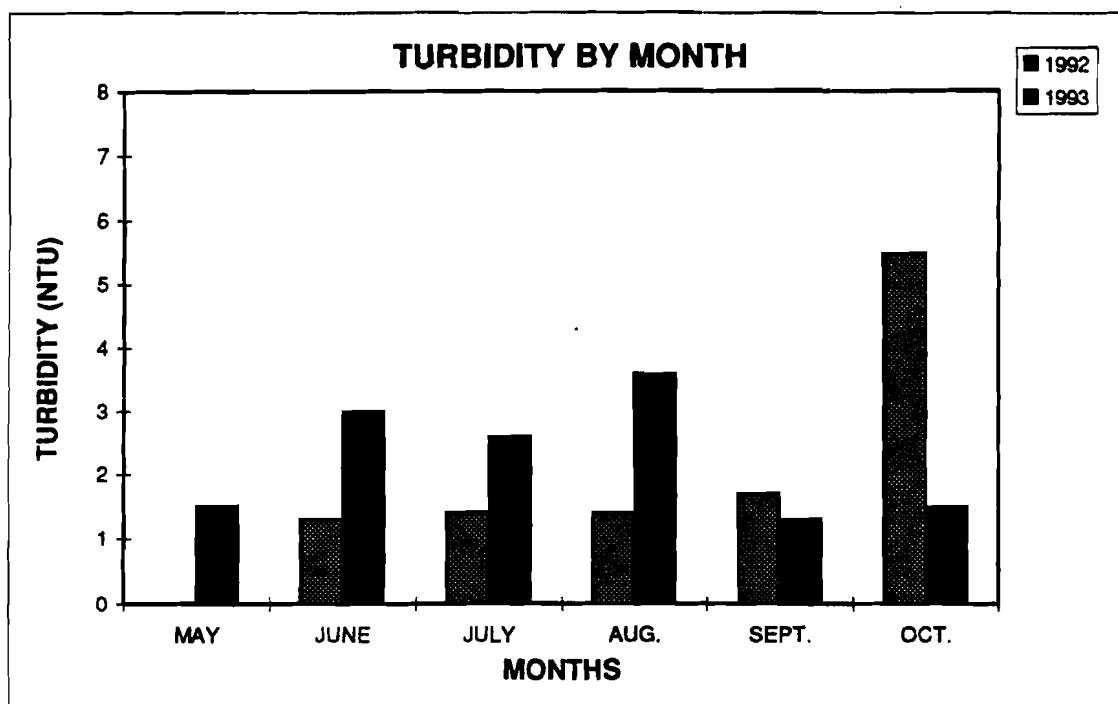


Figure 54. Mean monthly turbidity at upper site on Big Cottonwood Creek, May through October, 1992 and 1993.

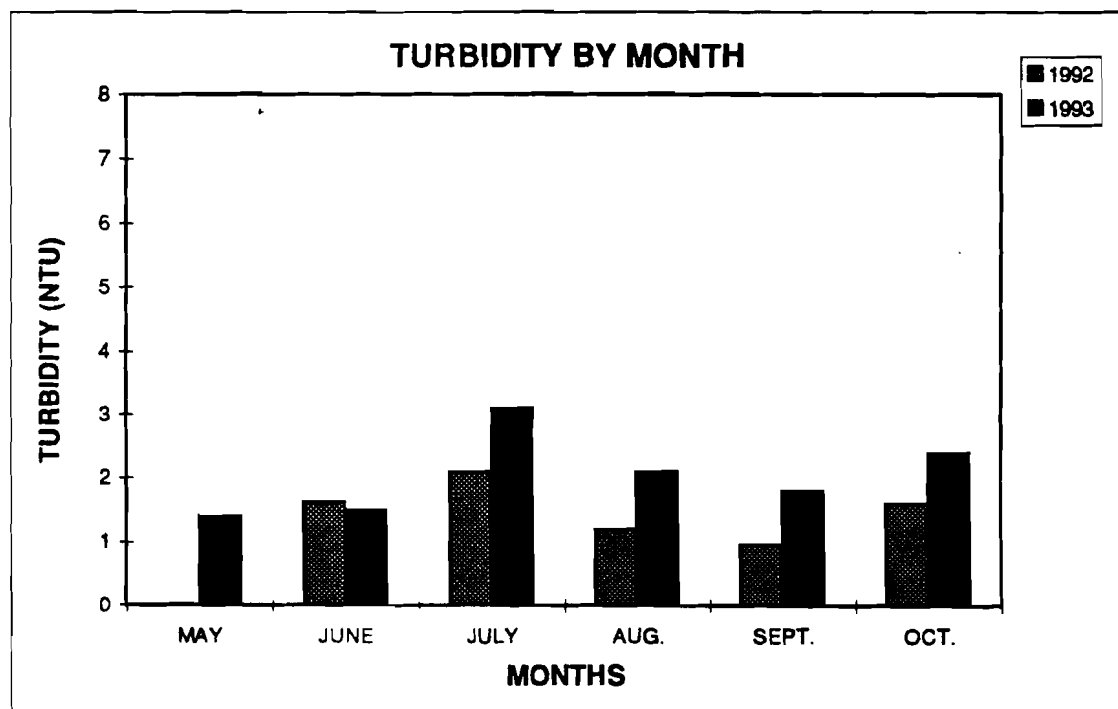


Figure 55. Mean monthly turbidity at lower site on Big Cottonwood Creek, May through October, 1992 and 1993.

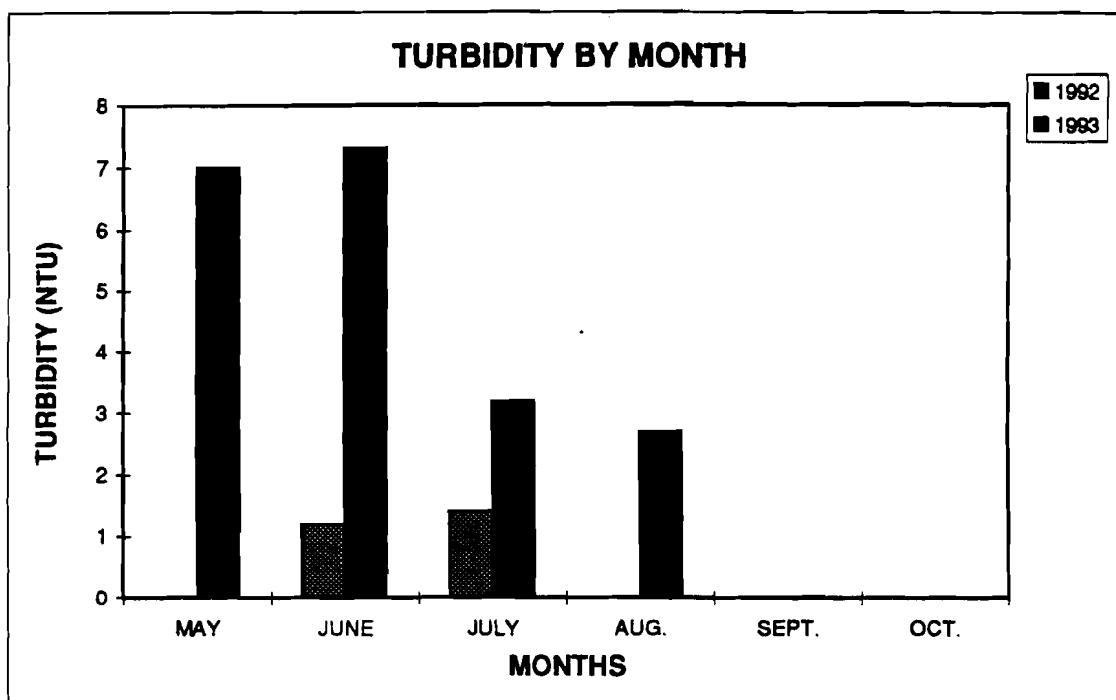


Figure 56. Mean monthly turbidity below Paymaster Mine on Big Cottonwood Creek, May through October, 1992 and 1993.

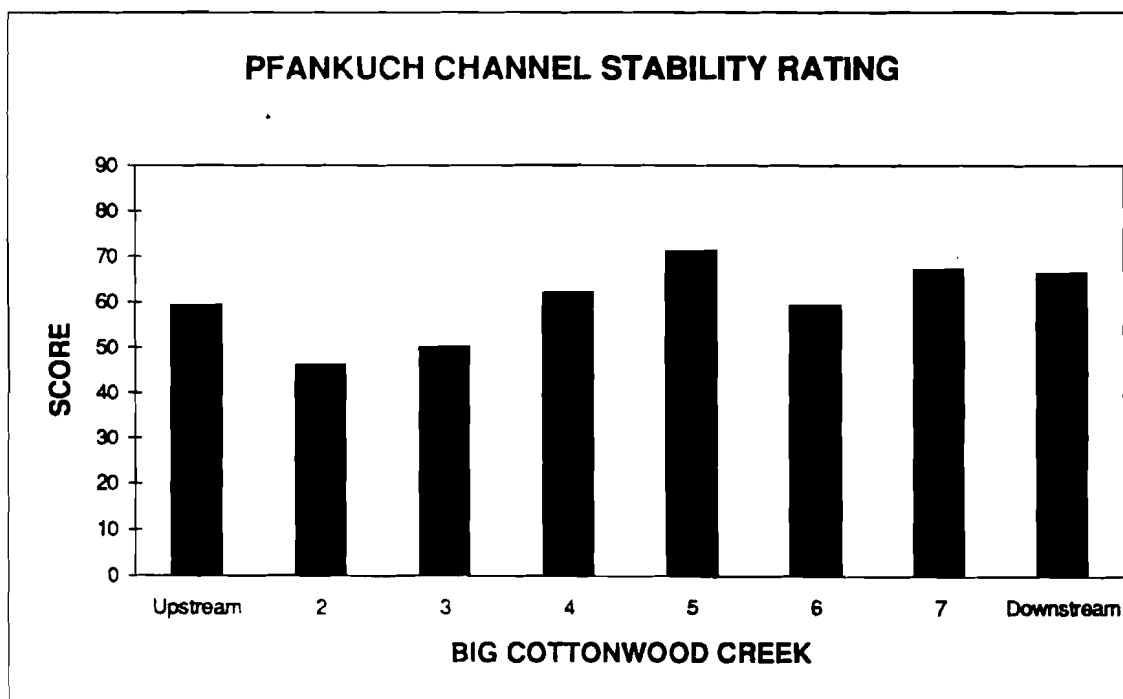


Figure 57. PFANKUCH stability rating for Big Cottonwood Creek, sites 1 through 8, May through October, 1992 and 1993.

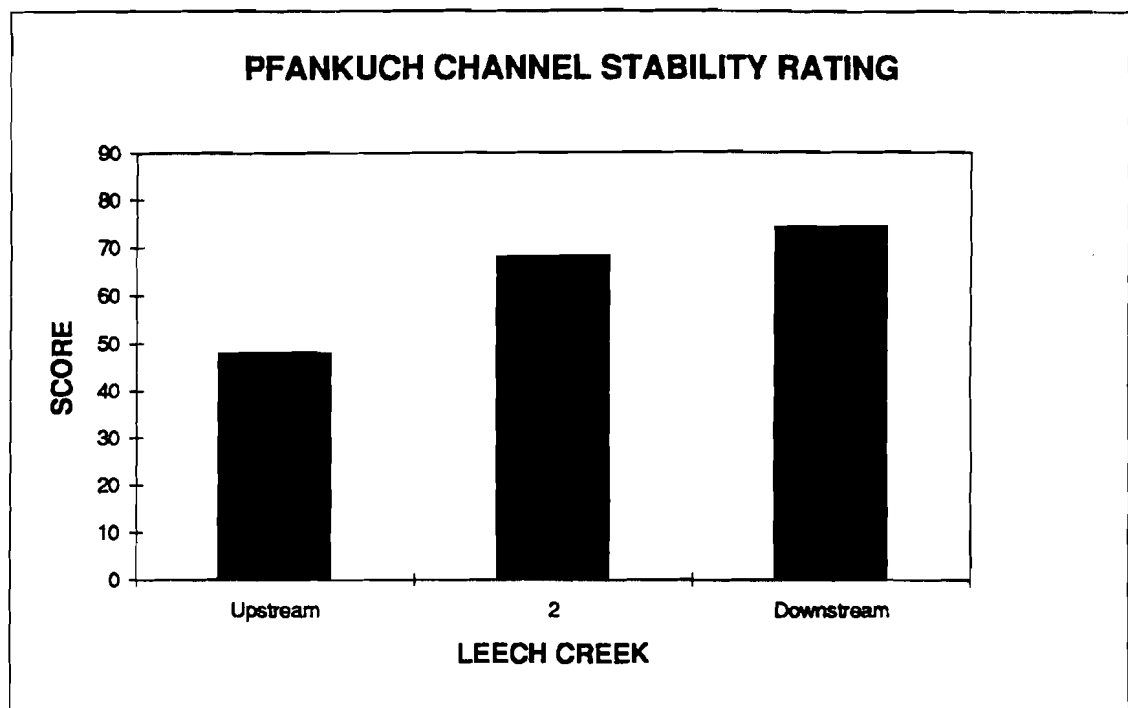


Figure 58. PFANKUCH stability rating for Leech Creek sites 1 through 3, May through October, 1992 and 1993.

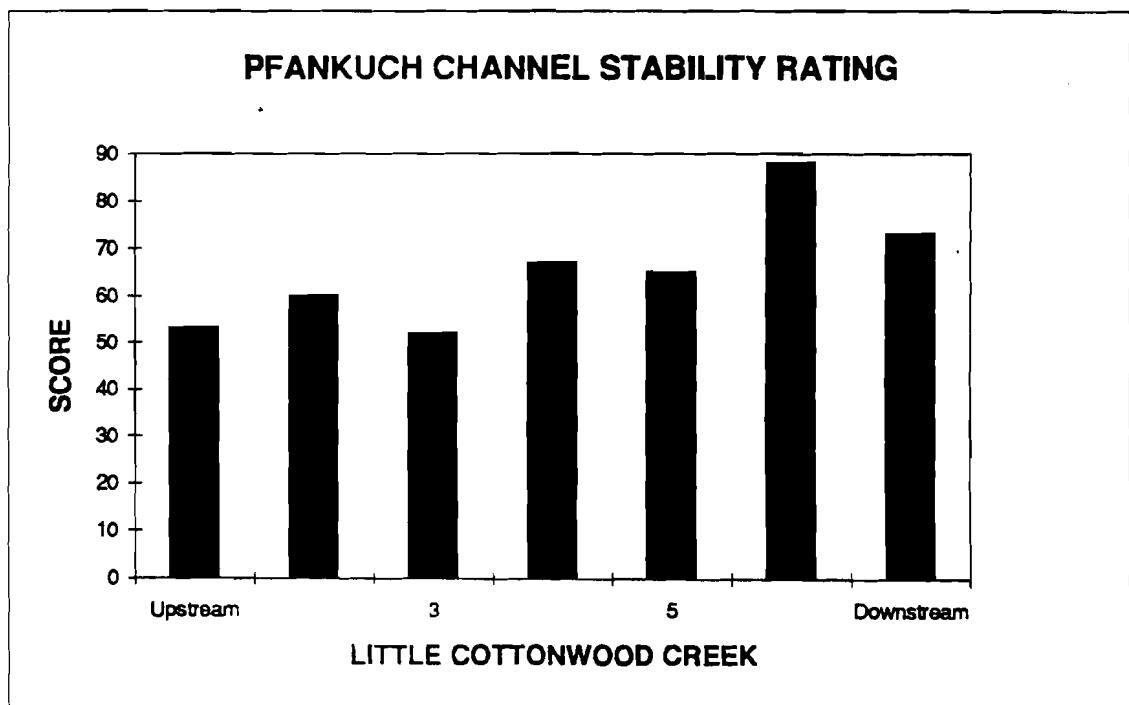


Figure 59. PFANKUCH stability rating for Little Cottonwood Creek sites 1 through 7, May through October, 1992 and 1993.

TABLES

Table 1. Leech Creek water quality data, 1992 at upper site (200 yards downstream from Monument boundary at an elevation of 6,420 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	11:15 AM	12:15 PM	8:20 AM	11:15 AM	11:00 AM	10:00 AM
Temperature (°C)	10.0	8.0	9.2	15.0	8.2	7.0
Oxygen (mg/l)	9.2	8.9	8.4	7.6	8.2	13.0
Conductivity (µmhos)	n/a	120.0	130.0	180.0	170.0	140.0
pH	7.34	7.28	7.95	6.80	5.80	8.66
Total Alkalinity (mg/l)	154.0	164.0	136.0	143.0	139.0	149.0
Carbon Dioxide (mg/l)	9.0	9.6	8.6	11.0	10.0	15.0
Turbidity (NTU)	n/a	1.44	1.05	1.40	1.10	1.60

Table 2. Leech Creek water quality data, 1992 at lower site (near research camp at an elevation of 6,000 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	1:22 PM	2:20 PM	DRY	DRY	12:26 PM	11:30 AM
Temperature (°C)	12.7	9.0	-----	-----	11.0	8.5
Oxygen (mg/l)	9.2	8.3	-----	-----	11.2	8.9
Conductivity (µmhos)	n/a	197.0	-----	-----	160.0	90.0
pH	7.44	7.40	-----	-----	6.30	8.45
Total Alkalinity (mg/l)	160.0	177.0	-----	-----	146.0	159.0
Carbon Dioxide (mg/l)	4.0	6.3	-----	-----	14.6	12.0
Turbidity (NTU)	n/a	8.50	-----	-----	1.13	1.34

Table 3. Leech Creek water quality data, 1993 at upper site (200 yards downstream from Monument boundary at an elevation of 6,420 feet mls).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	11:00 AM	7:30 AM	11:14 AM	11:10 AM	2:32 PM	11:30 AM
Temperature (°C)	8.6	9.0	9.5	10.9	10.2	8.5
Oxygen (mg/l)	9.2	8.9	9.6	8.8	8.5	9.4
Conductivity (µmhos)	172.0	200.0	210.0	215.0	180.0	210.0
pH	8.15	8.28	8.35	8.00	8.00	8.00
Total Alkalinity (mg/l)	147.3	173.6	175.0	179.6	175.6	170.3
Carbon Dioxide (mg/l)	9.0	12.6	12.6	2.3	6.7	8.6
Turbidity (NTU)	1.60	1.14	1.25	2.00	2.10	1.40

Table 4. Leech Creek water quality data, 1993 at lower site (near research camp at an elevation of 6,000 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	1:00 PM	8:30 AM	12:19 PM	12:25 PM	3:30 PM	12:20 PM
Temperature (°C)	9.6	9.0	10.5	11.1	12.5	8.5
Oxygen (mg/l)	9.40	8.40	9.40	9.20	7.52	10.00
Conductivity (µmhos)	186.0	200.0	210.0	225.0	225.0	21.0
pH	7.7	8.4	8.6	8.3	8.2	8.0
Total Alkalinity (mg/l)	157.0	163.3	177.0	182.6	210.0	178.0
Carbon Dioxide (mg/l)	6.0	11.6	4.0	0.0	3.2	2.6
Turbidity (NTU)	2.3	3.1	2.4	5.0	3.2	2.6

Table 5. Little Cottonwood Creek water quality data, 1992 at upper site (located at the head of Little Cottonwood Creek at an elevation of 6,720 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	11:00 AM	3:21 PM	10:43 AM	12:45 PM	1:30 PM	1:10 PM
Temperature (°C)	8.0	9.0	11.0	15.0	10.5	10.0
Oxygen (mg/l)	9.10	7.50	7.20	6.60	10.30	8.25
Conductivity (µmhos)	n/a	150.0	170.0	170.0	160.0	165.0
pH	7.55	7.26	7.50	6.20	6.40	7.79
Total Alkalinity (mg/l)	11.0	134.0	106.0	112.0	94.0	115.0
Carbon Dioxide (mg/l)	8.0	7.0	12.0	10.0	14.0	8.0
Turbidity (NTU)	n/a	3.40	1.26	1.47	1.30	1.50

Table 6. Little Cottonwood Creek water quality data, 1992 at middle site (located downstream the Martin Mine at an elevation of 6,240 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	12:30 PM	4:04 PM	DRY	DRY	DRY	3:00 PM
Temperature (°C)	10.0	10.0	-----	-----	-----	8.5
Oxygen (mg/l)	9.4	8.4	-----	-----	-----	8.6
Conductivity (µmhos)	186.0	200.0	-----	-----	-----	900.0
pH	7.7	8.4	-----	-----	-----	6.7
Total Alkalinity (mg/l)	157.0	163.3	-----	-----	-----	155.0
Carbon Dioxide (mg/l)	6.0	11.6	-----	-----	-----	16.0
Turbidity (NTU)	2.3	3.1	-----	-----	-----	1.6

Table 7. Little Cottonwood Creek water quality data, 1993 at upper site (located at the head of Little Cottonwood Creek at an elevation of 6,720 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	8:30 AM	10:21 AM	1:37 PM	1:16 PM	12:02 PM	2:15 PM
Temperature (°C)	8.0	8.0	11.0	10.5	8.5	9.0
Oxygen (mg/l)	8.6	8.4	7.8	5.4	8.0	9.6
Conductivity (µmhos)	95.0	115.0	140.0	150.0	155.0	145.0
pH	7.21	7.70	8.00	7.80	7.60	7.60
Total Alkalinity (mg/l)	84.3	104.3	120.0	120.6	132.2	111.6
Carbon Dioxide (mg/l)	7.6	10.3	13.0	50.0	6.6	5.6
Turbidity (NTU)	1.30	1.30	0.76	0.80	1.10	0.90

Table 8. Little Cottonwood Creek water quality data, 1993 at middle site (located downstream of the Martin Mine at an elevation of 6,240 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	10:00 AM	11:15 AM	2:20 PM	2:15 PM	12:50 PM	3:15 PM
Temperature (°C)	9.0	10.0	15.0	13.0	12.0	11.0
Oxygen (mg/l)	8.8	8.3	7.6	9.2	9.4	9.4
Conductivity (µmhos)	130.0	185.0	240.0	24.0	235.0	210.0
pH	7.42	8.20	8.40	7.80	7.80	8.00
Total Alkalinity (mg/l)	107.6	142.0	155.0	166.7	171.3	172.3
Carbon Dioxide (mg/l)	8.0	7.3	12.0	4.0	7.0	6.0
Turbidity (NTU)	1.8	2.3	1.5	1.2	1.3	1.2

Table 9. Big Cottonwood Creek water quality data, 1992 at station below Paymaster Mine (located at an elevation of 6,840 feet msl).

	May	June	July	Aug.	Sept.	Oct.
Time	3:18 PM	11:18 AM	4:20 PM	DRY	DRY	DRY
Temperature (°C)	19.3	29.0	24.0	-----	-----	-----
Oxygen (mg/l)	9.1	7.5	7.2	-----	-----	-----
Conductivity (µmhos)	n/a	150.0	170.0	-----	-----	-----
pH	7.55	7.26	7.50	-----	-----	-----
Total Alkalinity (mg/l)	110.0	134.0	106.0	-----	-----	-----
Carbon Dioxide (mg/l)	8.0	7.0	12.0	-----	-----	-----
Turbidity (NTU)	n/a	3.40	1.26	-----	-----	-----

Table 10. Big Cottonwood Creek water quality data, 1992 at upper site (located at an elevation of 6,640 feet msl).

	May	June	July	Aug.	Sept.	Oct.
Time	3:42 PM	12:29 PM	3:13 PM	11:45 AM	4:25 PM	4:30 PM
Temperature (°C)	15.4	16.2	13.5	15.0	11.5	12.0
Oxygen (mg/l)	8.5	8.0	7.3	8.0	11.	9.2
Conductivity (µmhos)	n/a	80.0	80.0	80.0	80.0	455.0
pH	7.23	7.14	7.10	7.20	7.20	7.50
Total Alkalinity (mg/l)	57.0	56.0	48.0	47.0	55.0	53.0
Carbon Dioxide (mg/l)	3.6	3.6	4.0	5.5	7.6	5.0
Turbidity (NTU)	n/a	1.30	1.40	1.40	1.70	5.46

Table 11. Big Cottonwood Creek water quality data, 1992 at lower site (located at an elevation of 6,010 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	8:20 PM	1:36 PM	4:14 PM	1:00 PM	5:32 PM	5:25 PM
Temperature (°C)	12.8	16.0	15.0	17.5	11.0	10.0
Oxygen (mg/l)	7.6	9.2	8.0	7.7	8.4	8.6
Conductivity (µmhos)	n/a	95.0	100.0	105.0	80.0	310.0
pH	7.14	7.27	7.40	7.20	7.60	7.50
Total Alkalinity (mg/l)	72.0	77.0	61.0	56.0	59.0	62.0
Carbon Dioxide (mg/l)	3.3	4.0	6.0	5.0	6.0	6.0
Turbidity (NTU)	n/a	1.63	2.10	1.20	0.96	1.60

Table 12. Big Cottonwood Creek water quality data, 1993 at station below Paymaster Mine (located at an elevation of 6,840 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	2:00 PM	1:13 PM	11:03 PM	11:00 PM	DRY	DRY
Temperature (°C)	15.4	16.2	13.5	15	-----	-----
Oxygen (mg/l)	8.5	8	7.3	8	-----	-----
Conductivity (µmhos)	n/a	80	80	80	-----	-----
pH	7.23	7.14	7.1	7.2	-----	-----
Total Alkalinity (mg/l)	57	56	48	47	-----	-----
Carbon Dioxide (mg/l)	3.6	3.6	4	5.5	-----	-----
Turbidity (NTU)	n/a	1.3	1.4	1.4	-----	-----

Table 13. Big Cottonwood Creek water quality data, 1993 at upper site (located at an elevation of 6,640 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	3:00 PM	1:51 PM	11:31 AM	3:00 PM	8:05 AM	8:00 AM
Temperature (°C)	8.8	11.0	12.0	11.0	6.5	4.5
Oxygen (mg/l)	9.4	8.2	8.0	9.0	11.6	9.0
Conductivity (µmhos)	46.0	85.0	90.0	115.0	60.0	60.0
pH	7.8	8.0	7.6	8.0	7.4	8.0
Total Alkalinity (mg/l)	35.3	45.0	53.0	63.6	58.0	62.0
Carbon Dioxide (mg/l)	4.0	2.3	3.0	3.3	3.3	4.0
Turbidity (NTU)	1.5	3.0	2.6	3.6	1.3	1.5

Table 14. Big Cottonwood Creek water quality data, 1993 at lower site (located at an elevation of 6,010 feet msl).

	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
Time	3:45 PM	2:30 PM	12:41 PM	4:30 PM	9:28 AM	9:17 AM
Temperature (°C)	10.9	12.5	13.5	12.0	8.0	6.0
Oxygen (mg/l)	8.7	8.0	7.6	9.4	11.2	8.6
Conductivity (µmhos)	70.0	85.0	270.0	110.0	75.0	80.0
pH	7.8	7.8	7.9	8.0	7.6	8.3
Total Alkalinity (mg/l)	43.3	49.3	57.3	57.6	63.6	58.3
Carbon Dioxide (mg/l)	4.0	3.6	5.6	3.0	3.3	3.7
Turbidity (NTU)	1.4	1.5	3.1	2.1	1.8	2.4

Table 15. Nutrient concentrations (mg/l) in Leech, Little Cottonwood, and Big Cottonwood Creeks, May through October, 1992.

DATE	LOCATION	TOTAL PHOSPHORUS (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TKN (mg/l)
05/31/92	Leech Creek, upper	0.03	0.15	0.04	0.18
05/31/92	Leech Creek, lower	0.08	0.14	0.00	0.34
06/01/92	Little Cottonwood Crk., upper	0.05	0.12	0.01	0.38
06/01/92	Little Cottonwood Crk., middle	0.09	0.26	0.00	0.22
06/01/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
06/01/92	Big Cottonwood Crk., below mine	0.12	0.18	0.01	0.08
06/01/92	Big Cottonwood Crk., upper	0.06	0.18	0.01	0.40
06/01/92	Big Cottonwood Crk., lower	0.15	0.23	0.00	0.64
06/16/92	Leech Creek, upper	0.04	0.24	0.00	0.12
06/16/92	Leech Creek, lower	0.10	0.24	0.00	0.42
06/16/92	Little Cottonwood Crk., upper	0.16	0.17	0.00	0.38
06/16/92	Little Cottonwood Crk., middle	0.11	0.23	0.00	0.32
06/16/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
06/21/92	Big Cottonwood Crk., below mine	0.03	0.12	0.00	0.18
06/21/92	Big Cottonwood Crk., upper	0.03	0.16	0.00	0.38
06/21/92	Big Cottonwood Crk., lower	0.04	0.17	0.00	0.22
07/13/92	Leech Creek, upper	0.01	0.10	0.00	0.06
07/13/92	Leech Creek, lower	Site Dry	-----	-----	-----
07/13/92	Little Cottonwood Crk., upper	0.06	0.08	0.00	0.08
07/13/92	Little Cottonwood Crk., middle	Site Dry	-----	-----	-----
07/13/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
07/13/92	Big Cottonwood Crk., below mine	*BDL	0.10	0.00	0.15
07/13/92	Big Cottonwood Crk., upper	*BDL	0.13	0.00	0.24
07/13/92	Big Cottonwood Crk., lower	0.06	0.15	0.00	0.28
08/08/92	Leech Creek, upper	0.03	0.12	0.00	0.02
08/08/92	Leech Creek, lower	Site Dry	-----	-----	-----
08/08/92	Little Cottonwood Crk., upper	0.04	0.24	0.00	0.16
08/08/92	Little Cottonwood Crk., middle	Site Dry	-----	-----	-----
08/08/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
08/08/92	Big Cottonwood Crk., below mine	Site Dry	-----	-----	-----
08/08/92	Big Cottonwood Crk., upper	0.03	0.19	0.00	0.20
08/08/92	Big Cottonwood Crk., lower	0.03	0.12	0	0.01

Table 15. Continued:

DATE	LOCATION	TOTAL PHOSPHORUS (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TKN (mg/l)
09/19/92	Leech Creek, upper	0.04	0.13	0.00	0.06
09/19/92	Leech Creek, lower	0.05	0.26	0.00	0.01
09/19/92	Little Cottonwood Crk., upper	0.02	0.11	0.01	0.16
09/19/92	Little Cottonwood Crk., middle	Site Dry	-----	-----	-----
09/19/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
09/19/92	Big Cottonwood Crk., below mine	Site Dry	-----	-----	-----
09/19/92	Big Cottonwood Crk., upper	0.03	0.19	0.00	0.32
09/19/92	Big Cottonwood Crk., lower	0.03	*BDL	0.00	0.16
10/24/92	Leech Creek, upper	0.03	0.18	0.00	0.16
10/24/92	Leech Creek, lower	0.09	0.35	0.00	0.22
10/24/92	Little Cottonwood Crk., upper	0.01	0.19	0.00	0.02
10/24/92	Little Cottonwood Crk., middle	0.06	0.16	0.00	0.06
10/24/92	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
10/24/92	Big Cottonwood Crk., below mine	Site Dry	-----	-----	-----
10/24/92	Big Cottonwood Crk., upper	0.03	0.61	0.00	0.44
10/24/92	Big Cottonwood Crk., lower	0.04	0.18	0.00	0.22

*BDL: Below Detection Limits

Table 16. Nutrient concentrations (mg/l) in Leech, Little Cottonwood, and Big Cottonwood Creeks, May through October, 1993.

DATE	LOCATION	TOTAL PHOSPHORUS (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TKN (mg/l)
06/03/93	Leech Creek, upper	0.03	0.08	0.00	0.32
06/03/93	Leech Creek, lower	0.03	0.09	0.00	0.16
06/02/93	Little Cottonwood Crk., upper	0.02	1.10	0.00	0.08
06/02/93	Little Cottonwood Crk., middle	0.03	1.67	0.00	0.14
06/02/93	Little Cottonwood Crk., lower	0.03	0.19	0.00	0.10
06/03/93	Big Cottonwood Crk., below mine	0.01	0.08	0.01	0.02
06/03/93	Big Cottonwood Crk., upper	0.01	1.53	0.01	0.16
06/03/93	Big Cottonwood Crk., lower	0.02	0.17	0.00	0.15
06/21/93	Leech Creek, upper	0.03	0.11	0.00	0.09
06/21/93	Leech Creek, lower	0.05	0.11	0.00	0.04
06/21/93	Little Cottonwood Crk., upper	0.01	0.11	0.00	0.02
06/21/93	Little Cottonwood Crk., middle	0.04	0.14	0.00	0.14
06/21/93	Little Cottonwood Crk., lower	0.02	0.12	0.00	0.06
06/21/93	Big Cottonwood Crk., below mine	0.01	0.08	0.01	0.02
06/21/93	Big Cottonwood Crk., upper	0.03	0.07	0.00	0.12
06/21/93	Big Cottonwood Crk., lower	0.03	0.07	0.00	0.08
07/18/93	Leech Creek, upper	0.03	0.09	0.00	0.19
07/18/93	Leech Creek, lower	0.04	0.04	0.00	0.14
07/18/93	Little Cottonwood Crk., upper	0.03	0.03	0.00	0.26
07/18/93	Little Cottonwood Crk., middle	0.06	0.12	0.00	0.28
07/18/93	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
07/19/93	Big Cottonwood Crk., below mine	0.02	0.01	0.01	0.02
07/19/93	Big Cottonwood Crk., upper	0.04	0.03	0.00	0.20
07/19/93	Big Cottonwood Crk., lower	0.03	0.02	0.00	0.10
08/09/93	Leech Creek, upper	0.04	0.14	0.00	0.05
08/09/93	Leech Creek, lower	0.06	0.14	0.00	0.24
08/09/93	Little Cottonwood Crk., upper	0.04	0.21	0.00	0.04
08/09/93	Little Cottonwood Crk., middle	0.05	0.27	0.00	0.08
08/09/93	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
08/09/93	Big Cottonwood Crk., below mine	0.03	0.09	0.00	0.01
08/09/93	Big Cottonwood Crk., upper	0.05	0.02	0.00	0.14
08/09/93	Big Cottonwood Crk., lower	0.04	0.21	0.00	0.16

Table 16. Continued:

DATE	LOCATION	TOTAL PHOSPHORUS (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TKN (mg/l)
09/17/93	Leech Creek, upper	0.04	0.13	0.00	0.14
09/17/93	Leech Creek, lower	0.05	0.18	0.00	0.16
09/17/93	Little Cottonwood Crk., upper	0.04	0.12	0.00	0.10
09/17/93	Little Cottonwood Crk., middle	0.05	0.18	0.00	0.16
09/17/93	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
09/17/93	Big Cottonwood Crk., below mine	Site Dry	-----	-----	-----
09/17/93	Big Cottonwood Crk., upper	0.04	0.09	0.00	0.18
09/17/93	Big Cottonwood Crk., lower	0.04	0.24	0.00	0.12
10/22/93	Leech Creek, upper	0.12	0.14	0.00	0.15
10/22/93	Leech Creek, lower	0.04	0.06	0.00	0.10
10/22/93	Little Cottonwood Crk., upper	0.07	0.08	0.00	0.08
10/22/93	Little Cottonwood Crk., middle	0.06	0.14	0.00	0.36
10/22/93	Little Cottonwood Crk., lower	Site Dry	-----	-----	-----
10/22/93	Big Cottonwood Crk., below mine	Site Dry	-----	-----	-----
10/22/93	Big Cottonwood Crk., upper	0.07	0.08	0.00	0.22
10/22/93	Big Cottonwood Crk., lower	0.03	0.12	0.00	0.20

Table 17. Nutrient concentrations (mg/l) at spring box on Little Cottonwood Creek, May through October, 1992 and 1993.

DATE	LOCATION	TOTAL PHOSPHORUS (mg/l)	NH3-N (mg/l)	NO3-N (mg/l)	TKN (mg/l)
08/08/92	Spring 1	0.00	0.17	0.00	>.01
08/08/92	Spring 2	0.00	0.05	0.01	>.02
08/08/92	Spring 3	0.00	0.04	0.00	>.02
09/19/92	Spring 1	0.01	0.10	0.01	>.02
09/19/92	Spring 2	0.01	0.09	0.01	>.02
09/19/92	Spring 3	0.13	0.15	0.01	>.01
10/24/92	Spring 1	0.02	0.27	0.00	>.02
10/24/92	Spring 2	0.00	0.07	0.01	>.02
10/24/92	Spring 3	0.02	0.10	0.00	>.02
06/02/93	Spring 1	0.00	1.17	0.01	>.02
06/02/93	Spring 2	0.00	0.14	0.01	>.02
06/02/93	Spring 3	0.00	0.13	0.01	0.02
06/21/93	Spring 1	0.00	0.09	0.00	>.02
06/21/93	Spring 2	0.00	0.02	0.01	>.02
06/21/93	Spring 3	0.01	0.03	0.00	>.02
07/18/93	Spring 1	0.01	0.13	0.00	0.02
07/18/93	Spring 2	0.00	0.00	0.01	>.02
07/18/93	Spring 3	0.02	0.00	0.01	0.06
08/08/93	Spring 1	0.02	0.11	0.00	>.02
08/08/93	Spring 2	0.02	0.06	0.01	>.02
08/08/93	Spring 3	0.03	0.06	0.01	>.02
09/17/93	Spring 1	0.04	0.12	0.01	0.02
09/17/93	Spring 2	0.03	0.07	0.01	>.02
09/17/93	Spring 3	0.03	0.07	0.01	0.02
10/22/93	Spring 1	0.03	0.10	0.01	0.02
10/22/93	Spring 2	0.07	0.02	0.01	>.02
10/22/93	Spring 3	0.03	0.06	0.01	>.02

Table 18. Fecal streptococcus and fecal coliform concentrations for Leech, Little Cottonwood, and Big Cottonwood Creeks, June 1992 and 1993.

DATE	LOCATION	MLS SAMPLE	FECAL STREPTOCOCCUS	FECAL COLIFORM
06/17/92	Leech Creek, upper	100	700	<100
06/17/92	Leech Creek, upper	100	400	<100
06/17/92	Leech Creek, upper	100	400	<100
06/17/92	Leech Creek, lower	100	300	<100
06/17/92	Leech Creek, lower	100	500	<100
06/17/92	Leech Creek, lower	100	200	100
06/17/92	Little Cottonwood Creek, upper	100	1300	<100
06/17/92	Little Cottonwood Creek, upper	100	300	<100
06/17/92	Little Cottonwood Creek, upper	100	1100	<100
06/17/92	Little Cottonwood Creek, below mine	100	200	<100
06/17/92	Little Cottonwood Creek, below mine	100	300	<100
06/17/92	Little Cottonwood Creek, below mine	100	300	<100
06/17/92	Big Cottonwood Creek, below mine	100	100	<100
06/17/92	Big Cottonwood Creek, below mine	100	300	<100
06/17/92	Big Cottonwood Creek, below mine	100	100	<100
06/17/92	Big Cottonwood Creek, upper	100	200	100
06/17/92	Big Cottonwood Creek, upper	100	200	100
06/17/92	Big Cottonwood Creek, upper	100	200	100
06/17/92	Big Cottonwood Creek, lower	100	600	<100
06/17/92	Big Cottonwood Creek, lower	100	300	<100
06/17/92	Big Cottonwood Creek, lower	100		
06/24/93	Leech Creek, upper	100	25	34
06/24/93	Leech Creek, upper	100	10	60
06/24/93	Leech Creek, lower	100	3	56
06/24/93	Leech Creek, lower	100	22	22
06/24/93	Little Cottonwood Creek, upper	100	<1	<1
06/24/93	Little Cottonwood Creek, upper	100	2	<1
06/24/93	Little Cottonwood Creek, below mine	100	36	10
06/24/93	Little Cottonwood Creek, below mine	100	37	2
06/24/93	Little Cottonwood Creek, lower	100	20	4
06/24/93	Little Cottonwood Creek, lower	100	13	4

Table 18. Continued:

DATE	LOCATION	MLS SAMPLE	FECAL STREPTOCOCCUS	FECAL COLIFORM
06/24/93	Big Cottonwood Creek, below mine	100	6	<1
06/24/93	Big Cottonwood Creek, below mine	100	6	<1
06/24/93	Big Cottonwood Creek, upper	100	4	6
06/17/92	Big Cottonwood Creek, upper	100	1	6
06/24/93	Big Cottonwood Creek, lower	100	9	8
06/24/93	Big Cottonwood Creek, lower	100	7	8

Table 19 . Metal concentrations ($\mu\text{g}/\text{ml}=\text{ppm}$) in Leech Creek, June 1992- September 1993.

Metal	EDL	1992				1993			
		June	June	September	September	June	June	September	September
		Upper Site	Lower Site	Upper Site	Lower Site	Upper Site	Lower Site	Upper Site	Lower Site
Aluminum	0.067	BDL	BDL	0.120	BDL	2.700	0.120	0.090	0.090
Barium	0.004	0.075	0.021	0.019	0.020	0.023	0.020	BDL	0.017
Beryllium	0.006	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	0.024	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Calcium	0.057	30.000	59.000	57.000	62.000	59.000	44.000	63.000	63.000
Chromium	0.023	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt	0.021	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper	0.032	BDL	BDL	BDL	BDL	0.060	BDL	BDL	BDL
Iron	0.027	BDL	0.440	0.160	0.130	6.900	0.290	0.250	0.150
Magnesium	0.031	4.100	5.300	4.300	5.800	4.900	3.600	4.900	4.700
Manganese	0.005	BDL	0.010	BDL	BDL	0.170	0.010	BDL	0.010
Molybdenum	0.111	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel	0.098	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Potassium	0.022	1.300	1.900	2.100	3.200	3.600	2.200	3.100	1.600
Silicon		NA	NA	NA	NA	NA	NA	NA	NA
Silver	0.158	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	4.400	5.800	6.700	5.600	7.200	7.100	6.400	6.400	5.800
Titanium	0.130	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	0.082	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	0.014	BDL	BDL	BDL	BDL	0.230	0.020	0.020	BDL
Arsenic	1 *		BDL						BDL
Lead	1 *		BDL						BDL

* = Concentration in $\mu\text{g}/\text{L}$ or ppb.

BDL = Below detection limit.

EDL = Estimated detection limit.

NA = Not applicable

Table 20. Metal concentrations ($\mu\text{g}/\text{ml}=\text{ppm}$) in Little Cottonwood Creek, June 1992- October 1993.

Metal	EDL	1992				1993			
		June	June	October	October	June	June	October	October
		Upper Site	Below Mine	Upper Site	Below Mine	Upper Site	Below Mine	Upper Site	Below Mine
Aluminum	0.067	0.200	0.210	BDL	BDL	BDL	0.140	0.090	0.130
Barium	0.004	0.020	0.016	0.015	0.016	0.011	0.014	0.016	0.019
Beryllium	0.006	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium	0.024	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Calcium	0.057	43.000	61.000	44.000	70.000	26.000	35.000	43.000	61.000
Chromium	0.023	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cobalt	0.021	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper	0.032	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.040
Iron	0.027	0.290	0.490	0.040	BDL	0.040	0.160	0.200	0.150
Magnesium	0.031	3.400	8.400	4.300	9.200	2.800	4.700	4.400	8.700
Manganese	0.005	0.020	0.070	0.010	BDL	BDL	0.030	0.010	0.020
Molybdenum	0.111	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel	0.098	BDL	BDL	BDL	BDL	BDL	BD;	BDL	BDL
Potassium	0.022	1.700	2.800	2.400	2.700	1.400	2.300	2.400	2.600
Silicon		NA	NA	NA	NA	NA	NA	NA	NA
Silver	0.158	NA	NA	NA	NA	NA	NA	NA	NA
Sodium	4.400	3.000	7.200	3.700	8.100	3.000	4.400	3.900	6.800
Titanium	0.130	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	0.082	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	0.014	BDL	0.030	BDL	BDL	BDL	0.020	BDL	0.030
Arsenic	1 *				6.8				4.2
Lead	1 *				2.0				BDL

* = Concentration in $\mu\text{g}/\text{L}$ or ppb.

BDL = Below detection limit.

EDL = Estimated detection limit.

NA = Not applicable

Appendix A

Attached Benthic Algae Chlorophyll *a* in Streams of the Craters of the Moon National Monument

Appendix Table A. Attached benthic algae chlorophyll a (mg/sq m) in Leech, Little Cottonwood, and Big Cottonwood Creeks, 1992 and 1993.

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Mean	s
21-Jun-92							
Leech Creek, upper site	0.2	0.3	0.2	0.4	0.6	0.3	0.2
Leech Creek, lower site	4.5	1.9	0.9	6.5	4.2	3.6	2.2
Little Cottonwood Ck, upper	0.8	3.2	1.5	5.2	1.3	2.4	1.8
Little Cottonwood Ck, middle	3.0	0.9	13.4	2.0	19.4	7.7	8.2
Little Cottonwood Ck, lower		Site		Dry			
Big Cottonwood Ck, < mine	4.3	3.1	7.8	1.3	1.1	3.5	2.7
Big Cottonwood Ck, upper	6.8	10.0	3.6	5.5	2.8	5.7	2.9
Big Cottonwood Ck, lower	1.3	0.4	0.6	0.4	0.6	0.7	0.4
8-Aug-92							
Leech Creek, upper site	3.2	31.3	39.3	15.7	4.9	18.9	16.0
Leech Creek, lower site		Site		Dry			
Little Cottonwood Ck, upper	2.5	3.6	5.9	1.5	2.2	3.1	1.7
Little Cottonwood Ck, middle		Site		Dry			
Little Cottonwood Ck, lower		Site		Dry			
Big Cottonwood Ck, < mine		Site		Dry			
Big Cottonwood Ck, upper	3.4	2.5	6.1	1.0	0.9	2.8	2.1
Big Cottonwood Ck, lower	5.4	7.9	2.8	4.3	2.3	4.5	2.2
8-Aug-93							
Leech Creek, upper site	1.4	2.5	1.9	1.7	0.9	1.7	0.6
Leech Creek, lower site	0.2	0.4	0.4	0.4	0.3	0.3	0.1
Little Cottonwood Ck, upper	0.5	0.3	0.2	2.4	2.3	1.1	1.1
Little Cottonwood Ck, middle	0.5	1.2	0.6	0.2	0.3	0.6	0.4
Little Cottonwood Ck, lower		Site		Dry			
Big Cottonwood Ck, < mine	4.1	3.5	7.3	2.1	2.2	3.8	2.1
Big Cottonwood Ck, upper	0.8	2.4	3.3	0.3	0.8	1.5	1.3
Big Cottonwood Ck, lower	0.4	0.6	0.3	0.6	0.3	0.4	0.2

Appendix B

Benthic Macroinvertebrates in Streams of the Craters of the Moon National Monument

Appendix Table B. Composition of aquatic macroinvertebrates found in Leech, Little Cottonwood, and Big Cottonwood Creeks, 1992 and 1993 composite.

Leech Creek								
Order	Diptera	Ephemeroptera	Plecoptera	Tricoptera	Coleoptera	Hemiptera	Oligochaeta	
Family / Genus	Brachyceridae Chironomidae Dixidae Phoridae Simuliidae Tipulidae	Baetidae Ephemerellidae Heptageniidae Leptophlebiidae	Chloroperlidae Nemouridae Peltoperlidae Perlidae	Glossosomatidae Lepidostomatidae Limnephilidae Polycetropodidae Psychomyiidae Rhyacophilidae	Elmidae Hydrophilidae			<i>Planaria</i>
Count (per sq ft Surber sample)	131	122	186	11.8	6.4		38	108.6
Percent	21.7%	20.2%	30.8%	1.9%	1.1%		6.3%	18.0%
Little Cottonwood Creek								
Order	Diptera	Ephemeroptera	Plecoptera	Tricoptera	Coleoptera		Oligochaeta	
Family / Genus	Ceratopogonidae Chironomidae Pelecorhynchidae Simuliidae Tipulidae	Baetidae Ephemerellidae Heptageniidae Leptophlebiidae Siphonuridae	Capniidae Chloroperlidae Nemouridae Peltoperlidae Perlidae	Brachycentridae Glossosomatidae Limnephilidae Rhyacophilidae	Dytiscidae Elmidae Hydrophilidae	Carabidae		<i>Planaria</i>
Count (per sq ft Surber sample)	615.0	33.2	111.2	42.6	11.2	1.0	12.4	124.0
Percent	64.7%	3.5%	11.7%	4.5%	1.2%	0.1%	1.3%	13.0%
Big Cottonwood Creek								
Order	Diptera	Ephemeroptera	Plecoptera	Tricoptera	Coleoptera		Oligochaeta	
Family / Genus	Chironomidae Simuliidae Stratiomyidae Tabanidae Tipulidae	Baetidae Ephemerellidae Heptageniidae Leptophlebiidae Siphonuridae	Chloroperlidae Nemouridae Perlidae Perlidae	Brachycentridae Glossosomatidae Limnephilidae Rhyacophilidae	Chrysomelidae Elmidae Hydrophilidae			<i>Planaria</i>
Count (per sq ft Surber sample)	153.6	134.2	55.2	13.6	9.2		5.6	4.4
Percent	40.9%	35.7%	14.7%	3.6%	2.4%		1.5%	1.2%

Appendix C

Riparian Habitat Evaluation Criteria

As part of the watershed management plan, we conducted a stream reach inventory and channel stability evaluation. We followed the United States Department of Agriculture's methodology of Pfankuch (1978) and Kappesser (1991). All streams in the study were surveyed over their entire length at one quarter mile intervals.

DEFINITION OF TERMS.

Upper Bank --

That portion of the topographic cross-section from the break in the general slope of the surrounding land to the normal high water line. Terrestrial plants and animals normally inhabit this area.

Lower Bank --

The intermittently submerged portion of the channel cross section from the normal high water line to the water's edge during the summer low flow period.

Channel Bottom --

The submerged portion of the channel cross section which is totally an aquatic environment at summer low flow.

DESCRIPTION OF KEY #

Upper Channel Banks

1. Landform Slope --

Excellent - Side slopes to the channel are generally less than than 30% on both banks.

- Good** - Side slopes up to 40% on one or occasionally both banks.
- Fair** - Side slopes up to 60% common on one or both banks.
- Poor** - Steep slopes, over 60%, provide larger volumes of soil to stream for downstream sedimentation.

2. Mass Wasting Hazard --

This represents the potential of banks sliding or slumping into creek channel.

Excellent - There is no evidence of mass wasting.

Good - There is evidence of infrequent and/or very small slumps.

Fair - Frequency and/or magnitude of the mass wasting situation increases to the point where normal high water aggravates the problem.

Poor - Mass Wasting is not difficult to detect because of the frequency and/or size of existing problem areas.

3. Debris Jam Potential (the floatable objects that are deposited on the stream bank) -

Excellent - Debris may be present, but there is no chance that the stream will float it away.

Good - The debris present offers some bank protection, but is small enough to be floated away in time.

Fair - There is noticeable accumulation of all sizes and the stream is large enough to float it away leaving the bank exposed, thus decreasing bank protection.

Poor - Moderate to heavy accumulations are present due to fires, insect attack, windthrow, or logging slash. High flows will dislodge most of this material.

4. Vegetative Bank Protection --

Excellent - 90% of the ground is covered by plants.

Good - 70-90% of the ground is covered by plants.

Fair - 50-70% of the ground is covered by plants.

Poor - Less than 50% of the ground is covered by plants.

Lower Channel Banks

5. Channel Capacity --

This is the ratio of channel width to channel depth.

Excellent - Width to depth ratio less than 7; *i.e.*, (36" wide/6" deep = 6).

Good - Width to depth ratio 8 to 15.

Fair - Width to depth ratio 15 to 25.

Poor - Width to depth ratio 25 or more.

6. Bank Rock Content --

Excellent - Rocks make up 65% or more of the volume of the banks.

Good - Rocks make up 40-65% of the volume of the banks.

Fair - Rocks make up 20-40% of the volume of the banks.

Poor - Rocks make up less than 20% of the bank volume.

7. Obstructions To Flow --

Excellent - Logs, rocks, and other obstructions are firmly embedded and produce a pattern of flow.

Good - Obstructions to flow and sediment traps are present, causing minor bank and bottom erosion.

Fair - Moderately frequent and quite often unstable obstructions, cause noticeable seasonal erosion of the channel.

Poor - Obstructions and traps so frequent they are indivisible, often unstable to movement and cause a shift of sediments at all seasons.

8. Cutting (the process of washing away the bank material due to a bend or obstruction in the stream channel)

Excellent - Very little or no cutting is evident.

Good - Some intermittent cutting along channel outcurves and at prominent constrictions.

Fair - Significant bank cutting occurs frequently in the reach.

Poor - Nearly continuous bank cutting.

9. Deposition --

Excellent - Very little or no deposition of fresh silt, sand, or gravel.

Good - Some fresh deposits on bars and behind obstructions.

Fair - Deposits of fresh, coarse sands and gravels observed with moderate frequency.

Poor - Extensive deposits of predominantly fresh, fine sands, some silt, and small gravel.

Channel Bottom

10. Angularity --

This refers to the shape of the rocks. As they spend more time in a water system they get rounded due to the tumbling motion. The more angular the rock, the more stable the channel bottom.

Excellent - Very angular.

Good - Somewhat angular.

Fair - Sub-angular.

Poor - Rounded.

11. Brightness --

Rocks in motion do not collect algae nor become stained.

Excellent - Less than 5% of the total bottom should be bright.

Good - 5 to 35% of the bottom appears bright.

Fair - About a 50/50 mixture of the rocks appear bright.

Poor - Bright, freshly exposed rocks predominate 2/3 or more of the bottom.

12. Consolidation or (Particle Packing) of Bottom Material --

Excellent - An array of sizes are tightly packed and wedged with much over-lapping.

Good - Moderately tight packing of particles with fast water parts of the cross section protected by overlapping rocks.

Fair - Moderately loose without any patter of overlapping.

Poor - Rocks in loose array, moved easily by less high flow conditions.

13. Bottom size distribution and percent stable materials --

Excellent - There is no noticeable change in size distribution. The rock mixture appears to be normal for the kind of geologic sources in the basin.

Good - Slight shift in either direction.

Fair - Moderate shift in size classes.

Poor - Marked, a pronounced shift.

14. Scouring and/or Deposition --

- Excellent** - Neither scouring nor deposition is much in evidence. Up to 5% of either or a combination of both.
- Good** - Affected length ranges from 5 to 30%.
- Fair** - Moderate changes are occurring; 30 to 50%.
- Poor** - Both cutting and deposition are common; 50% or more of the
 - Bottom materials are moving during all seasons of the year.

15. Aquatic Vegetation --

- Excellent** - Clinging plants are abundant throughout the reach from bank to bank.
- Good** - Plants are quite common in the slower portions of the reach but thin out or are absent in swift water.
- Fair** - Plants are found but their occurrence is spotty.
- Poor** - Clinging plants are rarely found anywhere in the reach.

Appendix D

Lists of Riparian Vegetation

Appendix Table D-1. Scientific and common names for plants in the Leech Creek riparian area.

<i>Agropyron spicatum</i>	bluebunch wheatgrass
<i>Artemisia tridentata</i> spp. <i>vaseyana</i>	mountain big sagebrush
<i>Artemisia tripartita</i>	three-tipped sagebrush
<i>Balsamorhiza sagittata</i>	arrowleaf balsalmroot
<i>Carex</i> spp.....	sedges
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush
<i>Cirsium</i> spp.....	thistle
<i>Festuca idahoensis</i>	Idaho fescue
<i>Heracleum lanatum</i>	cow parsnip
<i>Lepidium campestre</i>	pepper grass
<i>Mentha spicata</i>	wild mint
<i>Mimulus guttatus</i>	seep-spring monkey flower
<i>Myosotis scorpioides</i>	forget-me-nots
<i>Poa pratensis</i>	Kentucky bluegrass
<i>Populus trichocarpa</i>	black cottonwood
<i>Rudbeckia</i> spp.....	coneflower
<i>Senecio serra</i>	groundsel
<i>Symphoricarpos oreophilus</i>	mountain snowberry
<i>Urtica dioica</i>	stinging nettle
<i>Verbascum thapsus</i>	common mullein

Appendix Table D-2. Scientific and common names for plants found in the Little Cottonwood Creek riparian area.

<i>Achillea millefolium</i>	common yarrow
<i>Agropyron repens</i>	quackgrass
<i>Agropyron spicatum</i>	bluebunch wheatgrass
<i>Aquilegia formosa</i>	Sitka columbine
<i>Artemisia tridentata</i> spp. <i>vaseyana</i>	mountain big sagebrush
<i>Betula glandulosa</i>	bog birch
<i>Carex</i> spp.....	sedges
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush
<i>Cirsium</i> spp.....	thistle
<i>Heracleum lanatum</i>	cow parsnip
<i>Hydrophyllum</i> spp.....	waterleaf
<i>Koeleria</i> spp.....	Junegrass
<i>Lactuca</i> spp	prickley lettuce
<i>Lepidium campestre</i>	pepper grass
<i>Mentha spicata</i>	wild mint
<i>Mimulus guttatus</i>	seep-spring monkey flower
<i>Pershia tridentata</i>	Antelope bitterbrush
<i>Poa pratensis</i>	Kentucky bluegrass
<i>Prunus virginiana</i>	choke cherry
<i>Pseudotsuga menziesii</i>	Douglas fir
<i>Ranuncululus acris</i>	tall buttercup
<i>Rudbeckia</i> spp	coneflower
<i>Senecio serra</i>	groundsel
<i>Smilacina</i> spp	Solomon's plume
<i>Solidago</i> spp	golden rod
<i>Symphoricarpos oreophilus</i>	mountains snowberry
<i>Taraxacum</i> spp.....	dandelion
<i>Thalictrum</i> spp.....	meadow rue
<i>Urtica dioica</i>	stinging nettle
<i>Veratrum</i> spp.....	false helebore
<i>Verbascum thapsus</i>	common mullein

Appendix Table D-3. Scientific and common names for plants found in the Big Cottonwood Creek riparian area.

<i>Achillea millefolium</i>	common yarrow
<i>Agropyron spicatum</i>	bluebunch wheatgrass
<i>Agropyron repens</i>	quackgrass
<i>Aquilegia formosa</i>	Sitka columbine
<i>Artemisia tridentata</i> spp. <i>vaseyana</i>	mountain big sagebrush
<i>Betula glandulosa</i>	bog birch
<i>Bromus tectorum</i>	cheatgrass
<i>Carex</i> spp.....	sedges
<i>Cirsium</i> spp.....	thistle
<i>Galium</i> spp.....	bedstraw
<i>Heracleum lanatum</i>	cow parsnip
<i>Lactuca</i> spp.....	prickley lettuce
<i>Mimulus guttatus</i>	seep-spring monkey flower
<i>Oenothera</i> spp.....	primrose
<i>Philadelphica fleabane</i>	pink daisy
<i>Poa pratensis</i>	Kentucky bluegrass
<i>Populus tremuloides</i>	quaking aspen
<i>Potentilla glandulosa</i>	sticky cinquefoil
<i>Prunus virginiana</i>	chokecherry
<i>Solidago</i> spp.....	goldenrod
<i>Symphoricarpos oreophilus</i>	mountain snowberry
<i>Urtica dioica</i>	stinging nettle
<i>Veratrum</i> spp.....	false helebore
<i>Verbascum thapsus</i>	common mullein
<i>Veronica cusickii</i>	Cusick's speedwell

Appendix E

Riparian and Stream Channel Surveys on the Craters of the Moon National Monument

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 17 July 92 Time: 11:00 Obs.: Rud

Stream BIG COTTONWOOD CREEK

Sta. #2 FOUND DOWNSTREAM OF ROAD LEADING TO AN MATEL MINE

ELEV.
6640

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1	BANKS ARE LESS THAN 20%	2		
	2	NO EVIDENCE OF SLUMPING IN THIS REACH	3		
	3	DEBRIS IS PRESENT BUT IS TOO LARGE TO BE CARRIED AWAY.	2		
	4	BANKS ARE WELL PROTECTED BY GRASSES + WEEDS < 90%	3		
LOWER BANK	5			CHANNEL CAPACITY RATIO $\frac{50}{6}$	2
	6				
	7	OBSTRUCTIONS ARE PRESENT BUT ARE FIRMLY IMBEDDED	2		
	8	NO CUTTING APPARENT IN THIS REACH	4		
	9	NO DEPOSITION DUE TO SWIFTNESS OF WATER	4		
BOTTOM	10	ROCKS ARE VERY ANGULAR	1		
	11			SOME OF THE ROCKS ARE BRIGHT DUE TO FAST WATER	2
	12			PACKS ARE MODERATELY PACKED AND LAYERED	4
	13	BOTTOM SIZE IS NORMAL FOR AREA	4		
	14	NO SCOURING IN THIS REACH	6		
	15	AQUATIC PLANTS ARE VERY ABUNDANT	1		
EXCELLENT TOTAL			32	GOOD TOTAL	8

Add values in each column and record in spaces below, add column scores.

E 32 + G 8 + F 6 + P 0 = 46 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

Good RATING 46

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 17 July 92 Time: 12:00 Obs.: JD

Stream DIG COTTONWOOD CREEK Sta. 3 LOCATED DIRECTLY W. of Road
LEADING TO MINE SHACK
Elev. 6440

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2	NO SLUMPING IN THIS REACH IF STREAM	3		
	3	NO DEBRIS ON STREAM BANKS ONLY VEGETATIVE PLANTS	2		
	4	GROUND COVER HERE NEAR 100% MOSTLY GRASSES	3		
LOWER BANK	5	CHANNEL CAPACITY RATIO 35" w x 18" d ≈ 2	1		
	6			ROCKS HERE ARE NOT NUMEROUS BUT ARE OF THE SIZE CLASS 6-12"	4
	7	ROCKS ARE THE ONLY OBSTRUCTIONS AND THEY ARE FIRMLY EMBEDDED IN THE STREAM.	2		
	8			SOME CUTTING IS EVIDENT IN THIS STREAM REACH.	8
	9	VERY LITTLE OR NO DEPOSITS OF SEDIMENT IN THIS REACH	4		
BOTTOM	10	ROCKS HAVE VERY ANGULAR FORM IN THIS REACH	1		
	11	ROCKS ARE DULL IN COLOR.	1		
	12	ROCKS ARE TIGHTLY PACKED AND LAYERED ON ONE ANOTHER	2		
	13	BOTTOM SIZE IS NORMAL FOR BASIN.	4		
	14	NO SCOURING EVIDENT IN THIS REACH OF STREAM.	6		
	15				
EXCELLENT TOTAL			29	GOOD TOTAL	12

Add values in each column and record in spaces below, add column scores.

E 29 + G. 12 + F. 9 + P. 0 = 50 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED Good = 50

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 17 July 92 Time: 13:00 Obs.: Russ

Stream BIG COTTONWOOD CREEK

Sta. #4

LOCATED 1/4 MILE DOWNSTREAM OF STATION 3.

EICV 6250

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
U P P E R B A N K	1			BANK SIDRE 30-40% ON ONE OR BOTH BANKS	4
	2	NO EVIDENCE OF ANY SWAMPING IN THIS AREA.	3		
	3				
	4			THE BANKS HAVE BEEN HEAVILY GRAZED BY CATTLE BUT ROOTS + STEMS REMAIN.	6
L O W E R B A N K	5	CHANNEL CAPACITY RATIO 72" x 12"	1		
	6				
	7				
	8	NO CUTTING VISIBLE IN THIS REACH.	4		
	9	VERY FEW DEPOSITS OF SEDIMENT IN THIS REACH	4		
B O T T O M	10	ROCKS ARE VERY ANGULAR IN APPEARANCE	1		
	11	ROCKS ARE DULL AND STAINED BY THE WATER.	1		
	12	ROCKS ARE PACKED TIGHTLY TOGETHER AND ARE HARD TO DISLODGE	2		
	13	BOTTOM SIZE IS NORMAL	4		
	14	NO SCOURING PRESENT IN THIS REACH	6		
	15				
EXCELLENT TOTAL			26	GOOD TOTAL	10

Add values in each column and record in spaces below, add column scores.

E 26 + G. 10 + F. 6 + P. 20 = 62 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED GOOD = 62

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 18 July 92 Time: 10:00 Obs.: Kuss

Stream BIG COTTONWOOD CREEK Sta. #5 LOCATED 1/4 MILE DOWNSTREAM OF STA. 4

ELEV. 6120

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2				
	3			SOME DEBRIS IS PRESENT BUT WOULD ONLY FORM SMALL JAMS	4
	4			BANK PROTECTION 70-90% TREES / SHRUBS / GRASSES (ASPEN - BIRCH)	6
LOWER BANK	5	CHANNEL CAPACITY RATIO 39:112 ≈ 3	1		
	6			45-60% ROCK CONTENT IN BANK SIZE CLASS 3-6"	4
	7			SOME OBSTRUCTIONS PRESENT MIGHT CAUSE SEASONAL EROSION + SEDIMENT TRAPS.	4
	8	VERY LITTLE CUTTING IN THIS REACH	4		
	9			SOME DEPOSITION DOES OCCUR BEHIND OBSTRUCTIONS	8
BOTTOM	10			ROCKS APPEAR TO BE OF A SUB-ANGULAR SHAPE.	2
	11	ROCKS ARE VEG. DARK IN COLOR	1		
	12			ROCKS ARE MODERATELY PACKED AND LAYERED	4
	13	CREEK BED APPEARS NORMAL FOR SURROUNDING AREA	4		
	14	NO SIGN OF SCOURING IN THIS REACH	6		
	15				
EXCELLENT TOTAL			16	GOOD TOTAL	32

Add values in each column and record in spaces below, add column scores.

E. 16 + G. 32 + F. 3 + P. 20 = 71 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED Good = 71

* COWS HAVE HAD A BIG INFLUENCE ON STREAM BANK IN THIS REACH.

SIDEWATER REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 18 July 92 Time: 12:10 Obs.: Russ

Stream BIG COTTONWOOD CREEK Sta. 6 LOCATED 1/4 MILE DOWNSTREAM OF STA. 5 / JUST UPSTREAM OF WOODEN BRIDGE
ELEV. 6010

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1			SLOPE IS 15% LOW - 40% EXCEPT FOR SMALL SECTION NEAR 60%	4
	2	NO MASS WASTING IN THIS REACH	3		
	3	DEBRIS IS PRESENT BUT IS LARGE ENOUGH THAT IT CAN'T BE FLOATED AWAY	2		
	4	GOOD GROUND COVER OF TREES AND GRASSES	3		
LOWER BANK	5			Ratio $\frac{96}{8} = 12$	2
	6				
	7			OBSTRUCTIONS ARE PRESENT AND SHOW SIGNS OF TRAPPING SEDIMENT.	4
	8	THERE IS NO CUTTING VISIBLE IN THIS STREAM REACH	4		
	9				
BOTTOM	10	ROCKS ARE VERY ANGULAR HERE	1		
	11	ROCKS ARE VERY DULL IN COLOR	1		
	12	ROCKS OF VARIOUS SIZES ARE PACKED TIGHTLY TOGETHER	2		
	13	BOTTOM SIZE IS NORMAL FOR WATERSHED	4		
	14	NO AREAS OF SCOURING IN THIS REACH	6		
	15	CLINGING DIATOMS ARE ABUNDANT THROUGHOUT THE REACH	1		
EXCELLENT TOTAL			27	GOOD TOTAL	10

Add values in each column and record in spaces below, add column scores.

E. 27 + G. 10 + F. 6 + P. 16 = 59 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F.)

RATED Good = 59

* CONDS ARE ALSO PRESENT IN THIS REACH, BUT HAVE NOT CAUSED MUCH DAMAGE.

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/18/92 Time: 10:45 Obs.: JCM

Stream: LEACH CREEK OF PARK LOCATED AT N. BOUNDARY Sta. # 1 REACH 1 IS APP. 40 YRDS LONG
ELEV. 6440

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2			THERE IS SOME EVIDENCE OF BANK SLUMPING, BUT DOESN'T APPEAR TO BE A PROBLEM	6
	3	THERE IS SMALL DEBRIS SCATTERED ABOUT BUT IS OF A SIZE CLASS THAT DOESN'T POSE A THREAT	2		
	4			70-90% OF GROUND IS COVERED BY PLANTS/ ONLY VERY FEW TREES → (PRUNUS)	6
LOWER BANK	5			RATIO FIGURES TO BE $\approx 10.66 > 8-15$ CLASS	2
	6				
	7	ROCKS - MOSTLY SMALL GRAVEL - IT IS WELL EMBEDDED SO NOT TO BE WASHED AWAY.	2		
	8	THIS REACH OF STREAM IS VERY STRAIGHT + WATER IS TOO SLOW TO PRODUCE CUTTING.	4		
	9	THERE IS NO EVIDENCE OF DEPOS. IN THIS REACH. NOT EVEN BLIND LARGE OBSTRUCTIONS.	4		
BOTTOM	10			ROCKS DO HAVE GOOD ANGULARITY BUT HAVE UNDERGONE SOME ROUNDING	2
	11	ROCKS IN THIS REACH ARE COVERED WITH MOSS/ALGAE AND APPEAR STAINED	1		
	12	SUBSTRATE IS SMALL BUT SEEMS SUFFICIENTLY PACKED TO WITHSTAND TIMES OF HIGH FLOW.	2		
	13	MOSS AND ALGAE CAN BE FOUND FROM STREAM BANK TO STREAM BANK AND IS UNIFORM	4		
	14	LESS THAN 5% OF BOTTOM APPEARS TO BE AFFECTED BY SCOURING	6		
	15	ROCKS ARE COMPLETELY COVERED WITH VEGETATION	1		
EXCELLENT TOTAL		26	GOOD TOTAL		16

Add values in each column and record in spaces below, add column scores.

E 26 + G. 16 + F. 12 + P. 0 = 54 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

STREAM REACH X GOOD RATING

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 11:10 Obs.: Russ

Stream LEECH CREEK Sta. #2 LOCATED AT MID BOUNDARY

E189. 6/80

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2				
	3	THE BANK IS COVERED WITH SMALL LIMBS BUT ARE SITUATED AS TO NOT POSE A THREAT	2		
	4	GROUND COVER 90% OR GREATER HEAVY CANOPY CONSISTING OF HICKORY + CHERRY	3		
LOWER BANK	5	Ratio of this reach = 4.4	1		
	6	Rock content greater than 65% + many are larger than 12"	2		
	7			THERE ARE SMALL TWIGS LYING IN CREEK CHANNEL AND COULD BE DISLODGED IN TIMES OF HIGH FLOW	4
	8	NO CUTTING IS PRESENT IN THIS STREAM REACH, PLANTS ARE GROWING RIGHT NEXT TO WATERS EDGE	4		
	9				
BOTTOM	10	ROCKS ARE EXTREMELY ANGULAR AND UNIFORM IN DISTRIBUTION DUE TO SLOW CURRENTS	1		
	11	ROCKS IN THE BOTTOM OF THE CHANNEL ARE STAINED AND APPEAR DULL	1		
	12	ROCKS ARE STACKED AND ARE HARD TO DISLODGE	2		
	13	ALL SIZES OF ROCKS ARE FOUND HERE FROM 12" TO PEN SIZED GRAVEL	4		
	14			THIS REACH HAS SOME DEPOSITS OF SILT AND SEDIMENT BEHIND SMALL TWIGS + ROCKS	12
	15			VEGETATION IS PRESENT BUT DOESN'T STREAM FROM STREAM BANK TO STREAM BANK	2
EXCELLENT TOTAL			19	GOOD TOTAL	18

Add values in each column and record in spaces below, add column scores.

E19 + G18 + F15 + P16 = 68 Total Reach Score.

Adjective ratings: <38=Excellent, 38-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F.)

OVERALL RATING 68 = GOOD

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/25/92 Time: 12:32 Obs.: Kuss

Stream LEECH CREEK Sta. # 3 LOCATED NEAR RESEARCH CAMP AT CLEV. 6000 FT.

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
U P P E R B A N K	1	BOTH BANKS ARE NEAR A 10% SLOPE	2		
	2	THERE IS NO EVIDENCE OF MASS WASTING HERE DUE TO THE FLATNESS OF THE BANKS	3		
	3	THE DEBRIS IS LARGE ENOUGH THAT THE WATER EVEN DURING TIMES OF HIGH FLOWS WOULD NOT CARRY IT AWAY	2		
	4	90% OF GROUND IS COVERED BY TREES AND FORGES.	3		
L O W E R B A N K	5			CHANNEL RATIO = 9.25	2
	6				
	7				
	8	NO EVIDENCE OF CUTTING IN THIS REACH DUE TO LINEAR QUALITY OF STREAM.	4		
	9				
B O T T O M	10	FEW ROCKS ARE PRESENT BUT THOSE THAT ARE FOUND ARE VERY ANGULAR	1		
	11			ROCKS THAT ARE FOUND ARE BRIGHT DUE TO LACK OF WATER.	2
	12				
	13	ROCKS APPEAR TO BE NORMAL IN SIZE FOR THE BASIN.	4		
	14			SOME SCOURING IS EVIDENT IN THIS REACH MOSTLY AROUND TREE ROOTS	12
	15				
EXCELLENT TOTAL			19	GOOD TOTAL	16

Add values in each column and record in spaces below, add column scores.

E 19 + G. 16 + F. 15 + P. 24 = 74 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

THIS REACH RATED GOOD = 74

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 13:00 Obs.: Kuss

Stream LITTLE COTTONWOOD CREEK

Sta. # 1 LOCATED AT SPRING ~~AND~~ BOX ON
LITTLE COTTONWOOD CREEK.

ELEV. 6860

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1	BOTH SIDES OF STREAM ARE LESS THAN 30%		2	
	2			SMALL GAME TRAIL IN THIS REACH ALLOWS POTENTIAL FOR A SMALL AMOUNT OF SLUMPING	6
	3	THERE ARE NUMEROUS TWIGS AND BRANCHES BUT ARE OF A LARGE ENOUGH SIZE AS TO NOT POSE ANY THREAT.		2	
	4	GROUND COVER IS EXCELLENT 90% OR GREATER.		3	
LOWER BANK	5			BASSED ON RATIO THIS REACH IS GIVEN A VALUE OF 8 (40" W 5' D.)	2
	6				
	7			SOME BRANCHES ARE IN STREAM CHANNEL AND LOOK TO BE SMALL ENOUGH TO MOVE.	4
	8	THIS STREAM EXHIBITS NO CUTTING AT THIS STATION FLOW IS NOT ENOUGH TO CAUSE THIS SITUATION		4	
	9	ONLY A FEW SPOTS OF FRESH SILT AND SAND DEPOSITS ARE PRESENT.		4	
BOTTOM	10	ROCKS APPEAR VERY ANGULAR HERE DUE TO LACK OF FLOW		1	
	11	ROCKS HAVE A DULL APPEARANCE DUE TO WATER STAINS		1	
	12			ROCKS ARE PACKED IN A FAIRLY TIGHT PATTERN BUT ARE NO EXCELLENT.	4
	13	ROCKS ARE CONSISTANT IN SIZE FOR SURROUNDING AREA.		4	
	14	THERE IS NOT ENOUGH WINDY GRADE HERE TO CREATE EROSION.		6	
	15			PLANTS ARE PRESENT AND ABUNDANT, BUT DO NOT EXTEND FROM BANK TO BANK.	2
EXCELLENT TOTAL		27		GOOD TOTAL	
				18	

Add values in each column and record in spaces below, add column scores.

E 27 + G. 18 + F. 0 + P. 0 = 53 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATING Good = 53

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 13:30 Obs.: RWS

Stream LITTLE COTTONWOOD CREEK Sta. #2 LOCATED 1/4 MILE BELOW STATION 1

ELEV. 6660

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2				
	3	NOT MUCH DEBRIS HERE ONLY LIVE VEGETATIVE MATTER.	2		
	4			PLANTS COVER 70-90% OF GROUND TRANSITION ZONE	6
LOWER BANK	5			CHANNEL CAPACITY RATIO 6' x 10" = 7.2	2
	6			BANK ROCK CONTENT IS GOOD MANY BEING IN SIZE CLASS OF 6-12"	4
	7	THIS REACH CONTAINS ROCKS AND LOGS THAT ARE FIRMLY BEDDED AND POSE NO THREAT OF MOV.	2		
	8	THERE IS NO EVIDENCE OF CUTTING IN THIS REACH	4		
	9	THERE ARE NO DEPOSITS OF SILT OR SAND IN THIS REACH	4		
BOTTOM	10	ROCK ARE VERY ANGULAR	1		
	11	ROCKS APPEAR DARK IN COLOR AND ARE COVERED W/ALGAE	1		
	12	MANY DIFFERENT SIZES OF ROCKS ARE LAYERED AND PACKED TIGHTLY	2		
	13	SIZE IS CONSIST. WITH SURROUNDING ROCKS ON BANKS.	4		
	14	NO SCOURING IS PRESENT IN THIS REACH	6		
	15			AQUATIC PLANTS ARE COMMON BUT NOT EXCELLENT.	2
EXCELLENT TOTAL			26	GOOD TOTAL	14

→ SAGE BRUSH
SNOW BERRY
BIRCH / CHOKELCHUA
COW PARSNIP

Add values in each column and record in spaces below, add column scores.

E 26 + G 14 + F 0 + P 20 = 60 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

Good Rating 60

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 14:13 Obs.: RUN

Stream LITTLE COTTONWOOD CREEK Sta. 3 LOCATED 1/4 MILE BELOW STATION 2

Elev. 6460

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2			SOME BANK SLUMPING HAS OCCURRED IN THE PAST BUT DOESN'T APPEAR TO BE A PROBLEM	6
	3	DEBRIS IS PRESENT BUT DOESN'T HAVE POTENTIAL TO ENTER STREAM CHANNEL DUE TO SIZE	2		
	4	THERE IS VERY GOOD BANK PROT. TO KEEP WATER FROM ERODING STREAM BANK.	3		
LOWER BANK	5	CHANNEL CAPACITY RATING TO "w = 10" d = 4	1		
	6			Boulders AND COBBLES ARE COMMON IN THIS REACH BUT DON'T MAKE UP BANK OF STREAM.	4
	7			THERE ARE SOME OBSTRUCTIONS THAT HAVE TRAPPED SEDIMENTS	4
	8	THERE IS NO EVIDENCE OF CUTTING IN THIS STREACH OF STREAM.	4		
	9	THERE ARE A FEW PLACES WITH SILT BUT THE OCCURRENCE IS MINIMAL.	4		
BOTTOM	10	ANGULARITY IS EXCELLENT	1		
	11	ROCKS ARE DUL AND HAVE A WATER STAINING	1		
	12	ROCKS IN CHANNEL ARE CONSISTENT WITH THOSE IN THE BASIN AND ARE PLACED TIGHTLY	2		
	13	NO EVIDENCE OF SCOURING IN THIS REACH DUE TO ROLLY BOTTOM.	4		
	14	BOTTOM SIZE APPEARS NORMAL FOR THE BASIN	6		
	15			VEGETATION IS PRESENT BUT IS NOT CONTINUOUS.	2
EXCELLENT TOTAL		28	GOOD TOTAL		16

Add values in each column and record in spaces below, add column scores.

E2B 16 + G. 16 + F. 0 + P. 8 = 52 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

Good RATING → 52

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 15:35 Obs.: RMS

Stream LITTLE COTTONWOOD CREEK Sta. 4 Located just upstream from pond near Martin Mine

Elev. 6200

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1			SLOPE IS GREATER 30%, BUT LESS THAN 40%	4
	2	NO EVIDENCE OF MASS WASTING IN THIS SECTION	3		
	3	THERE IS NOT MUCH DEBRIS AT THIS REACH MOSTLY GRASSES OR SEDGES	2		
	4	GROUND COVER ON THE BANK IS NEAR 100% - GRASSES AND SEDGES	3		
LOWER BANK	5	CAPACITY RATIO = 4.6	1		
	6				
	7	Almost NO obstructions appear in this reach	2		
	8	NO CUTTING EVIDENT IN THIS STREAM REACH	4		
	9				
BOTTOM	10	ROCKS THAT ARE FOUND HERE ARE VERY ANGULAR	1		
	11	ROCKS APPEAR DULL/STAINED BY THE WATER.	1		
	12			ROCKS ARE MODERATELY TIGHTLY PACKED	4
	13				
	14	NO EVIDENCE OF SCOURING - NOT MUCH CHANGES IN FLOW	6		
	15			AQUATIC WEEDS ARE GROWING IN CHANNEL (RANUNCULUS)	2
EXCELLENT TOTAL			23	GOOD TOTAL	10

Add values in each column and record in spaces below, add column scores.

E 23 + G. 10 + F. 18 + P. 16 = 67 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

Ratio Good = 67

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/22/92 Time: 16:06 Obs.: RUM

Stream LITTLE COTTONWOOD CREEK Sta. #5 Located 1/4 mile below STA. 4

ELEV. 6140
App. 200' below
culvert.

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2	NO EVIDENCE IF THIS REACH DUE TO GRASS COVERED SLOPES	3		
	3	NOT MUCH DEBRIS ON BANK	2		
	4	GRASSES COVER GROUND COMPLETELY.	1		
LOWER BANK	5	CHANNEL CAPACITY RATIO = 2.08	1		
	6				
	7			TWIGS IN CHANNEL CAN FORM OBSTRUCTION DURING HIGH FLOW	4
	8	NO EVIDENCE OF CUTTING IN THIS REACH	4		
	9				
BOTTOM	10	ROCKS ARE VCR. ANGULAR	1		
	11	ROCKS APPEAR DAMAGED BY THE WATER	1		
	12			ROCKS ARE MODERATELY LAYED AND PACKED	4
	13	ROCKS APPEAR TO BE OF NORMAL SIZE	4		
	14	NO SCOURING IN THIS PART OF THE STREAM	6		
	15				
EXCELLENT TOTAL			25	GOOD TOTAL	8

Add values in each column and record in spaces below, add column scores.

E.25 + G. 8 + F.12 + P.20 = 65 Total Reach Score.

Adjective ratings: <38=Excellent, 38-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED GOOD = 65

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/23/92 Time: 13:10 Obs.: Russ

Stream LITTLE COTTONWOOD CREEK Sta. # 6 LOCATED 1/4 MILE FROM #5 AND WEST OF WELLS

ELEV. 6000

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2				
	3			DEBRIS OFFERS SOME PROTECTION BUT COULD BE FLOATED AWAY.	4
	4			BANK PROTECTION IS GOOD 70-90% MOSTLY GRASSES W/ WIP. FISHES	6
LOWER BANK	5	CHANNEL CAPACITY 6'w x 3'd = 2	1		
	6				
	7			MOST OBSTRUCTIONS HERE ARE OF VEG. PLANTS	4
	8				
	9				
BOTTOM	10	VERY FEW ROCKS IN THIS REACH BUT THOSE FOUND ARE ANGULAR	1		
	11	BOTTOM IS DULL IN COLOR	1		
	12				
	13	ROCK MIXTURE IS NORMAL TO SURROUNDING AREA	4		
	14	NO EVIDENCE OF SILTING IN THIS REACH	6		
	15				
EXCELLENT TOTAL			13	GOOD TOTAL	14

Add values in each column and record in spaces below, add column scores.

E 13 + G. 14 + F. 33 + P. 28 = 88 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED FAIR = 88

STREAM REACH INVENTORY & CHANNEL STABILITY EVALUATION

Reach Location: Date: 06/23/92 Time: 13:45 Obs.: Russ

Stream LITTLE COTTONWOOD CREEK Sta. 7 LOCATED 1/4 MILE DOWNSTREAM OF STA. 6

LEV 5940

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1				
	2			THERE ARE A FEW AREAS OF SLUMPING IN THIS REACH	6
	3	DEBRIS IS PRESENT BUT IS SITUATED AS NOT TO DAM STREAM.	2		
	4			PLANT COVER CONSIST OF MOSTLY GRASSES	6
LOWER BANK	5	CHANNEL CAPACITY 38"W x 11"D = 3.45	1		
	6				
	7	NO OBSTRUCTIONS IN THIS REACH	2		
	8				
	9	SOME DEPOSITION IS PRESENT BUT IT IS VERY LITTLE	4		
BOTTOM	10	ROCKS THAT FOUND ARE VERY ANGULAR	1		
	11	ROCKS ARE VERY DIM IN COLOR	1		
	12				
	13	BOTTOM SIZE APPEARS NORMAL FOR BASIN AREA.	4		
	14	NO SCOURING IN THIS REACH	6		
	15				
EXCELLENT TOTAL			21	GOOD TOTAL	12

Add values in each column and record in spaces below, add column scores.

E. 21 + G. 12 + F. 12 + P. 28 = 73 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED GOOD → 73

Reach Location: Date: 17 July 92 Time: 10:00 Obs.: RWD

Stream BIG COTTONWOOD CREEK Sta. #1 PAYMASTER MINE RUNN OFF

Elev.
6840

	Key #	Stability Indicators by Classes			
		EXCELLENT		GOOD	
UPPER BANK	1			THE SLOPE HERE APPROX 40%	4
	2	NO EVIDENCE OF MASS WASTING	3		
	3	DEBRIS IS PRESENT BUT IS LARGE ENOUGH AS NOT TO BE CARRIED AWAY.	2		
	4				
LOWER BANK	5	CHANNEL CAPACITY 13 - 2 = 6.5	1		
	6	BANKS CONSIST MOSTLY OF ROCK DUE TO PAST MINING	2		
	7			SOME ROCKS ARE LARGE ENOUGH TO CREATE SEDIMENT TRAPS	4
	8	THERE IS NO EVIDENCE OF CUTTING HERE.	4		
	9				
BOTTOM	10	ROCKS ARE VERY ANGULAR.	1		
	11	ROCKS ARE DULL IN APPEARANCE AND STAINED W/ IRON OXIDES	1		
	12			PARTICLES ARE MOD. PACKED.	4
	13	BOTTOM SIZE APPEARS NORMAL	4		
	14	NO SCOURING IS EVIDENT	6		
	15				
EXCELLENT TOTAL			24	GOOD TOTAL	12

Add values in each column and record in spaces below, add column scores.

E 24 + G. 12 + F. 15 + P. 12 = 63 Total Reach Score.

Adjective ratings: <38=Excellent, 39-76=Good, 77-114=Fair, 115+=Poor*

*(Scores above may be locally adjusted by C.M.F)

RATED Good = 63

Appendix Table F-a

Calculation of Manning's "n" or roughness coefficient from field observation on Craters of the Moon stream sites.

$$n = (n_0 + n_1 + n_2 + n_3 + n_4) m$$

	n	n ₀	n ₁	n ₂	n ₃	n ₄	m
Leech Creek Upper Station	0.053	0.028	0.015	0	0.010	0	1.00
Leech Creek Lower Station	0.058	0.023	0.015	0	0.018	0.002	1.00
Little Cottonwood Creek Upper Station	0.054	0.032	0.015	0	0.007	0	1.00
Little Cottonwood Creek Lower Station	0.042	0.020	0.010	0	0.005	0.007	1.00
Big Cottonwood Creek Upper Station	0.083	0.040	0.015	0	0.008	0.020	1.00
Big Cottonwood Creek Lower Station	0.056	0.024	0.012	0	0.008	0.012	1.00

Appendix Table F-b. Key used to derive "n" components. From: Cowan, W.L. 1956. Estimating hydraulic roughness coefficients. Agricultural Engineering. 37: 83-85.

Channel condition	Value
Additive factors.....	
Material involved	n ₀
Earth	0.020
Rock Cut	0.025
Fine Gravel	0.024
Coarse Gravel	0.028
Cobble	0.030-0.050
Boulder	0.040-0.070
Degree of irregularity	n ₁
Smooth	0.000
Minor (slight scour)	0.015
Moderate (slumping)	0.010
Severe (eroded banks)	0.020
Variation in channel cross section (location of thalweg)	n ₂
Gradual	0.000
Alternating occasionally	0.005
Alternating frequently	0.010-0.015
Effect of obstructions	n ₃
Negligible	0.000
Minor (15% of area)	0.010-0.015
Appreciable (up to 50%)	0.020-0.030
Severe (> 50% is turbulent)	0.040-0.060
Vegetation	n ₄
None	0.000
Low (grass/weeds)	0.005-0.010
Medium (brush, none in streambed)	0.010-0.025
High (young trees)	0.025-0.050
Very high (brush in streams, full grown trees)	0.050-0.100
Multiplicative factors.....	
Degree of Meandering	m
Minor	1.000
Appreciable	1.150
Severe	1.300