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The impact of nonpoint source pollution from mining wastes on water quality, Elko County, Nevada

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THE IMPACT OF NONPOINT SOURCE POLLUTION FROM MINING WASTES ON WATER QUALITY, ELKO COUNTY, NEVADA

by

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ABSTRACT

A study was performed at a mine site in Elko County, Nevada to determine the effects on water quality resulting from waste rock at the site. Statistically significant (alpha less than or equal to 0.05) increases of several constituents, including sulfate (272 mg/L), calcium (46 mg/L), and magnesium (39 mg/L), were found to occur in the North Fork of the Humboldt River as it flows through the mine site. Geochemical modeling and historical data suggested that waste rock from the mine is primarily responsible for the increase in dissolved solids concentration. Electrical conductivity of the water exhibits seasonal fluctuations, with high values occurring in association with both snowmelt in the spring, and increased precipitation in the fall. Mass loading of dissolved constituents was found to be controlled by river discharge. Many of the deleterious impacts commonly associated with mine wastes, such as acidification and increases in suspended sediment concentrations were not found to be occurring at the site, due to factors such as carbonate buffering of acidity and the presence of sediment control structures at the site.

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CHAPTER 1

INTRODUCTION

This study was designed to gain an understanding of the effect of waste rock from gold mines in northern Nevada on water quality. A gold mine at which extraction activities had recently ceased was selected for study. Water sampling, flow measurement, historical data analysis, and geochemical modeling were performed in an attempt to determine if water quality was being affected by the mine waste, and if so, to what extent. Seasonal variations in water quality were also examined.

Over 30 major mining facilities are currently operating in northern Nevada, and many abandoned mine sites are present in the area as well. Certain aspects of these mining operations that have the potential to produce pollution, such as leach ponds and crushers, have been well studied, but the potential for pollution from other sources, such as waste rock heaps and haul roads, has not been studied as widely. In general, the nature of runoff from these nonpoint pollution sources is poorly understood, especially for arid and semi-arid areas such as Nevada. Research indicates that nonpoint source pollution from mining operations, both existing and abandoned, can have a major impact on water quality (Galbraith et al., 1972; Mink et al., 1972; Kelly, 1988;

Powell, 1988; Salomons and Förstner, 1988; Mudroch et al., 1989; Choubey and Rawat, 1991; Cohen and Gorman, 1991; Zaihua et. al, 1991; and Dreher and Finkelman, 1992).

The area of concern for the study was the Humboldt River Basin in northern Nevada, but certain results are applicable to mines throughout the arid West, and other areas of the world as well. The Humboldt River Basin encompasses 43,623 km^2 in parts of six counties. The Humboldt is a meandering river about 4,699 stream kilometers long, making it the largest river contained wholly in the State of Nevada. Sixty-four lakes or reservoirs with a total surface area of 113 km^2 lie within its basin. Approximately 96 percent of all water used in the basin is from the Humboldt or its tributaries, with the remaining four percent being supplied by wells and springs. Irrigation is the predominant use of water from the basin, accounting for 98 percent of the total (Desert Research Institute, 1994).

Approximately two-thirds of the land in the Humboldt River Basin is managed by the Federal Government, including the Bureau of Land Management, the United States Forest Service (USFS), and the Bureau of Reclamation. Agriculture accounts for 95 percent of the private land use in the basin, but a dramatic increase in mining has occurred recently, due to the discovery of new gold deposits, rising gold prices and improvements in cyanide leaching technologies. Most of the 30 mining operations currently active in the basin are located near the Humboldt or one of its tributaries (Desert Research Institute, 1994).

MINE WASTE IMPACTS ON WATER QUALITY

Many of the things we take for granted in our lives are, at least in part, the product of mining. Mining is a necessary component of our society, but it also has the potential to harm the environment. Many of the deleterious impacts of mining operations, such as the removal of vegetation, the disturbance of natural topography, and the dust created by blasting and crushing, are obvious, even to non-scientists. Several parts of the ore purification process, such as leach ponds, are widely recognized as being potentially harmful to the environment as well. At first glance, other aspects of mining may seem to pose no environmental threat at all. "Barren" rock containing low concentrations of ore, which must be removed to excavate the ore body, is piled in large heaps, and is often used to build the roads traveled by ore hauling trucks. The tailings which are left after the metals have been extracted from the ore are disposed of in large piles, similar to those used for waste rock. These features may seem innocuous, but they can be major contributors to environmental degradation.

The problem of nonpoint source pollution from mines is extensive. According to Cohen and Gorman (1991), about 1.36×10^{10} metric tons of mining waste exists in the United States. Over 60,000 sources of runoff from coal mining operations in Appalachia have caused adverse effects on approximately 16,898 km of streams; and mining refuse in the midwest has polluted over 8,047 km of streams and rivers.

Mines in the U. S. are currently required to reclaim the land they disturb, a process that usually includes dismantling haul roads, covering waste rock and tailings

heaps with soil, and encouraging vegetation growth, but this was not always the case. In the past, mine wastes were simply left out in the open. In these conditions, mine wastes can cause pollution until the responsible minerals are entirely depleted, a process that can take several thousand years (Ficklin et al., 1994). In addition, early mining operations often used refining and extraction techniques much less sophisticated than those of today. As a result, recovery rates for ores were relatively low, meaning that old tailings heaps usually contain greater concentrations of metals than those created recently (Mink et al., 1972). For these reasons, the nonpoint source pollution from abandoned mines often presents an environmental hazard more serious than that from reclaimed mines.

There are three major deleterious effects on water quality that commonly result from nonpoint sources at mining operations--an increase in the concentration of suspended solids, acidification, and increased metals content.

High concentrations of suspended and dissolved solids can render water unpotable, and harm fish and other aquatic species. Increased levels of particulate matter in water can occur as the result of several processes. The removal of vegetation from the mine sites leaves large areas unprotected from erosional forces. Moving materials from the subsurface environment to the atmosphere exposes them to many forces which cause weathering and erosion. The excavation process breaks up solid rock into many smaller pieces, thus increasing its susceptibility to weathering and erosion. Further exacerbating the problem is the fact that waste rock heaps and tailings piles are usually constructed with steep slopes, in order to minimize the area they cover and the

effort and expense required to construct them. The steep slopes of these structures renders them even more prone to erosion.

Water acidification is a problem because most species of flora and fauna can survive only within fairly narrow ranges of pH values, and low pH quickens the decomposition of feldspars, carbonates, and clays (Kelly, 1988). Even small changes in pH can adversely impact several species of flora and fauna. Acidification typically occurs as a result of the oxidation of sulfide minerals which are present in excavated materials. Although sulfide minerals are fairly common throughout the earth's crust, they are often present in higher than usual concentrations where deposits of coal, silver, gold, uranium, lead, copper, zinc, and sulfur are found, making wastes from mines producing these products very susceptible to acidification (Kelly, 1988). Sulfide minerals present at the study site include pyrite, arsenopyrite, chalcopyrite, sphalerite, and stibnite. Pyrite, the most common sulfide mineral, can be oxidized by three separate reactions, as described by Powell (1988):

$$FeS_2 + \tfrac{7}{2}O_2 + H_2O \Rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \quad (1)$$
$$Fe^{2+} + \tfrac{1}{4}O_2 + H^+ \Rightarrow Fe^{3+} + \tfrac{1}{2}H_2O \quad (2)$$
$$Fe^{3+} + 3H_2O \Rightarrow Fe(OH)_3 \downarrow + 3H^+ \quad (3)$$

$$FeS_2 + \tfrac{15}{4}O_2 + \tfrac{7}{2}H_2O \Rightarrow Fe(OH)_3 \downarrow + 2SO_4^{2-} + 4H^+ \quad (4)$$

This represents the pyrite oxidation process which occurs when water is present, but it is very rare that mine waste heaps are not at least partially saturated. The initial

oxidation reaction which occurs under saturated or semi-saturated conditions produces ferrous iron, which is then oxidized to ferric iron in a subsequent reaction. Ferric iron is generally insoluble, and precipitates out of solution, often forming yellow-orange deposits and sludges. In acidic conditions at the earth's surface, bacteria of the genus *Thiobacillus*, which oxidize metals as part of their metabolic process, can cause this reaction to take place up to one million times faster than the purely chemical process (Kelley, 1988). Bacterial activity can be a significant contributor to sulfide oxidation when pH is between 3.5 (Cohen and Gorman, 1991), and 6.6 (Galbraith et al., 1972). Also of note is the fact that in the overall reaction, as shown in Equation 4 (the summation of the first three reaction equations), for each mole of pyrite that is oxidized, four moles of hydrogen ions are produced. This is one of the most efficient weathering reactions in terms of causing acidity.

The reactions that produce acidity require the presence of oxygen. In their undisturbed state, most sulfide minerals occur underground, where anoxic conditions are prevalent. The extent of anoxicity depends on factors such as depth below surface, soil and rock types in the area, and microbial activity (Jury et al., 1991). By bringing these materials to the earth's surface, where they are exposed to an abundant supply of oxygen and increased bacterial activity, the rate of reaction is greatly increased. Another problem is that the breaking and crushing of rocks during excavation and milling operations provides a much greater surface area for chemical reactions to take place. Kelly (1988) notes that most sulfides can remain in their reduced state as long as they

are in an anaerobic environment, and that, although there are some naturally occurring acidic streams, the vast majority of acidic streams are the result of mining operations.

Although the acidity produced by the oxidation of sulfide minerals can be harmful, in areas where carbonate rocks are present, the acidity may be partially or totally neutralized. Although buffering alleviates many of the negative impacts of acidification, it is not a totally benign process. Carbonate buffering increases the amount of dissolved solids present in the water, and increases water hardness. Steinberg (1996) describes the buffering of acid by calcite as follows:

$$2CaCO_3 + H_2SO_4 \Rightarrow 2Ca^{2+} + 2HCO_3^- + SO_4^{2-}$$

Acidity is a problem in its own right, but it also contributes to the problem of increased metals concentration. This is because the dissolved concentrations of metals are directly affected by pH. In mildly alkaline or neutral conditions, the solubility of metals in water is fairly low, but in acidic conditions, metal solubility increases dramatically. A drop of one standard pH unit can increase metal solubility by as much as 35% (Bourg, 1988). Under acidic conditions, higher than normal concentrations of metals will be leached from mine wastes.

If acidity is kept low by buffering, this will keep metals at fairly low dissolved concentrations in the water. In a groundwater system, this will greatly reduce the potential of contaminant migration. In a surface water system, however, contaminant migration is still possible. Metals leached from mining wastes would precipitate out of

solution in the presence of high pH waters, but they could still be transported as suspended sediment, colloids, or bedload by streamflow. In fact, in surface drainages, the vast majority of the metals load is usually carried in the suspended phase, not the dissolved phase (Gibbs, 1977; Horowitz, 1985). If the stream eventually flows though non-carbonaceous rocks, and buffering capacity is lost, these metals can become soluble once again, increasing contaminant concentrations at some distance downstream of the mining operation, even when the stretch of the drainage flowing through the mine has relatively low dissolved concentrations of these metals (Cohen and Gorman, 1991).

CHAPTER 2

SITE DESCRIPTION

SITE LOCATION

The site that was examined during this study is that of the Big Springs Project, a gold mine located near Big Springs in Elko County, Nevada. It is approximately 105 km north of Elko, in the northernmost part of the Independence Mountains. The mine is located at the approximate coördinates of latitude 41° 33' 45" N and longitude 115° 57' 30" W. A map showing the site location is provided in Figure 1.

CLIMATE

The climate is typical of high elevation areas in the Basin and Range physiographic province, with significant daily and seasonal fluctuations in temperature. At the Wildhorse Reservoir weather station, approximately 18 km away, average daily temperatures range from 9.2° C in January to 16.4° C in July.

At the mine site, average annual precipitation is 60-70 cm, most of which occurs as snow. Snow typically makes up almost all of the site's precipitation between October 1 and May 1. (USDA Forest Service and USDI Bureau of Land Management,

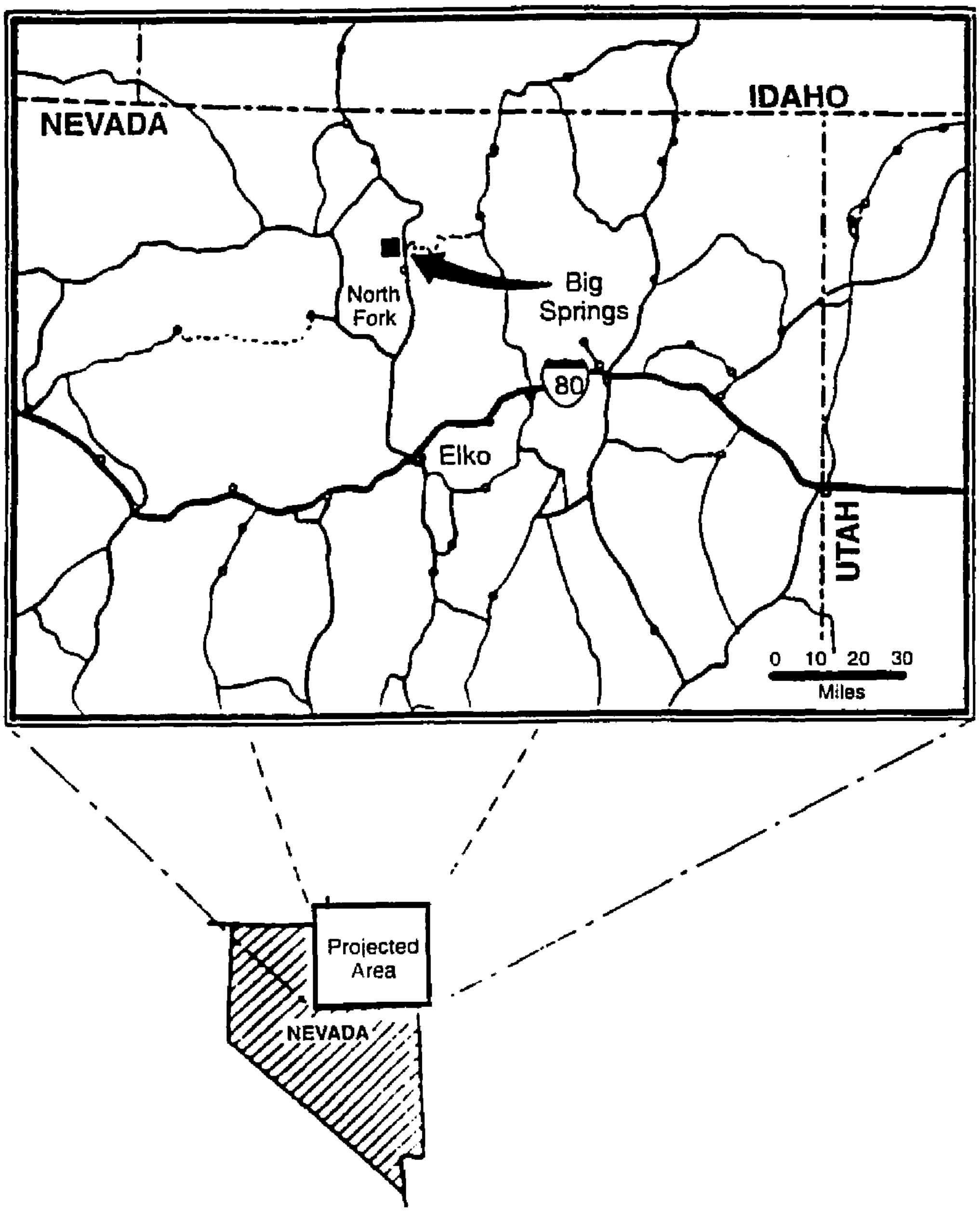


Figure 1: Site Location (After Knight, Piesold and Co., 1984)

1987). At Wildhorse Reservoir, the closest site for which daily precipitation records are available, seasonal precipitation patterns are similar, with wet winters and springs providing the bulk of the precipitation, and the summer and fall months being relatively dry.

SITE GEOLOGY

Four major rock groups are present at the mine site, as depicted in Figure 2, with all rocks belonging to the Schoonover Formation, and being either Mississipian (320-360 million years before present) or Pennsylvanian (286-320 million years before present) in age. An undifferentiated section of the Schoonover Formation, uppermost in the stratigraphic sequence, is Mississipian in age, but was emplaced atop younger rocks by thrust faulting. It is a 610 m thick layer of interbedded siliceous argillite, carbonaceous siltstone, chert, limestone, conglomerate, volcaniclastic sediment, and submarine volcanic rock. A bioturbated quartz siltstone with a calcite/dolomite matrix between 30 and 152 m thick occurs below the undifferentiated Schoonover in the stratigraphic column. The upper 1.5 to 3 m of the siltstone are highly sheared and brecciated as a result of the faulting which emplaced the undifferentiated Schoonover sequence above it. The bottom 3 m are also highly brecciated, due to interaction with the underlying volcanic layer during thrusting. The rock underlying the siltstone is a 4.6 to 15 m thick submarine volcanic deposit. Aphanitic in texture, the rock has been classified as a tholeiitic andestite based on its chemical composition. Lowest in the stratigraphic column is a sandy siltstone estimated to be over 305 m thick. This

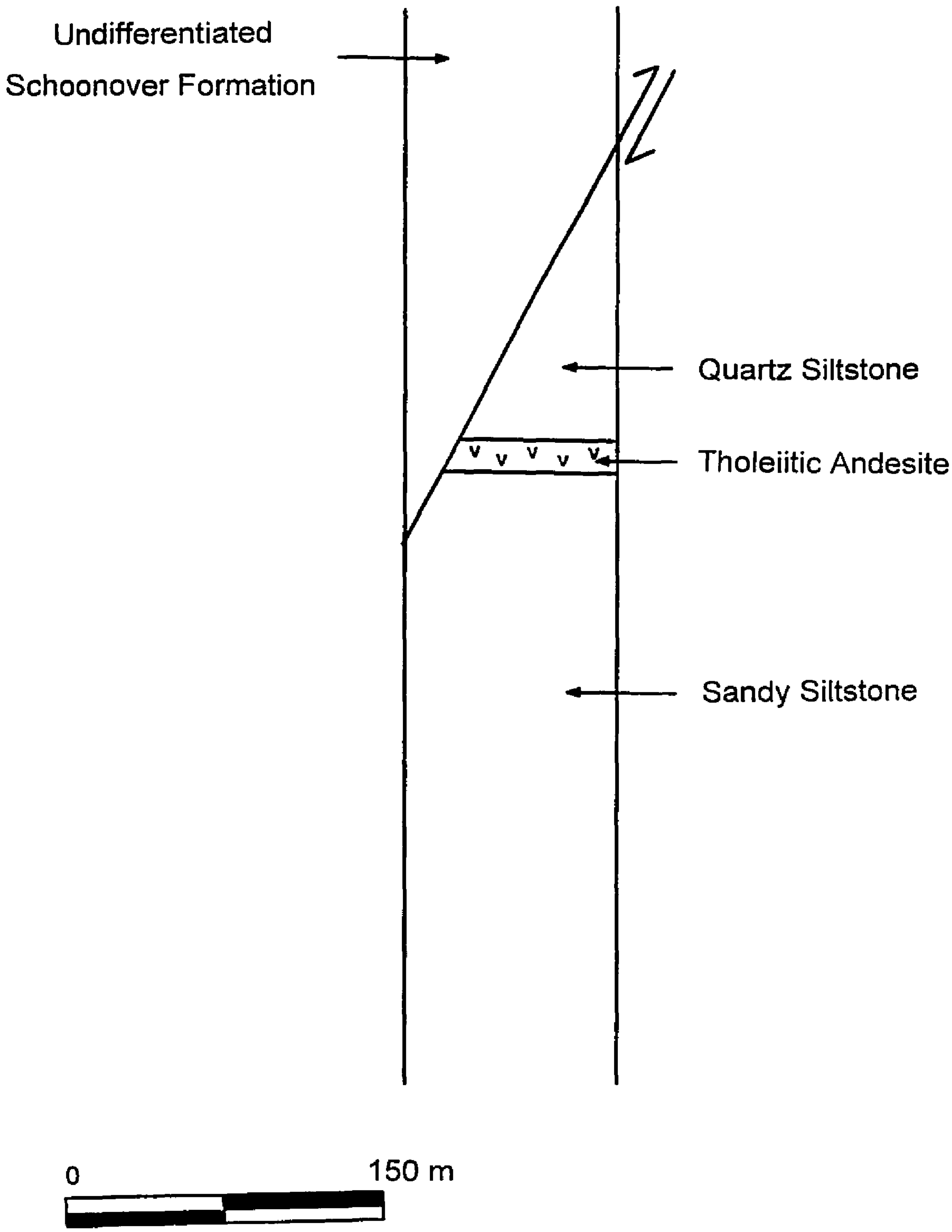


Figure 2: Generalized Stratigraphic Cross-Section for the Big Springs Site (After Youngerman, 1992)

marine sandstone is moderately calcareous, and contains brachiopod and crinoid fossils. Although the sandstone contacts the andesite layer along a fault, no alteration is described (Youngerman, 1992).

ALTERATION AND MINERALIZATION

The Big Springs mine is a Carlin-type gold deposit. Carlin-type deposits exhibit dissemination of ore, sedimentary host rocks, and fine-grained gold particles (Guilbert and Park, 1986). The general model for the formation of these sediment hosted deposits involves hydrothermal fluid upwelling along faults and fractures, and deposition of gold and associated minerals in favorable host rocks, as depicted in Figure 3 (Evans, 1993).

At Big Springs, gold is found in altered rocks as particles below 4 μm in diameter, either free in the rock matrix or associated with pyrite or geothitic oxidation aggregates after pyrite (Collord et al., 1987). Alteration of rocks at the Big Springs site occurred in two stages, one prior to mineralization, the other during and after ore deposition. Pre-deposition alteration consisted mainly of carbon enrichment and greenschist metamorphism. Concurrent and post-depositional alteration includes dolomitization, sericitization, silicification, decarbonatization, and quartz/carbonate veining. The quartz/carbonate veins appear to cross-cut other types of alteration, and although some pyrite and stibnite is found within them, they are not gold-bearing. The decarbonatization and dolomitization processes, which increase permeability, appear to have the best association with ore deposition. In many parts of the deposit,

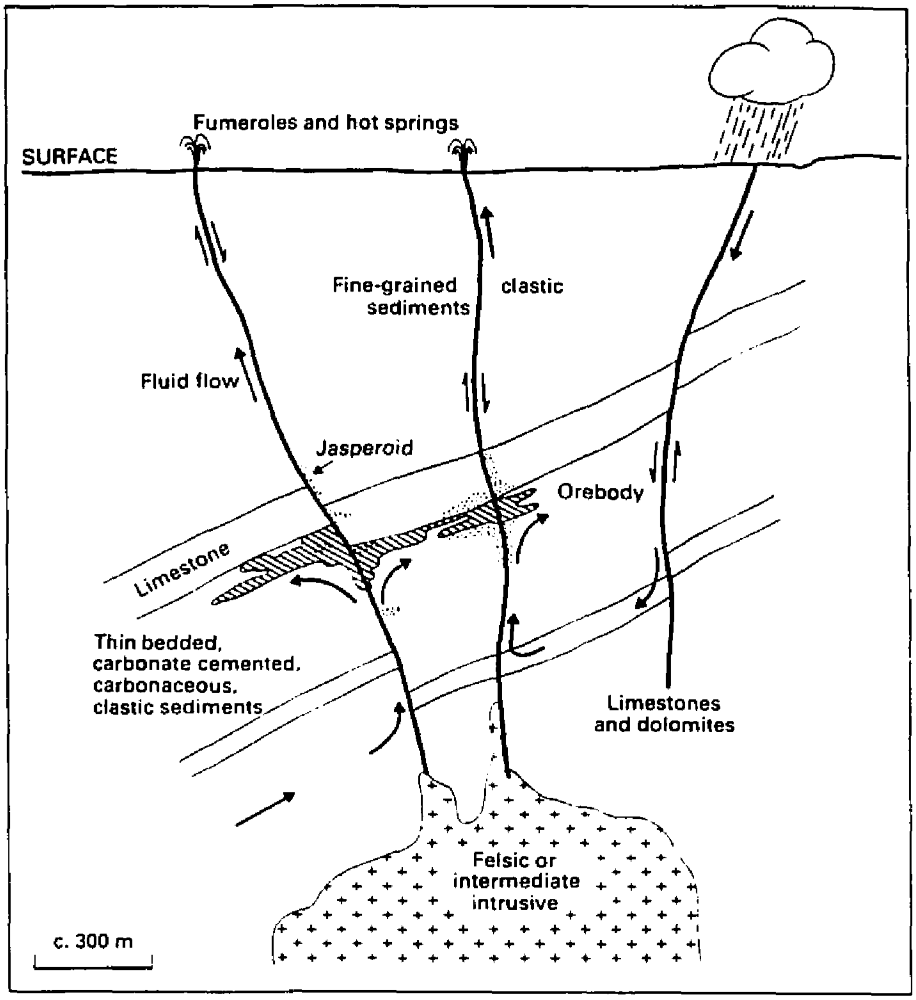


Figure 3: Carlin-Type Deposit Formation Model (Evans, 1987)

mineralization appears to be structurally controlled, with most gold occurring within 3-6 m of a fault. The ore and gangue minerals most abundant at the site are pyrite, marcasite, arsenopyrite, sphalerite, chalcopyrite, stibnite, and gold. Goethite is present along some fractures where oxidation by ground water caused the alteration of pyrite, arsenopyrite, and marcasite. Rutile and zircon are both present in most rocks at the site, and are thought to have been part of the original sedimentary deposition. Certain mineralized areas also contain minor quantities of tetrahedrite (Youngerman, 1992).

MINE WORKINGS

The main features of the Big Springs Mine are shown in Figure 4. Three major pits were mined: North Sammy Creek, South Sammy Creek, and Mac Ridge. Figure 5 excludes the Mac Ridge area, but shows the remaining features in greater detail. Some waste rock was backfilled into previously constructed pits, but the majority was placed in several dumps. As opposed to tailings, which have been milled as part of the processing operation, waste rock is larger and more variable with regard to size. Small pieces of waste rock are pebble-sized, but large pieces are boulder-sized. The relatively large size of the waste rock will typically allow water to flow through at a fairly rapid rate. In addition, during dump construction at Big Springs, large-diameter waste rock was placed in natural drainage channels in order to minimize hindrance of flow (Freeport McMoRan Gold Company, 1986). As can be seen in Figures 4 and 5, many of these waste rock dumps are directly in the route of ephemeral drainages which are tributaries to the North Fork. Figure 5 shows that sediment control structures were

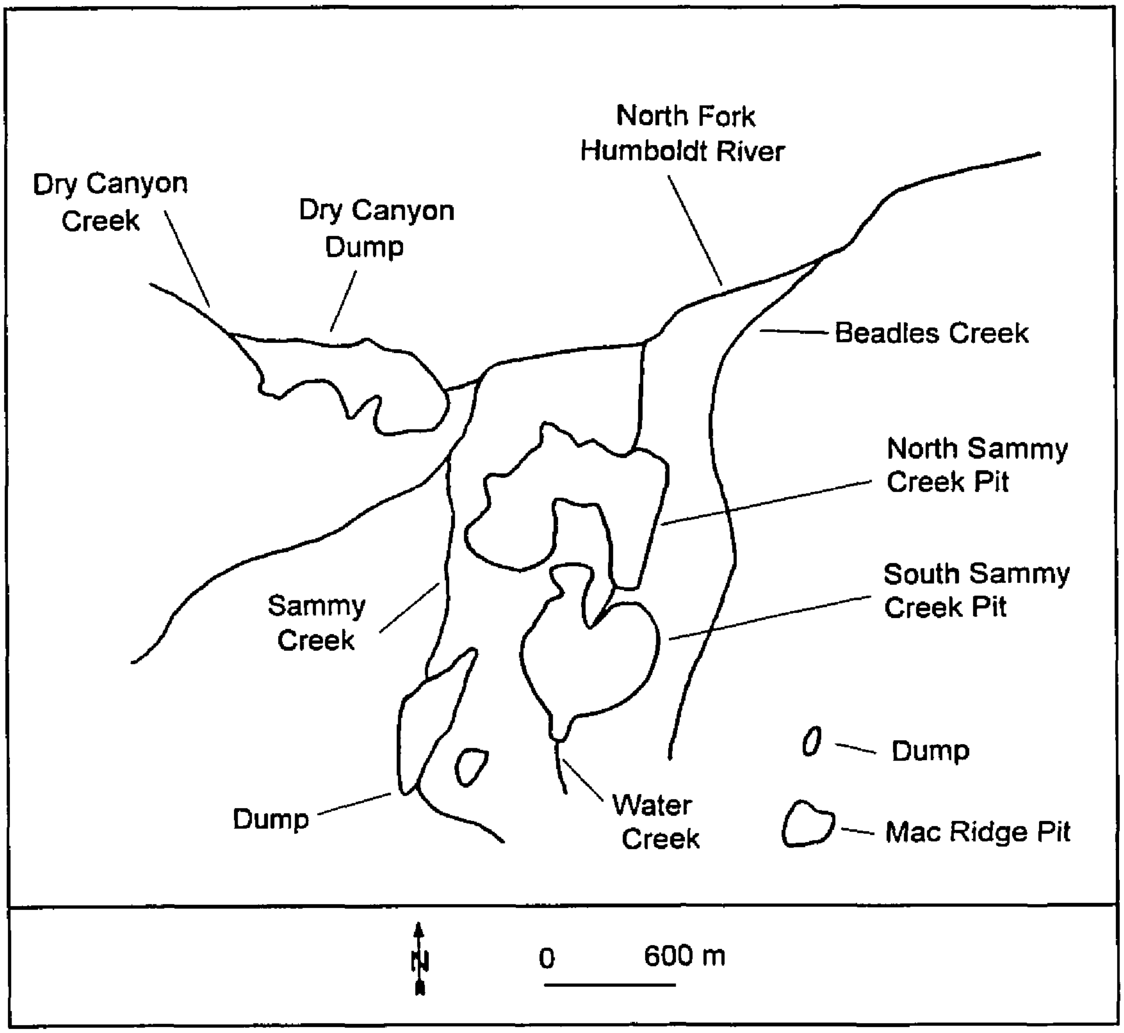


Figure 4: Overview of Mine Workings (After Anderson et al., 1994)

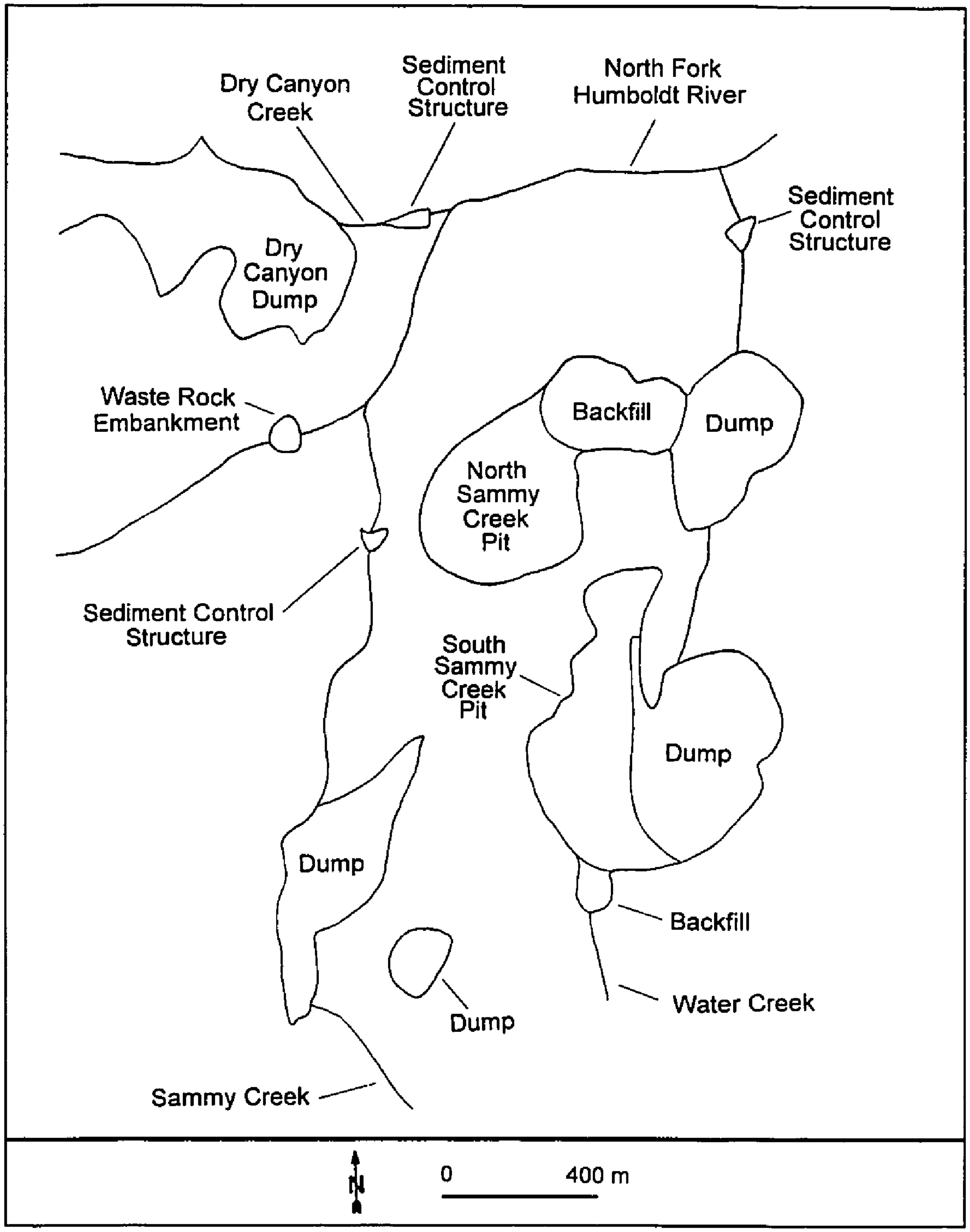


Figure 5: Detail of Mine Workings (After Anderson et al., 1994)

constructed on these tributaries by Independence Mining Company (IMC) in an effort to minimize particulate inflow to the Humboldt. In addition, most haul roads at the site are constructed with waste rock. Mining began in 1987 (Youngerman, 1992), with excavation ceasing in December, 1993, although excavated ore was still being hauled through October, 1994. A total of 34,946 kt of rock was mined, of which 31,144 kt was waste (Anderson et al., 1994).

CHAPTER 3

DESCRIPTION OF PROCEDURES AND METHODS

BACKGROUND

Based on temporal and fiscal constraints, the investigation of conditions at one mine site in the Humboldt River Basin was chosen as the method to investigate the impact of waste rock on water quality. A site with high apparent potential for nonpoint source pollution of surface waters from both natural factors, such as topography and streambed gradient, and operational features such as the location of waste rock piles and haul roads in relation to drainages was sought. In addition, a perennial stream had to flow near the site, in order to allow for water sampling throughout the year.

SITE SELECTION

At a meeting with regulators from the Nevada Department of Conservation and Natural Resources, Division of Environmental Protection (NDEP) and Bureau of Mining Regulation and Reclamation (NBMRR) familiar with mines throughout the state, a list of about fifteen sites that met the criteria for selection was compiled. After discussing the attributes of these sites, and examining maps and regulatory files, the three

most promising sites from the list were chosen. All three of these sites were visited during the early part of November, 1994, and examined for suitability. Water samples were collected at the two sites that were deemed most suitable.

The Big Springs site was chosen for several reasons. The North Fork of the Humboldt River flows in close proximity to waste rock features, and high relief is present in these areas. The mine had recently shut down, meaning that no excavation or processing would be carried out during the study, thus eliminating them as potential sources of pollution. In addition, with the exception of crushing, all of the ore processing was performed in a different drainage basin, at a site approximately 5 km from of the closest sampling point used during the study, thus ruling out such factors as tailings and leach ponds as contamination sources. Finally, analysis of the water samples collected during the site selection process suggested that many constituents in the Humboldt were present at higher levels downstream of mining activities than upstream.

DATA COLLECTION AND ANALYSIS

Historical data and background information collected by Independence Mining Company (IMC) and other parties was obtained from IMC, the USFS, and the NBMRR. These data were analyzed in an attempt to discern trends in contaminant concentrations over time, and seasonal variation in contamination.

Two sites on the North Fork were selected for water sampling, one upstream of mining disturbances, the other downstream of mining disturbances, but upstream of

tributaries which did not drain mine-disturbed areas (Figure 6). Lengths of concrete reinforcement rod were installed at these sites to delineate them for sampling activities during the study. Water samples and water quality data were then collected at these sites on an approximately monthly basis. Seven sampling trips were made, but on one trip, weather conditions prevented access to the upstream site. The initial set of samples was analyzed for over 20 metals in addition to major anions and cations. After the results of the first analyses were obtained, several metals were eliminated from subsequent analyses, due to the fact that they were undetectable in both the upstream and downstream samples. Water samples and field data were collected at a third location (referred to as the "Steel Burrito" site) in May, 1995, in order to determine the effect on water quality of a large waste rock embankment crossing the Humboldt; field measurements of water quality were made at that site on all subsequent sampling trips.

At each sampling site, three separate samples were collected for laboratory analysis: a 1.89 L sample in a clean high density polyethylene (HDPE) container for total suspended solids (TSS) analysis; a 1 L sample in a clean glass bottle, which was immediately acidified to pH 2 with trace metal grade nitric acid, for metals analysis; and a sample pumped through a 0.45 μm filter into a clean 473 ml HDPE bottle for gross chemical analysis. On the last three sampling trips, samples for total organic carbon analysis were collected in 237 ml clean HDPE bottles. All collection bottles were field rinsed before collection (bottles for the filtered samples were rinsed with filtered water).

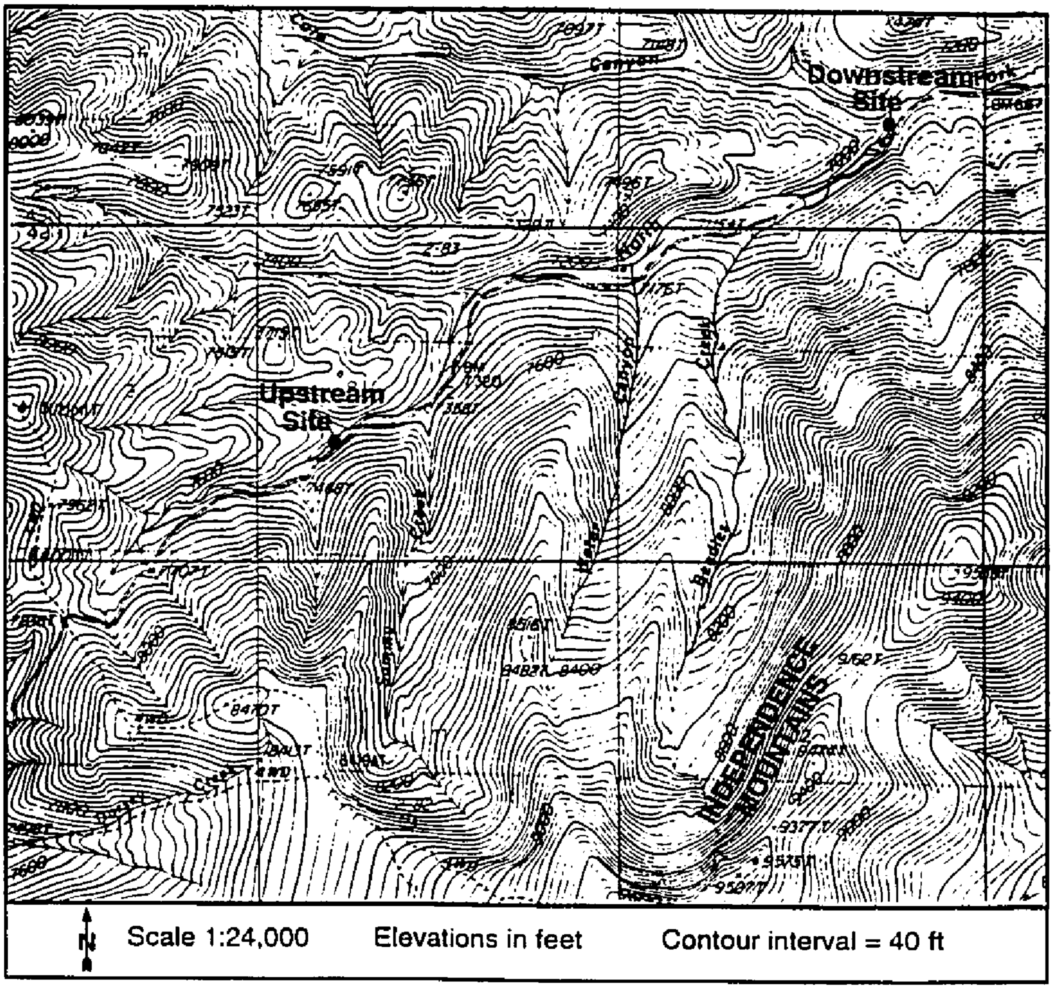


Figure 6: Sampling Site Location Map (Base Map from USGS, 1986)

Field measurements were made of temperature, electrical conductivity (EC), dissolved oxygen (DO), and pH. Prior to each measurement, the DO meter was calibrated to saturated atmospheric oxygen content, with compensation made for altitude and temperature. The pH and EC meters were calibrated using standard solutions which bracketed, or came as close as possible to bracketing the conditions of the water. Calibration was rechecked after each measurement. If measured "recheck" values were not within ten percent of the original calibration values for the EC and DO meters, or 0.1 standard units for the pH meter, the entire process was repeated.

A data logger was installed at the downstream site to allow for the constant monitoring of river stage (water height above the streambed) and EC during the study. At the upstream site, the North Fork flows in a single channel, but at the downstream site, it is split into two channels. To monitor stage, a pressure transducer (which allows water depth to be determined based on the pressure of the overlying water column in the stream) was installed in each of the channels, one in February, 1995, the other in March. Based on field measurements of EC in the two channels, which showed no discernible variation, it was not deemed necessary to install an EC probe in each channel. Discharge measurements were taken at both the upstream and downstream sites each time water samples were gathered, in order to establish stage-discharge relationships.

QUALITY ASSURANCE METHODS

Although the Water Laboratory at Desert Research Institute (DRI), which performed the analyses for the study, is an Environmental Protection Agency-approved facility that maintains strict internal controls, duplicate samples from the upstream and downstream sites were collected in July, 1995 and analyzed at a separate laboratory for quality assurance (QA) purposes.

GEOCHEMICAL ANALYSIS AND MODELING

A Stiff diagram, which graphically represents concentrations of major ions in a water sample, was constructed for each sample collected during the project. A Piper diagram, which graphically compares waters based on the proportions of major ions they contain, was constructed using all the analyses. The geochemical modeling program PHREEQE (Parkhurst et al., 1980) was used to help validate hypothesized scenarios for the chemical evolution of waters at the site.

STATISTICAL METHODS

Tests were performed to determine if statistically significant differences existed between the upstream and downstream data sets for each constituent, and, if applicable, to estimate the magnitude of difference between them. For comparing constituent concentrations from the upstream and downstream sites, significance was tested using the Wilcoxson rank-sum test. If significant differences were suggested, the Hodges-Lehmann estimator was used to estimate the magnitude of that difference.

These tests are nonparametric, and thus have no underlying assumption of normality. This is especially important due to the fact that only seven sampling trips were made, resulting in small n-values for each data set. Many authors, including Helsel and Hirsch (1992), recommend applying only nonparametric tests to such small data sets. This is because parametric tests should only be used on normally distributed data, since they often fail to reject false null hypotheses when used on data that is not normally distributed. Unfortunately, tests for normality can provide misleading results when data sets are small, possibly leading to the improper application of a parametric test. Further discussion of the Wilcoxson rank-sum test and the Hodges-Lehmann estimator, and their applicability to data of the type collected in this study is provided by Hollander and Wolfe (1973), Gilbert (1987), and Helsel and Hirsch (1992).

CHAPTER 4

RESULTS

HISTORICAL DATA ANALYSIS

Historical data was analyzed by constructing time series plots for the concentrations of various chemical constituents, and the values of parameters such as EC, TDS, and pH that had been collected by IMC over several years. Data from several IMC monitoring stations, as well as a location map and descriptions of their locations are provided in Appendix I. Two notable trends were discovered as a result.

Many constituents and parameters showed a marked increase in concentration or level in 1991. This is illustrated in Figure 7, which shows the concentration of sulfate at IMC's S140 monitoring station (located near the downstream site) for the years 1987-1994. Sulfate is representative of the behavior of most constituents and parameters, such as EC, calcium, magnesium, chloride, bicarbonate, and sodium, in that concentrations are low for the years 1987-1990, then began increasing in 1991, with minimum values for 1992-1994 being higher than maximum values for the 1987-1990.

When constituents were present at lower concentrations in the first years of mining, there was no readily apparent cycling of concentration values over the course

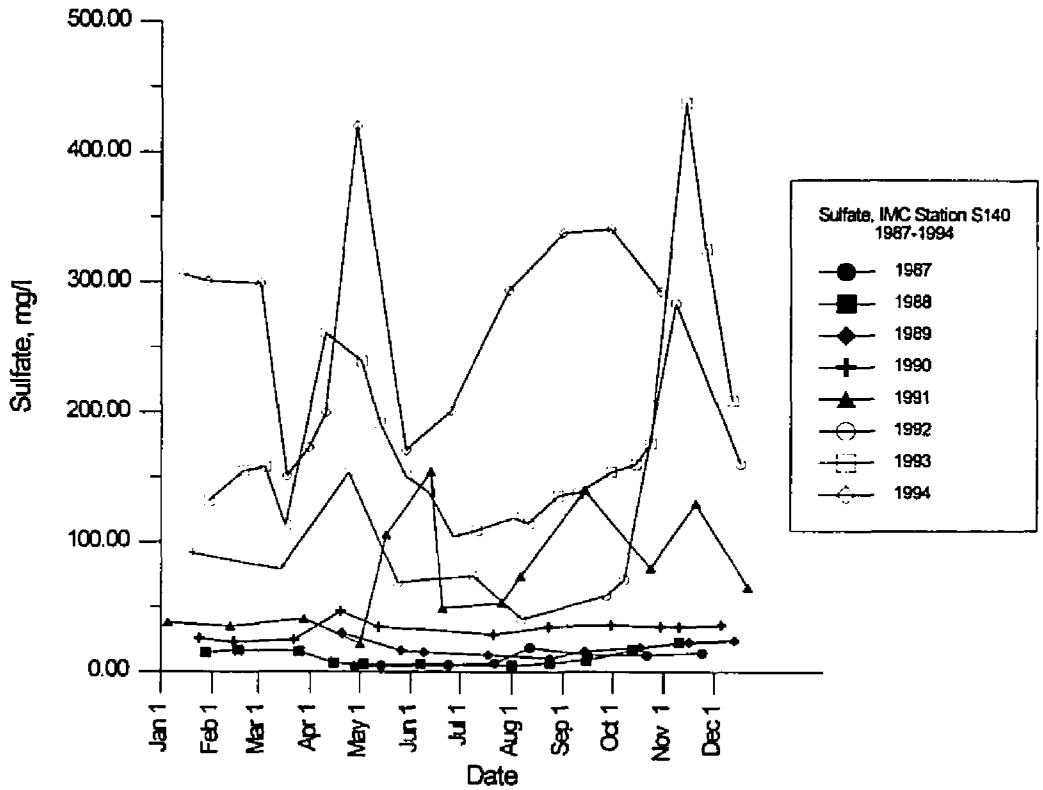


FIGURE 7: Sulfate Concentrations, IMC S140 Station, 1987-1994

of a year. Starting in 1992, when higher levels had been attained, many constituents and parameters began to exhibit a seasonal pattern, with high concentration 'spikes' in their plots occurring in April/May and October/November of each year, with the late year spike typically being higher, as can be seen by examining individual year data in Figure 7. Again, in this respect, sulfate is typical of most other constituents and parameters analyzed.

WATER SAMPLING

Results of the water sample analyses are given in Table 1. Methods of analysis used by the DRI Water Laboratory are provided in Appendix II. Plotting the results of

TABLE 1: Chemistry Data From Study Samples

	11/10/94	11/10/94	2/5/95	2/4/95	3/11/95	4/8/95	4/8/95	5/16/95	5/16/95	5/16/95	6/20/95	6/20/95	6/20/95
	US	DS	US	DS	DS	US	DS	US	SB	DS	US	SB	DS
FIELD DATA													
pH (standard units)	7.80	8.15	7.74	8.86	8.51	8.12	8.41	7.87	7.66	7.65	8.43	8.68	8.09
EC (µs/cm)	87	631	60	1043	696	100	755	70	81	680	33	44	351
DO (mg/l)	8.0	8.6	9.6	10.2	11.0	8.5	9.0	9.3	8.9	8.6	10.5	10.0	11.1
Temp (°C)	6.2	2.2	2.6	1.0	1.6	7.0	6.5	13.0	12.0	9.3	13.0	10.0	11.8
LABORATORY DATA													
EC (µs/cm)	88	666	59	791	590	82	659	70	77	785	51		413
SiO2 (mg/l)	8.00	5.50	7.20	6.90	5.60	6.70	5.80	8.10	8.20	8.00	6.40		6.60
pH(standard units)	7.11	7.88	7.10	7.55	7.39	7.37	7.15	7.10	7.16	7.35	7.38		7.70
HCO3(mg/l)	35.00	81.50	23.80	46.20	44.70	37.90	47.80	30.70	31.10	40.00	22.70		37.10
Cl (mg/l)	0.80	7.40	1.14	6.30	5.18	1.12	5.47	0.81	1.06	5.19	0.50		2.10
SO4 (mg/l)	10.70	281.00	5.82	365.00	245.00	4.56	277.00	3.42	5.73	370.00	2.38		164.00
NO3 (mg/l)	0.09	1.46	0.89	12.40	8.77	1.99	9.13	2.48	2.84	14.80	1.28		7.62
Na (mg/l)	2.17	4.23	2.22	4.43	3.80	0.85	3.80	2.03	2.07	3.66	1.54		2.58
K (mg/l)	0.60	1.16	0.61	1.47	1.10	0.26	1.09	0.56	0.56	1.23	0.51		0.78
Ca (mg/l)	9.46	69.30	5.95	64.40	48.70	8.37	52.80	6.85	7.62	60.30	4.81		32.40
Mg (mg/l)	3.45	41.30	2.11	59.90	41.00	3.33	49.20	2.36	2.75	65.70	1.69		28.60
NO3 (mg/l)	0.02	0.33	0.20	2.81	1.98	0.45	2.06	0.56	0.64	3.33	0.29		1.72
TDS (mg/l)	46.00	466.00											
TSS (mg/l)	1.3	1.3	6.8	6.4	4.8	1.0	3.2	24.0	12.0	4.8	1.9		6.3
F (mg/l)	0.06	0.06	0.05	0.09	0.12	0.05	0.08	0.06	0.06	0.12	0.006		0.14
As (mg/l)	0.005	0.010	0.004	0.009	0.008	0.006	0.007	0.010	0.010	0.010	0.012		0.016
Fe (mg/l)	0.06	0.34	0.65	0.43	0.34	0.18	0.25	0.91	0.55	0.34	0.58		0.46
Mn (mg/l)	<0.01	0.12	<0.01	0.10	0.05	<0.01	0.03	0.02	<0.01	0.09	0.010		0.08
Zn (mg/l)	0.010	<0.005	<0.005	0.005	<0.005	<0.005	0.008	0.026	0.015	0.021	0.011		0.043
Ba (mg/l)	0.221	0.098	0.178	0.095	0.073	0.198	0.080	0.230	0.214	0.120	0.166		0.113
Se (mg/l)	<0.002	<0.002	<0.002	0.009	0.008	<0.002	0.009	<0.002	<0.002	0.018	<0.002		0.007
Al (mg/l)	0.13	0.08	1.00	0.25	0.13	0.24	<0.1	0.93	0.72	0.29	0.68		0.42
Sr (mg/l)	0.050	0.165	0.038	0.153	0.112	0.050	0.122	0.040	0.043	0.123	0.029		0.066
B (mg/l)	0.130	0.150	0.066	0.076	0.060	0.060	0.040	0.186	0.043	0.059	0.040		0.030
Cu (mg/l)	<0.005	<0.005											
Cd (mg/l)	<0.005	<0.005											
Cr (mg/l)	<0.010	<0.010											
Pb (mg/l)	<0.050	<0.050											
Hg (mg/l)	<0.0002	<0.0002											
Ag (mg/l)	<0.005	<0.005											
Ni (mg/l)	<0.01	<0.01											
Co (mg/l)	<0.01	<0.01											
Be (mg/l)	<0.001	<0.001											
Li (mg/l)	<0.005	<0.005											
TOC (mg/l)								3.1	3.4	2.2	1.9		1.5
Tl (mg/l)					<0.05	<0.05	<0.05						
V (mg/l)					<0.02	<0.02	<0.02						
Ti (mg/l)					<0.01	<0.01	<0.01						
Cu (mg/l)					<0.005	<0.005	<0.005						
Calc. TDS (mg/L)	70.94	493.87	51.73	568.22	404.75	65.86	452.71	59.72	63.79	570.07	43.14		283.16

TABLE 1 (CONTINUED)

	7/31/95 US	7/31/95 SB	7/31/95 DS
FIELD DATA			
pH (standard units)	7 45	8 07	8 63
EC (µs/cm)	78	101	548
DO (mg/l)	5 7	6 8	8 0
Temp (°C)	15 0	19 0	15 0
LABORATORY DATA			
EC (µs/cm)	76		565
SiO2 (mg/l)	9 00		7 00
pH(standard units)	7 44		8 05
HCO3(mg/l)	41 20		64 90
Cl (mg/l)	0 43		3 14
SO4 (mg/l)	3 82		223 00
NO3 (mg/l)	0 04		8 15
Na (mg/l)	2 05		3 48
K (mg/l)	0 65		1 09
Ca (mg/l)	7 88		46 10
Mg (mg/l)	3 04		38 40
NO3 (mg/l)	0 01		1 84
TDS (mg/l)			
TSS (mg/l)	0 6		6 40
F (mg/l)	0 06		0 090
As (mg/l)	0.009		0 01
Fe (mg/l)	0 09		0 45
Mn (mg/l)	<0 01		0.070
Zn (mg/l)	<0 005		<0.005
Ba (mg/l)	0 214		0 123
Se (mg/l)	0 002		0 01
Al (mg/l)	<0 1		0.300
Sr (mg/l)	0 05		0 107
B (mg/l)	0 044		0 091
Cu (mg/l)			
Cd (mg/l)			
Cr (mg/l)			
Pb (mg/l)			
Hg (mg/l)			
Ag (mg/l)			
Ni (mg/l)			
Co (mg/l)			
Be (mg/l)			
Li (mg/l)			
TOC (mg/l)	1 0		1 7
Tl (mg/l)			
V (mg/l)			
Ti (mg/l)			
Cu (mg/l)			
Calc TDS (mg/L)	68 56		396 51

Key:
US-Upstream Site
DS-Downstream Site
SB-Steel Burrito Site

the analyses for water samples collected during the study on a Piper diagram (Figure 8) shows two distinct groupings of the samples, with waters from the upstream site and the Steel Burrito site plotting as calcium-bicarbonate type, while downstream waters plot as magnesium-sulfate type. As would be expected from the grouping of the samples on the Piper diagram, samples from the upstream and downstream sites exhibit distinctly different Stiff diagram shapes, with the Steel Burrito Stiff diagram resembling that typical of upstream waters. Typical Stiff diagram shapes for each of the sampling sites are shown in Figure 9, and a complete set of diagrams is given in Appendix III.

It was determined from statistical tests that there were significant (alpha less than or equal to 0.05) increases in the downstream concentrations/values relative to the upstream concentrations/values of the following constiuents/parameters: EC (both field and laboratory values), bicarbonate, chloride, sulfate, nitrate (both total, and as nitrogen), sodium, potassium, calcium, magnesium, fluoride, manganese, selenium, and strontium. It should be noted that some of the increase in many (or possibly all) of these constituents would occur even if mining had never been conducted in the area, due to the natural mineralization present in the area. The exact magnitude of "natural contamination" is hard to gauge in the absence of a definitive baseline study, but using IMC's early (1987-1988) data may provide the most reasonable estimate. Figure 10 shows a Piper diagram for IMC's S140 data from 1987 and the Upstream and Steel

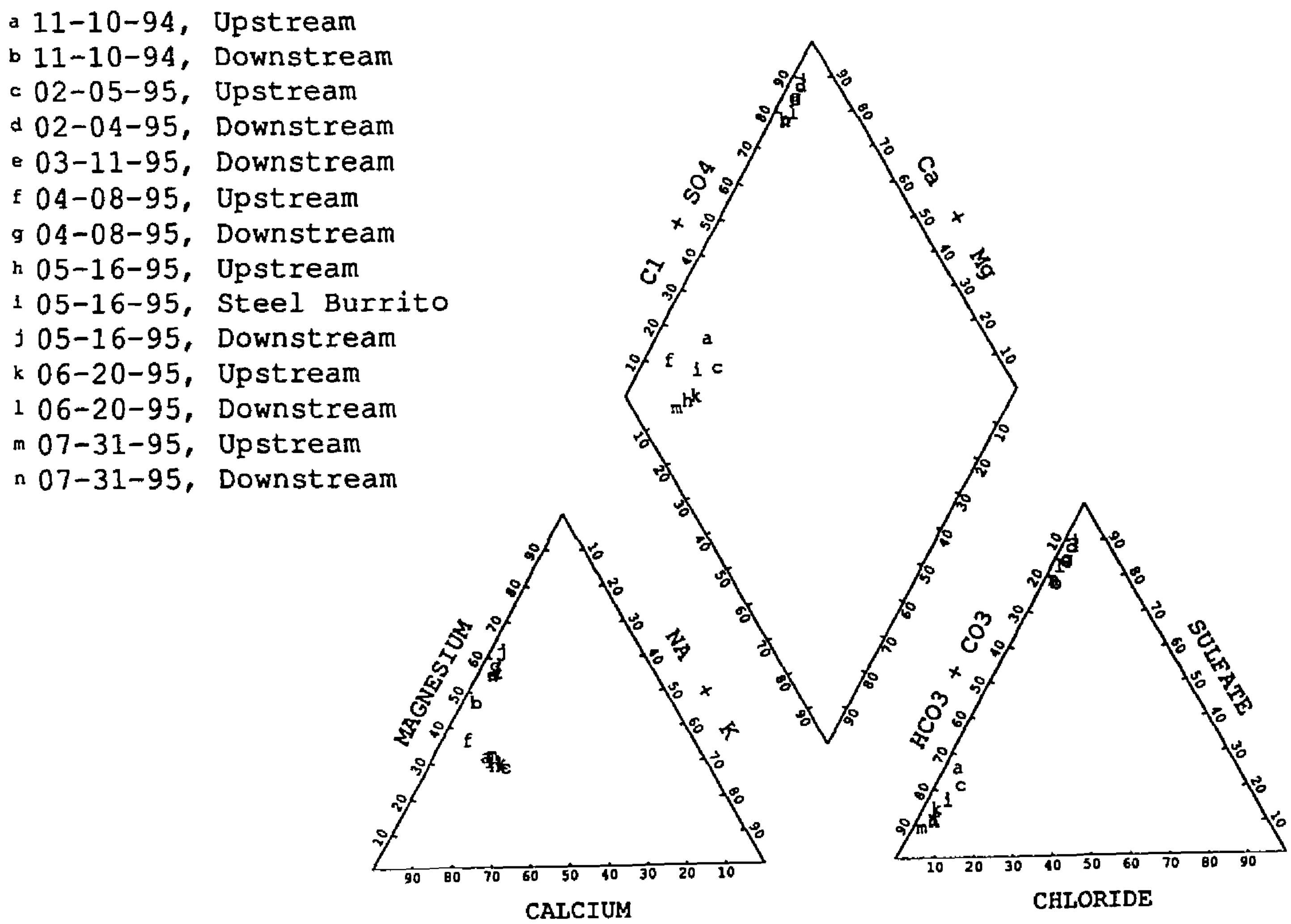


Figure 8: Piper Diagram for Study Samples

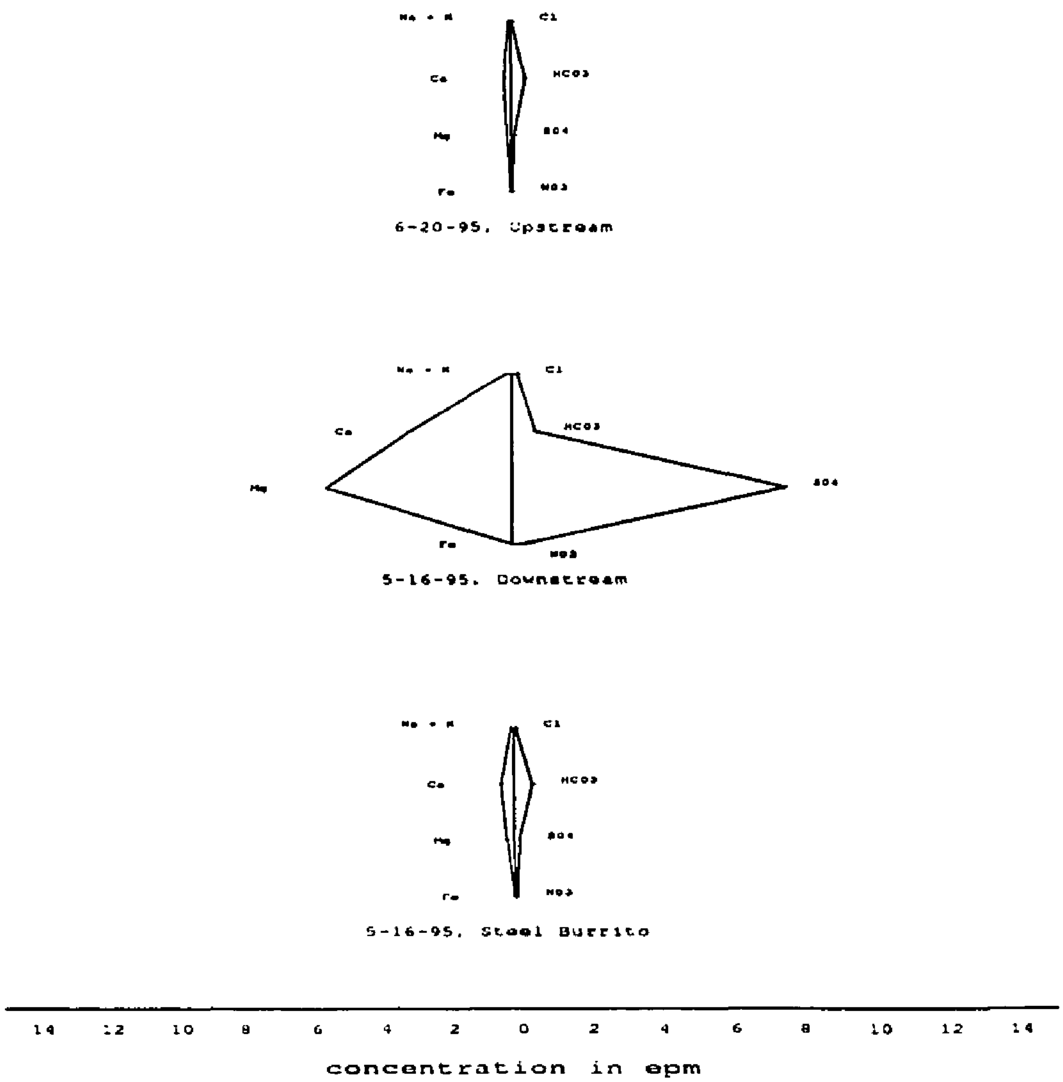


Figure 9: Typical Stiff Diagrams for Study Sampling Sites

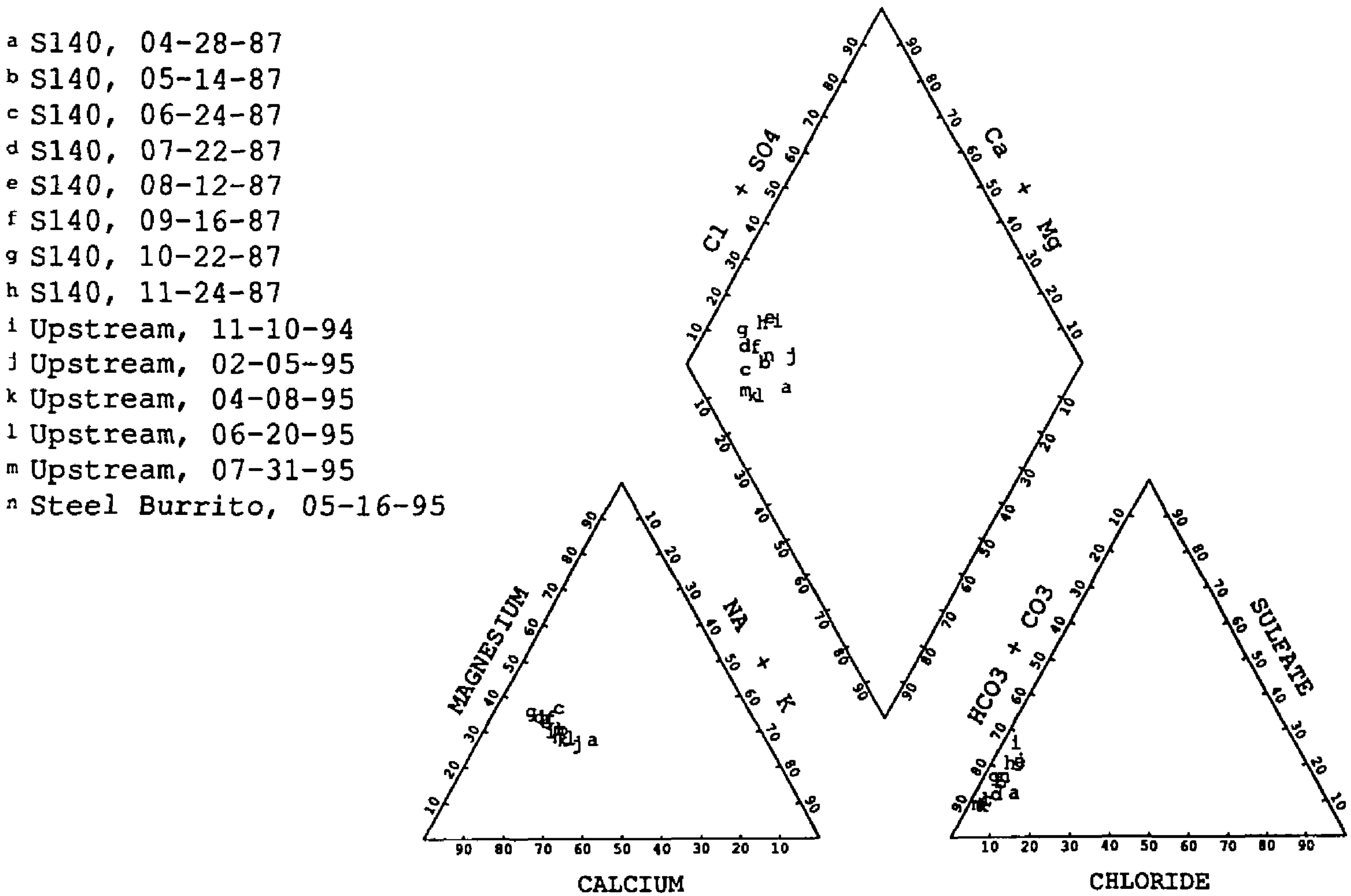


Figure 10: Piper Diagram Comparing "Upstream" Study Samples With 1987 IMC S140 Samples

Burrito data collected during this study. As opposed to the distinct separation shown in Figure 8, all the waters plot as a single group of calcium-bicarbonate type, suggesting that prior to mining, downstream waters were chemically similar to upstream waters, thus supporting the suitability of 1987 values as substitute baseline data.

The concentration of barium was found to have a statistically significant decrease from upstream to downstream. No significant change from upstream to downstream was found to occur for the following constituents/parameters: temperature, pH, dissolved oxygen content, TSS, quartz, arsenic, zinc, boron, iron, and aluminum.

Alpha values for each of these tests and, where applicable, the estimated magnitude of increase or decrease are provided in Appendix IV.

In addition to the constituents described above, copper, cadmium, chromium, lead, mercury, silver, nickel, cobalt, beryllium, lithium, thallium, vanadium, and titanium were not present in sufficient quantities to be detected when they were first tested, and were thus eliminated from subsequent analyses.

Although no statistical analyses were performed on 'Steel Burrito' data, due to the lack of repeated sampling, it appears that no distinct increase in concentration occurs due to the waste rock embankment.

SEASONALITY OF EC AND STAGE

Measurements of stage and EC in the southern channel at the downstream site were made every fifteen minutes, with every four readings averaged by the data logger

to yield hourly values. A summary of daily averages of the hourly values for stage and EC in the southerly channel at the downstream site are presented in Appendix V, and a plot of daily average values for stage and discharge appears as Figure 11. The hourly values did not appear to show any diurnal cycling. During the early part of the monitoring period, daily EC values were generally high, but prone to fluctuation, whereas the EC values in later time are generally lower and more stable.

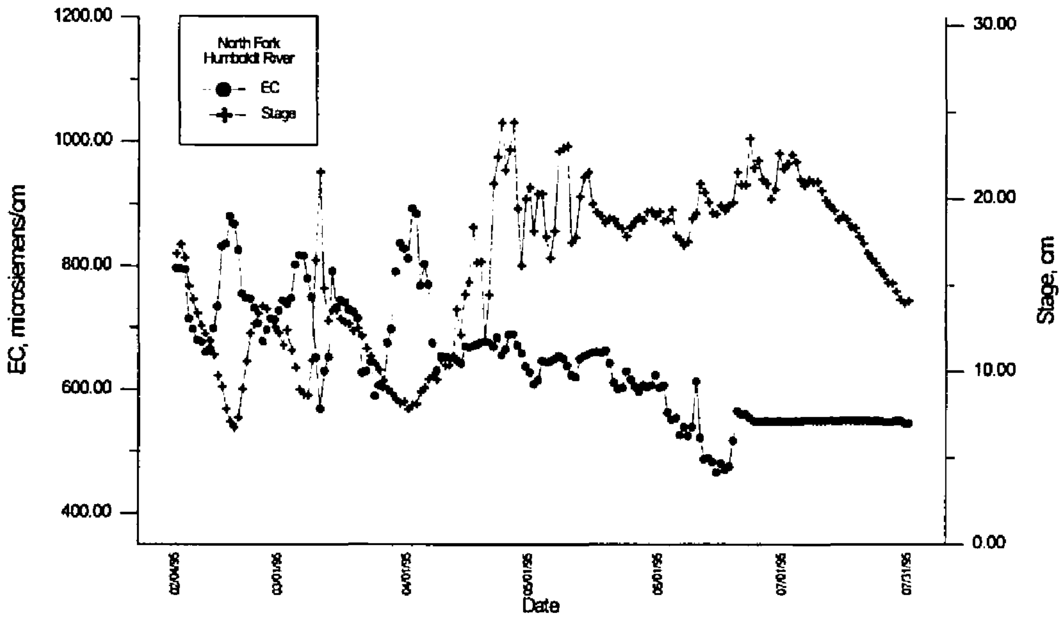


Figure 11: Average Daily Stage and EC Values

In the data from the first two months of the study, there are two distinct relationships between stage and EC, with some periods exhibiting a direct relationship, but others showing a strong inverse correlation. In the subsequent two and a half months, an inverse relationship predominates, with stage generally rising and EC generally declining. If this overall trend is ignored, a direct relationship can be seen, with

increases in stage generally coinciding with increases in EC. In the final period of the study, changes in stage seem to have little effect on EC.

STAGE-DISCHARGE AND MASS LOADING CALCULATIONS

The stage-discharge measurements gathered during the study are provided in Appendix VI. The attempt to develop a stage-discharge rating curve (which allows discharge to be estimated based on stage values) for the downstream site was not without problems. Based on the incorrect assumption that the North Fork would be flowing in a single channel, only one pressure transducer for measuring river stage was brought for installation. When it was recognized that two channels were present in that area, it was placed in the southern channel of the river, because that channel appeared to have higher flow, based on a visual discharge estimate. A second pressure transducer was installed in the northern channel on the next sampling trip, but due to an improper modification of the data logger program code, no data was actually recorded until the error was corrected about five weeks later. In addition, the northern channel experienced many heavy sediment loads which altered its morphology, and, on two occasions, either buried the pressure transducer, or displaced it from its intended location. The southern channel is well incised, with steep banks protruding above water level, even during periods of high flow, so increases in flow volume will generally cause increases in stage. The northern channel is poorly incised, and increases in flow volume are accommodated, at least in part, by a widening of the cross-sectional area of flow.

Due to the poor channel conditions and the changes in channel morphology, the best fit line for a stage-discharge graph for the northern channel showed a coefficient of determination of only 0.20 (Figure 12).

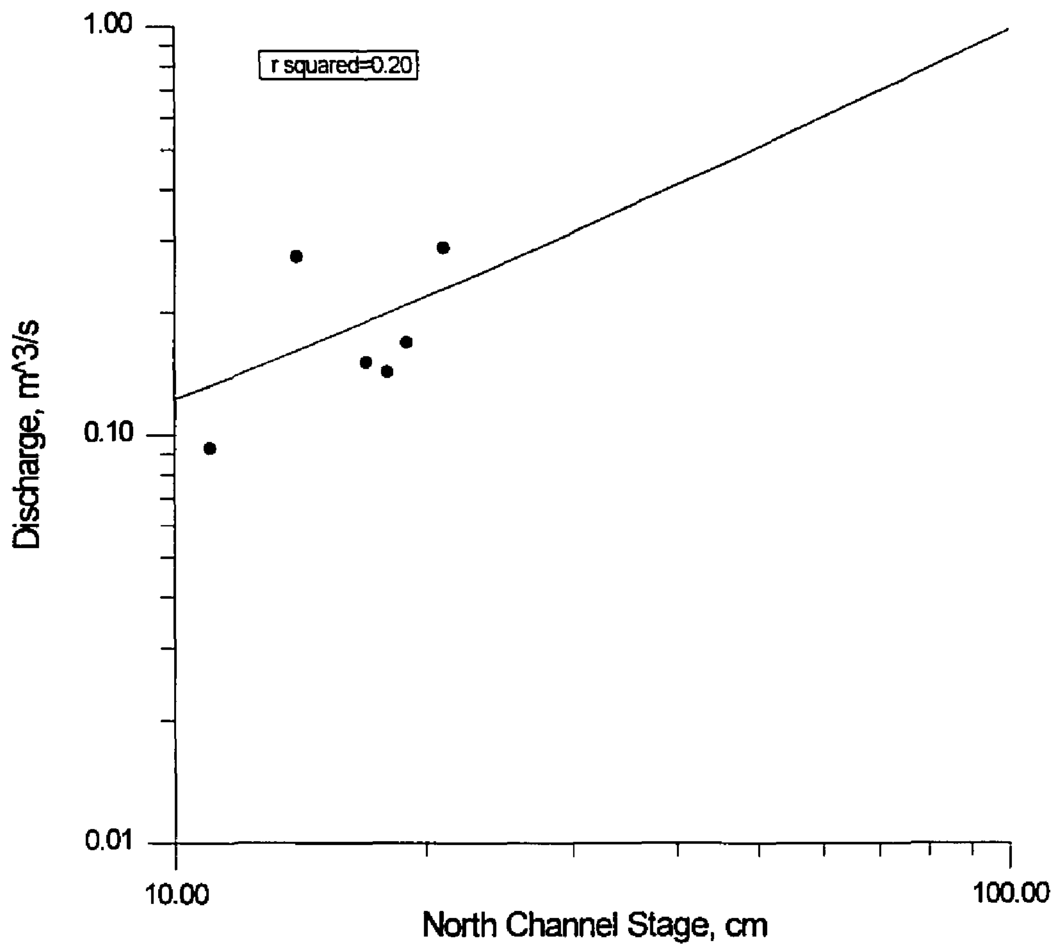


Figure 12: Stage-Discharge Relationship, Northern Channel

The southern channel, which had no significant changes in morphology over the study period, yielded somewhat better results, in that the coefficient of determination for the stage-discharge curve was 0.59 (Figure 13). In an attempt to improve the accuracy

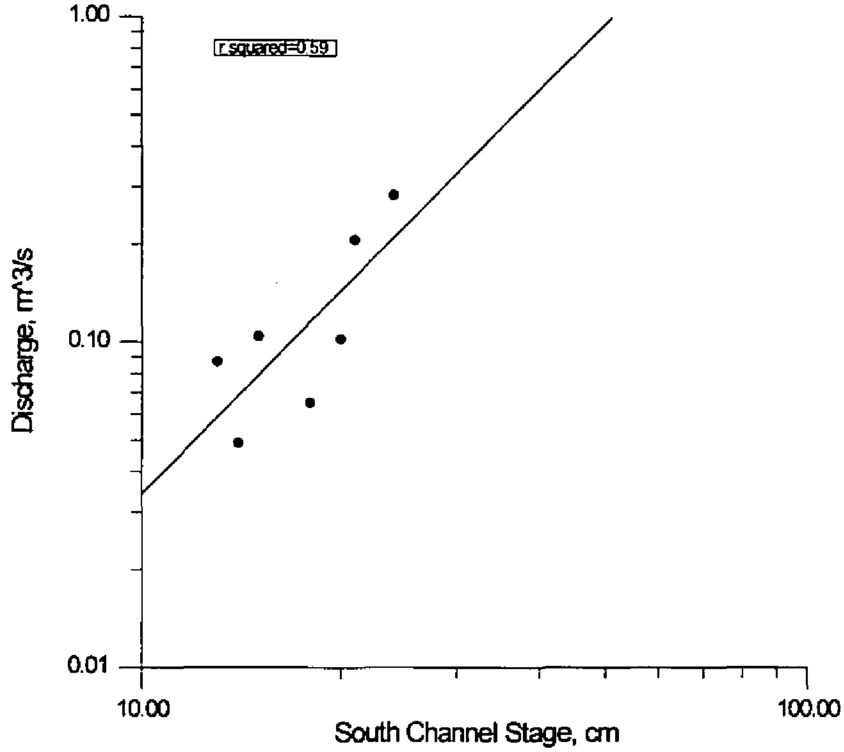


Figure 13: Stage-Discharge Relationship, Southern Channel

of flow estimates in the northern channel over those possible from the stage-discharge relationship, a discharge-discharge plot for the two 'downstream' channels was constructed. Based on the occasions for which discharge data was available for both channels, a discharge-discharge relationship with a determination coefficient of 0.90 (Figure 14) was found to be present, allowing an estimate of flow in the northern channel to be made based on flow in the southern channel.

For much of the study period, a beaver dam caused flow to divert from the Humboldt onto a nearby road, thus bypassing the downstream site. Visual estimates of the flow over the road suggest that the amount of flow diverted around the site was

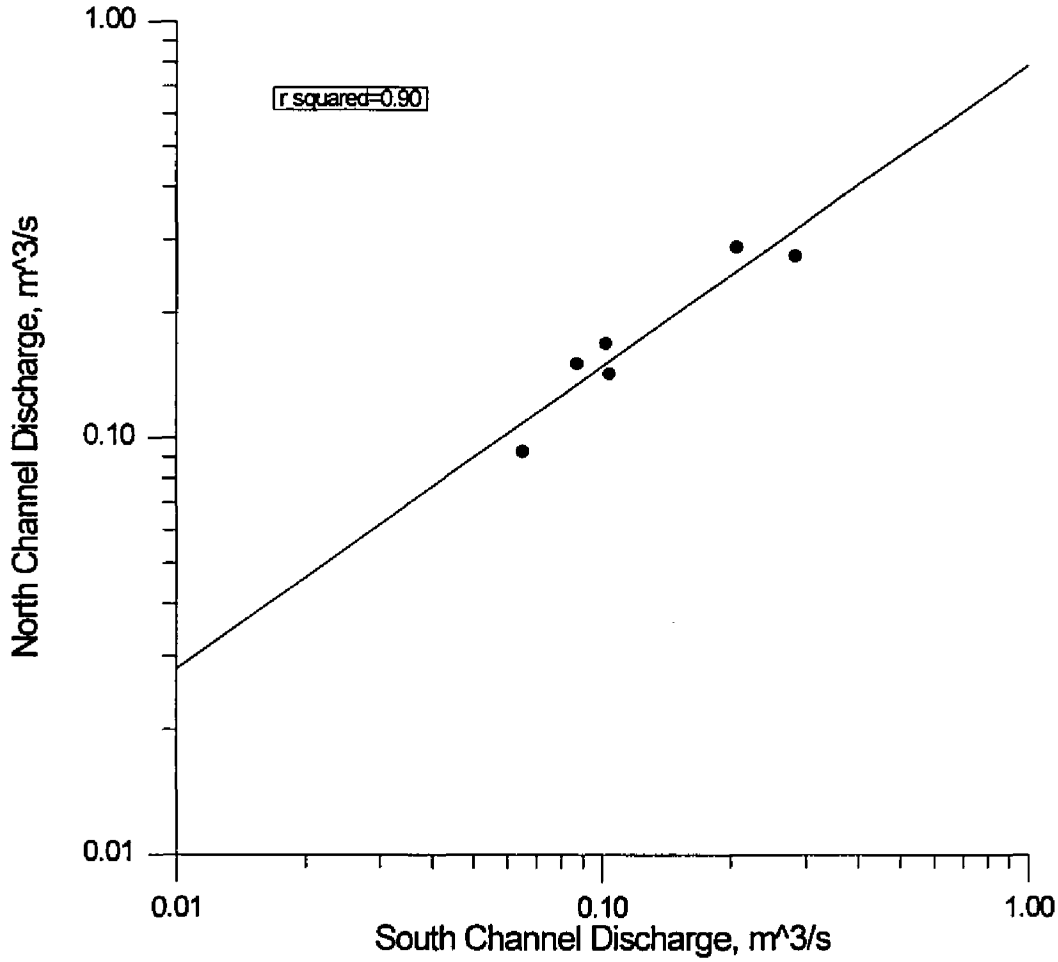


Figure 14: Discharge-Discharge Relationship, Northern and Southern Channels

approximately one-tenth of the total flow in the two river channels. Based on these facts, it should be noted that any calculations for flow or mass loading based on stage measurements are, at best, approximations, and are most probably lower than the actual values.

Hem (1989) indicates that if the EC of a water sample is known, total dissolved solids (TDS) content can be estimated using the formula KA=S, where K is EC

in µS/cm, S is the TDS concentration in mg/L, and A is a constant for the particular body of water from which the sample was obtained, based on the relationship between EC and TDS. A plot of EC versus TDS for the samples collected during the study (Figure 15) indicates an A-value of 0.71, which appears to correlate with Hem's (1989) assertion that if a specific A-value is not known, it can be approximated based on the tendency of A-values of numerous natural waters to group between 0.55 and 0.75, with the higher values occurring in waters with high levels of sulfate.

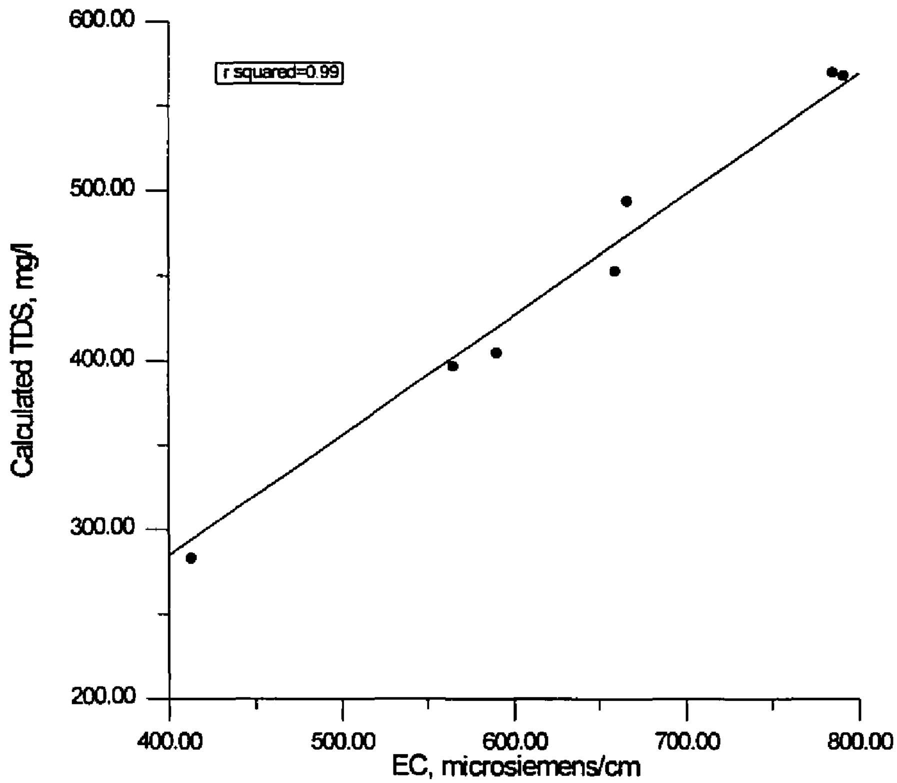


Figure 15: TDS-EC Relationship

Daily mass loading was estimated by multiplying each daily average TDS concentration (mg/L) by total discharge (m^3/s) and multiplying the resultant value by 0.0864 (a constant for unit conversion), yielding a value in metric tons per day.

Data for estimated daily discharge and estimated mass loading of dissolved solids are provided in Appendix V.

GEOCHEMICAL MODELING

The computer code PHREEQE was utilized in an attempt to support the validity of hypothesized scenarios which had been developed to account for past and present changes in water quality at the mine site. A model was designed and run for each scenario. If the output of a model approximated the conditions at the site (i.e. modeled values for pH, calcium, magnesium, bicarbonate, and sulfate within 15 percent of expected values), this was considered to support the validity of the given scenario.

PHREEQE (PH-REdox-EQuilibrium-Equations) is a geochemical program which can model the evolution of a water by simulating the water's reaction with minerals and gases, the titration of the water with another solution, the mixing of the water with another water in any specified proportion, or some combination thereof (Bird, 1993). Geochemical reactions are predicted based on an ion-pairing model, with a user-modifiable thermodynamic database (Matuska, 1989). When modeling the reaction of a water with a mineral assemblage, PHREEQE's default setting will allow the reaction to proceed to equilibrium for all minerals present in the system. To allow the

code to be used to model natural systems which are not in equilibrium, a saturation index (SI) may be specified for any mineral participating in a reaction. The simulated reaction will then proceed until specified SI values are reached. As described by Appelo and Postma (1994), if the SI for a mineral equals zero, it is at equilibrium with the solution in which it is present; if SI<0, the mineral is subsaturated, and SI>0 indicates supersaturation.

The first scenario involving the site dealt with the conditions which existed prior to mining. It was hypothesized that prior to mining, sulfide minerals were present in the area, but they occurred mostly in the subsurface, and were thus exposed to such minimal amounts of oxygen that they were essentially non-reactive. The minimal increases in constituent concentration from upstream to downstream (~11 mg/L TDS, ~ 4 mg/L sulfate) were thought to be the result of the interaction of the Humboldt and its tributaries with the rock material through which they flow (carbonaceous Quaternary alluvium).

To model this scenario, the chemical parameters for a typical "pre-mining" upstream water were input into PHREEQE. PHREEQE was then instructed to model the reaction of this water with a mineral assemblage representative of the major components of the bank material, and atmospheric gases which would participate in reactions involving these minerals. The mineral assemblage consisted of calcite, dolomite, gypsum, and CO_2 gas. Because computations based on "pre-mine" downstream water chemistry indicated that these waters were not in equilibrium, as might be expected for

a fast-flowing river where time for interaction with minerals is minimal, typical SI values for each mineral in the assemblage (as given by PHREEQE) were included in the model input, and PHREEQE stopped reactions when these values were attained. Given this set of input data, the modeled water should closely resemble the "target" water which it is trying to approximate, provided the proper mineral assemblage is chosen. If improper minerals are chosen for the assemblage, the modeled water could bear little resemblance to the target water.

Since no true baseline data for typical water quality prior to mining is available, assumptions had to be made to allow the modeling of a "historical" scenario. No data from IMC's S95 station (located near the upstream site) are available for dates prior to 1992, but these waters appear to be uniformly dilute and unaffected by mining, so a set of present day values is probably a reasonable representation of pre-mining water. Similarly, no true pre-mining data is available for the downstream site, but as shown in Figure 10, S140 values from 1987 are probably representative of pre-mining downstream water. Table 2 shows the input parameters for the initial water (S95 water, 3/12/92), the parameters for the "target" water (S140 water, 8/12/87), and lists the mineral assemblage with which the initial water was reacted. The SI values input for each mineral, as suggested by analysis of the target water are also included (P_{CO_2} is included as a "mineral" in the table because it is treated as such by PHREEQE--the "SI" value for P_{CO_2} is actually the log P_{CO_2}). Values in parentheses represent assumed

TABLE 2: INPUT AND TARGET PARAMETERS FOR THE "PRE-MINE" MODEL

	Initial Water	Target Water
Constituent	S95 3/12/92	S140 8/12/87
Ca (molality)	1.90×10^{-4}	5.24×10^{-4}
Mg (molality)	1.48×10^{-4}	3.37×10^{-4}
Na (molality)	1.44×10^{-4}	1.74×10^{-4}
K (molality)	1.28×10^{-5}	1.79×10^{-5}
Fe (molality)	3.76×10^{-6}	2.14×10^{-6}
Al (molality)	1.85×10^{-5}	7.41×10^{-6}
SiO2 (molality)	(1.17×10^{-4})	(1.17×10^{-4})
Cl (molality)	2.82×10^{-5}	1.13×10^{-3}
HCO3 (molality)	4.92×10^{-4}	1.28×10^{-3}
SO4 (molality)	8.32×10^{-5}	1.98×10^{-4}
NO3 (molality)	1.61×10^{-6}	8.06×10^{-6}
pH	7.58	7.8
Temperature (degrees C)	(20)	(20)
pe	(4.5)	(4.5)
Mineral Assemblage		
Mineral		SI
Calcite		-0.45
Dolomite		-1.03
PCO2		-2.95
Gypsum		-2.66

values which were required as input to the model, but for which no actual values were available.

Table 3 provides a summary of the "pre-mine" model results, comparing the pH value and the molalities of the four major ions projected by the model to the values observed for the target water. These values are within the acceptable range of error, supporting the hypothesis that prior to mining, sulfide mineral oxidation, if occurring at all, was not causing any discernible impact on water quality in the Humboldt.

TABLE 3: RESULTS OF THE "PRE-MINE" MODEL

Parameter	Measured Value	Modeled Value	Percent Error
pH	7.8	7.8	0
Ca^{2+}	5.24×10^{-4}	5.26×10^{-4}	0.4
Mg^{2+}	3.37×10^{-4}	3.39×10^{-4}	0.6
HCO_3^-	1.28×10^{-3}	1.31×10^{-3}	2.3
SO_4^{2-}	1.98×10^{-4}	1.96×10^{-4}	1

Constituent concentrations reported as molalities, pH reported in standard units.

The second scenario modeled with PHREEQE involved the formation of concentrated tributary water. On tributary streams which have flowed through waste rock dumps, but have not passed through a sediment control structure, EC values frequently exceed 2,000 μS/cm, and sulfate concentrations are often over 1,000 mg/L.

It was hypothesized that these tributary waters were formed by the interaction of rainwater and/or snowmelt with waste rock. This scenario was modeled by

providing PHREEQE with chemical concentrations for rainwater typical of the area (from Berner and Berner, 1996), as input. PHREEQE was instructed to simulate the interaction of this rainwater with a mineral assemblage representative of waste rock present at the site. This mineral assemblage consisted of calcite, dolomite, CO_2 gas, pyrite, and ferric hydroxide. Gypsum was not included in this mineral assemblage because the amount of sulfate produced by gypsum dissolution was thought to be negligible compared to the amount produced by pyrite oxidation. Ferric hydroxide was included because it is a product of the pyrite oxidation process, and is typically extremely insoluble. Although iron was not used to compare modeled results against reality, if ferric hydroxide was not included in this model, the suggested iron concentration was extremely high compared to the actual concentration. Although sulfide minerals other than pyrite are present in the area, pyrite is the most abundant, and for the sake of simplicity, it is used to represent other sulfide minerals. Table 4 shows the input parameters, including the SI values for the mineral assemblage (as suggested by PHREEQE analysis of tributary water chemistry), and the values which the model was attempting to match. Again, given the input of specific SI values, the modeled water should closely resemble the target water, provided the proper mineral assemblage is selected.

Results from the model, shown in Table 5, are within the acceptable range of error, supporting the hypothesis that the concentrated waters in tributary streams are produced by the reaction of rainwater and/or snowmelt with waste rock.

TABLE 4: INPUT AND TARGET PARAMETERS FOR THE TRIBUTARY WATER FORMATION MODEL

	Initial Water	Target Water
Constituent	(Berner and Berner, 1996)	S112 4/8/94
Ca (molality)	-	2.82 X 10^{-3}
Mg (molality)	4.11 X 10^{-6}	4.61 X 10^{-3}
Na (molality)	1.43 X 10^{-4}	2.36 X 10^{-4}
K (molality)	5.63 X 10^{-6}	4.84 X 10^{-5}
Fe (molality)	-	1.21 X 10^{-5}
Al (molality)	-	2.34 X 10^{-6}
Cl (molality)	8.46 X 10^{-6}	1.33 X 10^{-4}
HCO3 (molality)	3.28 X 10^{-7}	6.46 X 10^{-4}
SO4 (molality)	2.96 X 10^{-5}	7.23 X 10^{-3}
NO3 (molality)	2.32 X 10^{-5}	1.15 X 10^{-4}
pH	5.7	7
Temperature (degrees C)	(20)	(20)
pe	(4.5)	(4.5)
	Mineral Assemblage	
Mineral		SI
Calcite		-1.36
Dolomite		-2.72
PCO2		-2.57
Pyrite		-91.84
Ferric Hydroxide		1.78

TABLE 5: RESULTS OF THE TRIBUTARY WATER FORMATION MODEL

Parameter	Measured Value	Modeled Value	Percent Error
pH	7.0×10^{0}	7.0×10^{0}	0
Ca^{2+}	2.82×10^{-3}	2.81×10^{-3}	0.4
Mg^{2+}	4.61×10^{-3}	4.60×10^{-3}	0.2
HCO_3^-	6.46×10^{-4}	6.37×10^{-4}	1.4
SO_4^{2-}	7.23×10^{-3}	7.13×10^{-3}	1.4

Constituent concentrations reported as molalities, pH reported in standard units.

The final scenario modeled with PHREEQE involved the formation of present day downstream water in the North Fork. It was hypothesized that the increases in constituent concentrations from upstream to downstream are primarily the result of dilute upstream waters mixing with more concentrated waters from the tributaries which flow through waste rock dumps. In this case, water which had flowed through a sediment control structure was used to represent the tributary water. Data collected by IMC suggests that constituent concentrations at sites downstream of sediment control structures my be different than those upstream of the structures.

This scenario was modeled by providing constituent concentrations for a typical upstream water, chemical concentrations for a typical post-sediment control structure tributary stream as input to PHREEQE . PHREEQE was then instructed to mix these waters together. After mixing was complete, PHREEQE was instructed to simulate the reaction of the resultant water with a mineral assemblage representative of that which would be present in the streambank material. Several mixing ratios were modeled, and the best match to the measured data was found to occur when the mixed

water was composed of 15 percent upstream water and 85 percent tributary water. Table 6 shows the input parameters for this model, the mineral assemblage with which the mixed water was reacted, and the values for the target water.

As shown in Table 7, the modeled values are within the acceptable range of error, supporting the hypothesis that downstream water is produced by mixing dilute upstream water with more concentrated inflow from tributary streams which flow through waste rock dumps, and minimal input from interactions with minerals present in the bank materials.

TABLE 6: INPUT AND TARGET PARAMETERS FOR THE DOWNSTREAM WATER FORMATION MODEL

	Initial Water 1	Initial Water 2	Target Water
Constituent	Upstream, 4/8/95	S115, 4/8/94	Downstream, 4/8/95
Ca (molality)	2.09×10^{-4}	2.54×10^{-3}	1.32×10^{-3}
Mg (molality)	1.37×10^{-4}	3.85×10^{-3}	2.02×10^{-3}
Na (molality)	3.70×10^{-5}	2.22×10^{-4}	1.65×10^{-4}
K (molality)	6.65×10^{-6}	4.61×10^{-4}	2.79×10^{-5}
Fe (molality)	3.22×10^{-6}	8.96×10^{-7}	4.48×10^{-6}
Al (molality)	8.90×10^{-6}	4.23×10^{-6}	1.85×10^{-6}
Si (molality)	1.12×10^{-4}	9.99×10^{-5}	9.66×10^{-5}
Cl (molality)	3.16×10^{-5}	1.22×10^{-4}	1.54×10^{-4}
HCO3 (molality)	6.21×10^{-4}	6.12×10^{-4}	7.83×10^{-4}
SO4 (molality)	4.75×10^{-5}	6.19×10^{-3}	2.88×10^{-3}
NO3 (molality)	3.21×10^{-5}	1.15×10^{-4}	1.74×10^{-4}
pH	8.12	7.2	8.41
Temperature (C)	7	3.7	6.5
pe	(4.5)	(4.5)	(4.5)
Mineral Assemblage			
	Mineral	SI	
	Calcite	-0.04	
	Dolomite	-0.05	
	PCO2	-3.88	
	Gypsum	-1.33	
	Ferric Hydroxide	3.44	
	Ca-Montmorillonite	2.29	

TABLE 7: RESULTS OF THE DOWNSTREAM WATER FORMATION MODEL

Parameter	Measured Value	Modeled Value	Percent Error
pH	8.41	8.44	0.4
Ca^{2+}	1.31×10^{-3}	1.24×10^{-3}	5.6
Mg^{2+}	2.02×10^{-3}	2.12×10^{-3}	4.9
HCO_3^-	7.84×10^{-4}	8.52×10^{-4}	8.7
SO_4^{2-}	2.88×10^{-3}	3.03×10^{-3}	5.2

Constituent concentrations reported as molalities, pH reported in standard units.

CHAPTER 5

QUALITY ASSURANCE

QUALITY ASSURANCE TESTING

On the 7/31/95 sampling trip, two sets of water samples were collected at the upstream and downstream sites, using identical procedures and materials. The extra samples were analyzed by the author at the Chemistry Department, University of Nevada, Las Vegas.

On the 11/10/94 sampling trip, IMC collected samples at the same locations sampled for this study, and submitted these samples to the WestChem Environmental Lab in Elko, NV for analysis. Although IMC's sampling techniques and materials differed slightly from those used for this study, these differences would probably cause only minor discrepancies, if any, between analyzed values for most constituents. The results of both these sets of analyses are given in Appendix VIII.

Due to the dearth of repeated QA results, statistical tests on the data would be meaningless, so only general inferences can be drawn, but the QA numbers do not appear to be grounds for concern regarding the accuracy of the DRI analyses. The largest difference present between a DRI value and a QA value appears to be the result of

an error on the part of the laboratory used by IMC. On first inspection, the downstream EC value of 83.7 μS/cm reported by the lab appears to cast some doubt on DRI's value of 666. Upon further examination, the value 83.7 seems questionable when one observes that this laboratory reports upstream EC as 87.2 μS/cm, and TDS concentrations of 44.9 mg/L upstream and 464 mg/L downstream. As previously discussed, Hem (1989) states that the value of TDS concentration in mg/L for natural waters can generally be determined by multiplying the water's EC value (μS/cm) by a value between 0.55 and 0.75. By solving the expression KA=S, for K, one finds that the value for EC of most waters is 1.3 to 1.8 times larger than the value for TDS. This suggests that the actual EC value for a water with TDS concentration of 464 mg/L should be between 619 and 844 μS/cm. If the A-value of 0.71 found to apply to DRI data is used in this equation, the predicted EC value for a water with a TDS concentration of 464 mg/L is 654 μS/cm, less than two percent lower than the DRI value of 666 μS/cm.

CHAPTER 6

DISCUSSION

Data collected for the study indicate that there is a significant change (including increases of 400 mg/L TDS and 272 mg/L sulfate) in the water quality of the Humboldt as it flows through the mine site. The data collected by IMC suggest that the majority of the increase has resulted from the mining operation. Assuming modern upstream water is representative of 1987 upstream water, the increases in TDS and sulfate from upstream to downstream in 1987 were approximately 38 mg/L and 4 mg/L, respectively. Constituent concentration increases were generally negligible until the opening of the South Sammy Creek pit late 1990-early 1991. The South Sammy Creek pit contained higher grade ore and waste rock with higher levels of sulfide mineralization than had been excavated previously (Collord, personal communication). Since the mine was not in operation during the time of this study, and most processing operations were carried out some distance away, it can be concluded that the increase in constituent levels is derived mostly from waste rock, both in dumps and haul roads, with minor contributions from rock exposed at pit faces, and input from minerals

present at the site which were contributing to constituent loading in the Humboldt even before mining began.

No statistical tests were used to compare study data to IMC's data from the same time period. The differences in location between the study sites and IMC sites probably causes some minor differences between the values. More importantly, as can be seen in Figure 11, a time difference of just three days can cause EC to vary by 175 μS/cm, so the lack of simultaneous collection could easily cause study values to deviate from IMC values. In order to obtain some support for a link between study data and IMC data, downstream values from the study were plotted on a Piper diagram along with IMC's S140 data from 1995. As shown in Figure 16, the IMC data groups with the downstream data, suggesting that the two data sets are comparable.

The negligible increases in constituent concentration in the Steel Burrito water versus the upstream water (~11 mg/L TDS) are attributable to a decision by IMC to use rock with low sulfide mineralization for haul road construction whenever possible. If waste rock with higher levels of sulfide mineralization had been used to construct the embankment crossing the Humboldt, a much greater increase in mass loading than that which was observed would probably be occurring.

Several constituents show statistically significant increases in concentration from upstream to downstream, including sulfate (272 mg/L), calcium (46 mg/L), magnesium (39 mg/L), and bicarbonate (16 mg/L). Sulfate concentrations at the downstream site regularly exceed the State of Nevada drinking water standard of 250 mg/L, and manganese concentrations occasionally exceed the standard of 0.05-0.10 mg/L.

a S140, 02-24-95
b S140, 04-12-95
c S140, 04-28-95
d S140, 05-30-95
e S140, 06-28-95
f S140, 07-27-95
g S140, 09-07-95
h S140, 09-28-95
i S140, 10-31-95
j S140, 12-04-95
k 11-10-94, Downstream
l 02-04-95, Downstream
m 03-11-95, Downstream
n 04-08-95, Downstream
o 05-16-95, Downstream
p 06-20-95, Downstream
q 07-31-95, Downstream

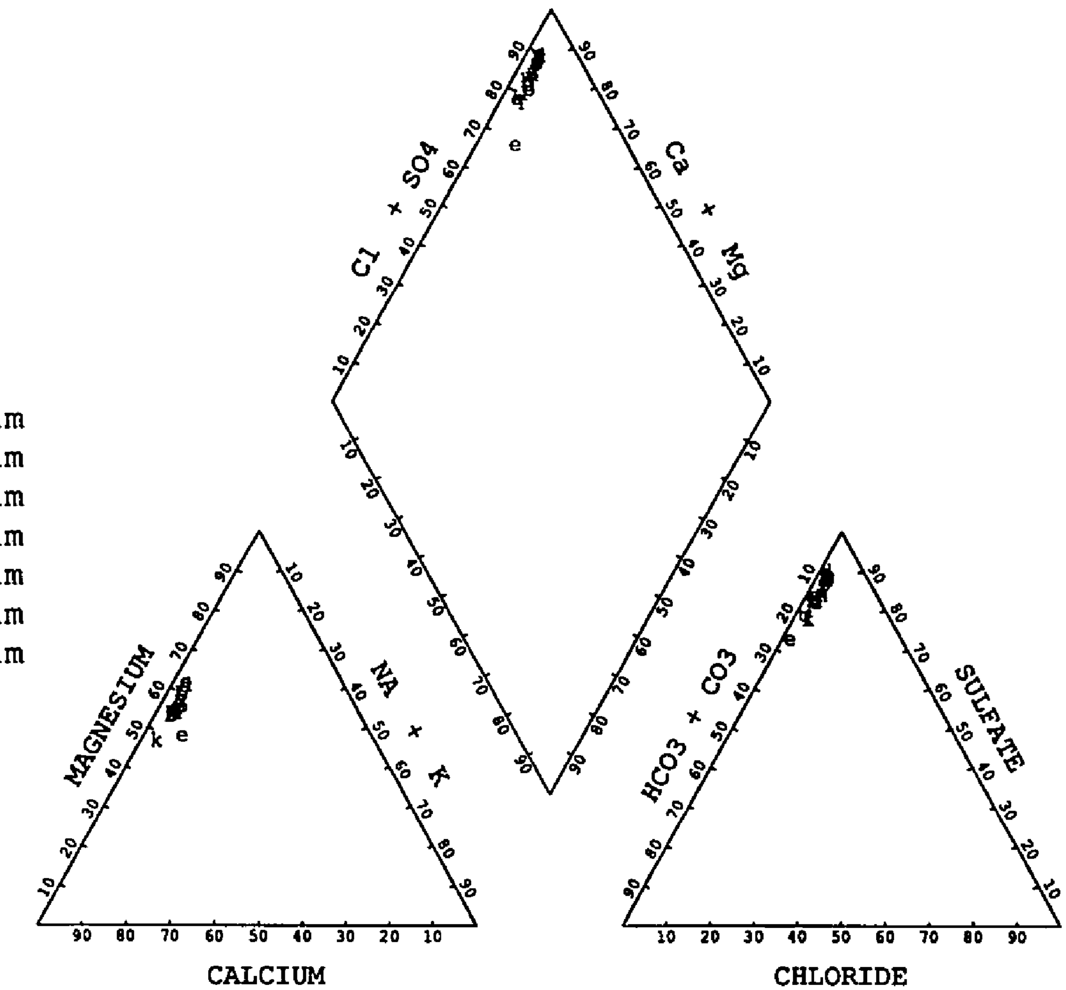


Figure 16: Piper Diagram Comparing "Downstream" Study Samples With 1995 IMC S140 Data

but other constituents, including those showing statistically significant increases, are uniformly below the guidelines. No attempt was made to compare constituent concentrations to guideline values for plant or animal toxicology, livestock watering, or irrigation. The relatively low impact seen in the area is probably due mainly to the carbonate buffering of acidity produced by sulfide mineral oxidation, which reduces metal solubilities; and the effective use of sediment control structures preventing particulate matter from entering the North Fork via its tributaries. As a result, the input of metals to the Humboldt, and their transport by sorption onto suspended particles has been minimized.

The spikes appearing in constituent concentration graphs after 1991 appear to be the result of seasonal effects. The spring spikes are probably due to a flushing effect resulting from snowmelt. Based on weather records from Wildhorse Reservoir, the fall spikes appear to correlate with a seasonal increase in precipitation after the dry summer months, indicating a second period of flushing. The variability of daily average EC values in the early part of the study appears to cöincide with the early year flushing event. The lower, more stable EC values measured later in the study probably represent a year-round baseline.

Although EC and stage do not exhibit a statistically strong correlation (Figure 17), a trend is discernible, with higher EC values generally occurring during periods of low flow, and lower EC values generally occurring during periods of high flow. During low flow periods, groundwater and interflow contributions to the North Fork are

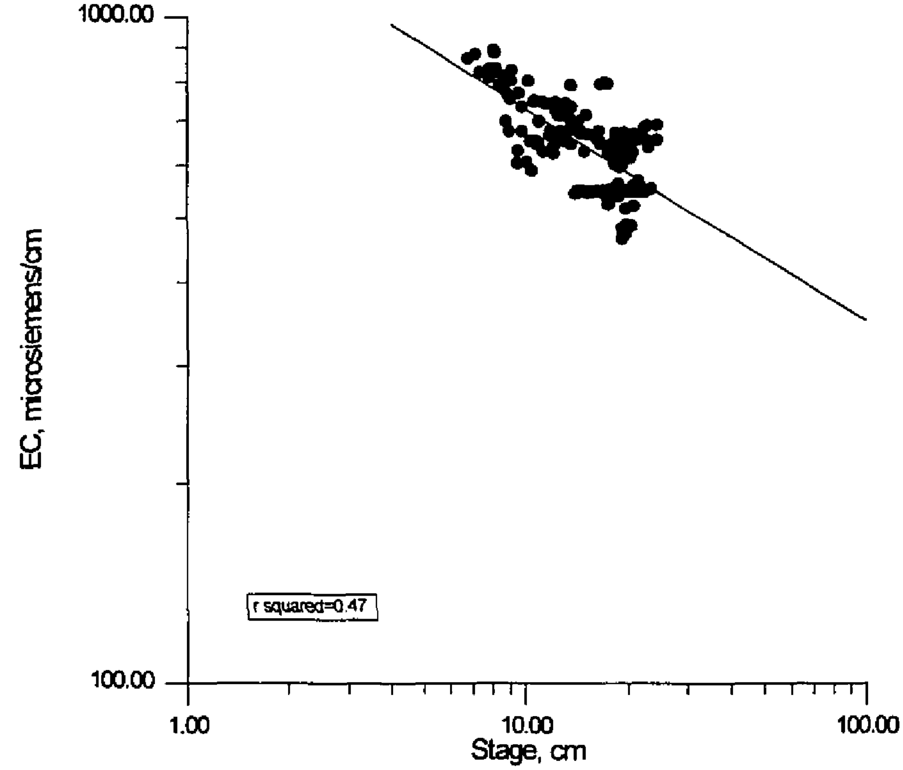


Figure 17: EC-Stage Relationship

probably much greater than those from snowmelt or precipitation, and this water has had more time in contact with waste rock than overland flow water, and probably contains higher concentrations of dissolved constituents, thus increasing EC in the Humboldt as it contributes a greater proportion of overall flow.

Although EC tends to be higher during periods of low flow, daily loading of dissolved solids in the North Fork appears to be highest during high flow. Daily loading estimates are derived from estimated average daily dissolved solids concentration (based on average daily EC) and estimated daily discharge (based on average daily stage). Because of this relationship, loading is not independent of either EC or

discharge, but plots comparing it to these parameters are nonetheless informative regarding the factor which most influences mass loading in the Humboldt. A plot of estimated daily dissolved solids loads versus estimated total discharge (Figure 18) shows a strong correlation, while a plot of estimated daily dissolved solids loads versus EC (Figure 19) shows extremely weak correlation, indicating that loading is controlled by discharge, with variations in EC having at most a minor effect.

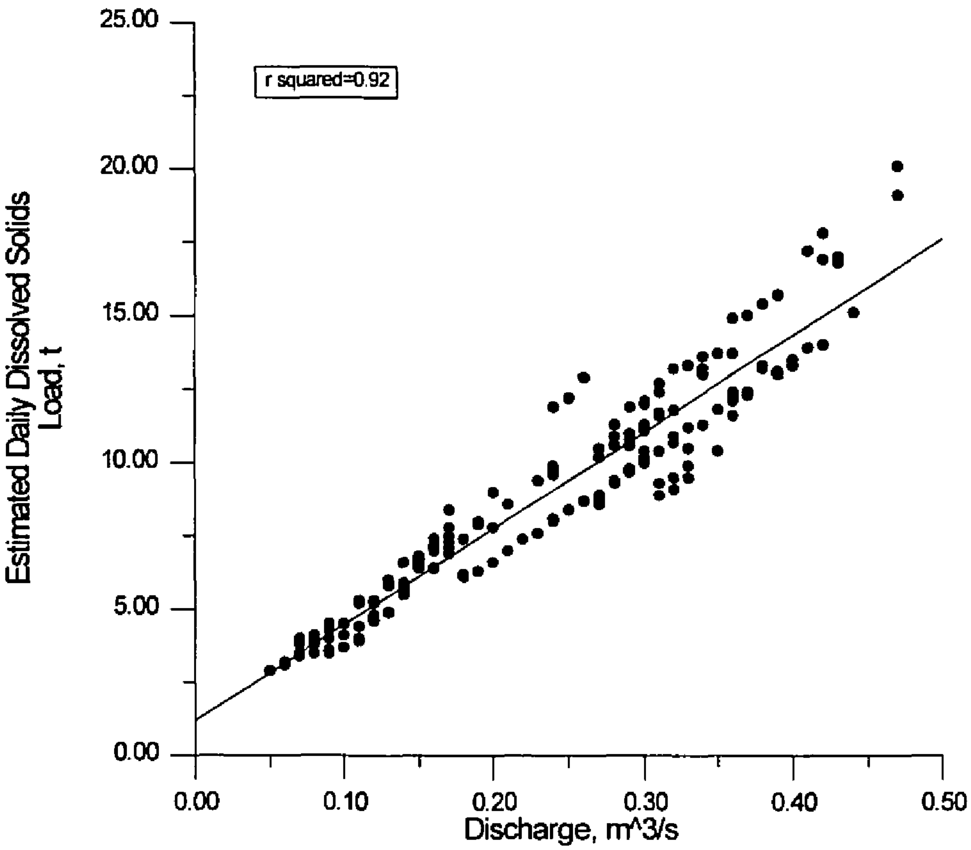


Figure 18: Estimated Daily Dissolved Solids Load Versus Estimated Daily Total Discharge

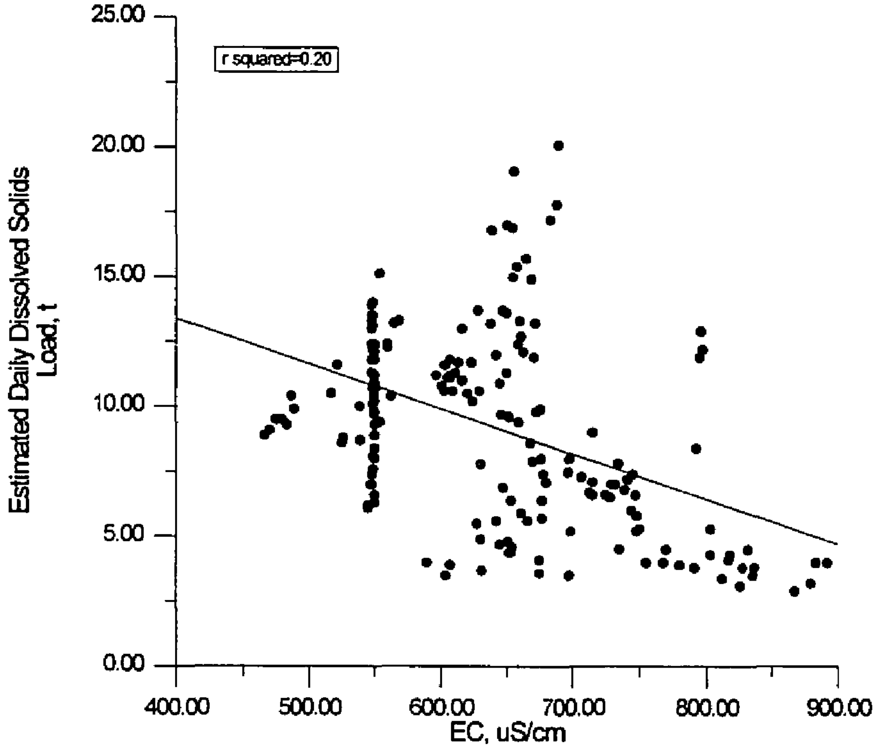


Figure 19: Estimated Daily Dissolved Solids Load Versus Daily Average EC

The driving force or forces behind changes between periods of inverse and direct correlation between EC and stage (as shown in Figure 11) are not clear. One of the periods of inverse correlation cöincided with the March 11, 1995 sampling trip, during which precipitation at the site was extremely heavy. It is thought that the high stage that day was caused mostly by dilute precipitation running off over the top of the snowpack, thus lowering the EC.

It was hypothesized that the switch between periods of direct and inverse correlation of stage and EC is due to variations in runoff due to snowmelt, precipitation, or some combination thereof. Weather records from the Wildhorse Reservoir were

analyzed in an effort to test this hypothesis, but no confirmation was obtained. This may be due to the intricacy of the snowmelt process, the relatively short duration of monitoring, or the difficulties inherent in attempting to estimate precipitation and snowmelt runoff at the site based on temperature data from an off-site weather station in an area with fairly significant local weather patterns.

CONCLUSIONS

It appears that waste rock from the mining operation is causing some adverse impacts on water quality in the North Fork of the Humboldt, most notably an average increase of approximately 362 mg/L of TDS, and 265 mg/L of sulfate from the up-stream site to the downstream site. Although many constituents showed statistically significant increases in concentration from upstream to downstream, only sulfate regularly exceeds State of Nevada guidelines for drinking water. Some deleterious impacts on water quality commonly associated with waste rock, such as acidification and increased levels of suspended sediment, are not occurring at the site, due to the presence of carbonate rocks, the installation of sediment control structures at the site, and the use of waste rock with low sulfide mineralization for the construction of haul roads and embankments near the river.

FURTHER STUDY

It would be valuable to monitor water quality in the future, both to determine the long-term impacts of waste rock, and to gauge the effectiveness of the reclamation

program currently underway. The current literature on long-term effects of reclamation programs on water quality is sparse.

A more complete knowledge of groundwater flow, quality, and influence on the composition of the North Fork in the study area would allow a more complete interpretation of how contaminants from waste rock at the site reach the Humboldt, and might also provide insight into seasonal patterns in constituent concentrations.

Meteorological data collected at the site could help to determine the factor or factors controlling the switch between direct and inverse EC-stage relationships.

Data from the mine area was examined during this study, but no attempt was made to examine the propagation of observed impacts downstream of the site. Sampling at locations downstream from the site would provide a better picture of overall impact to the region than can be determined from this study.

APPENDIX I

SELECTED DATA FROM THE IMC MONITORING PROGRAM

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	DATEVAL	pH	COND UMHO	TSS mg/l	TURB NTU	HCO3 mg/l	Na mg/l	Ca mg/l
03/12/92	33675	7.58	85	1	3.5	30	3.3	7.6
04/21/92	33715	7.54	60	14	11.0	19	3.1	5.7
05/29/92	33753	7.52	85	5	1.3	30	2.3	6.7
06/03/92	33758	7.39	71	2	1.0		3.0	19.8
11/06/92	33914	7.65	90	10	1.7	31	2.1	9.4
01/23/92	33992	7.25	110	1	0.3	34	2.0	8.7
02/18/93	34018	6.99	90	1	0.2	30	1.9	9.5
03/04/93	34032	7.7	100	1	0.4	36	1.8	9.2
03/16/93	34044	7.42	875	1	2.6	38	2.1	11.0
04/06/93	34065	6.91	85	1	5.0	35	2.0	9.2
04/29/93	34088	7.01	83	3	3.0	35	2.1	9.0
05/07/93	34096	7.36	75	5	4.2	23	2.0	7.8
05/26/93	34115	7.47	40	11	3.5	10	1.1	4.3
06/10/93	34130	7.67	65	1	1.6	20	1.5	5.4
06/25/93	34145	7.58	57	4	0.1	15	1.4	4.3
07/09/93	34159	7.44	55	10	1.3	23	1.3	5.0
07/29/93	34179	7.45	64	3	0.8	25	1.8	6.4
03/28/94	34421	7.42	79	<5	2.6	27	2.1	7.0
04/07/94	34431	7.49	82	<5	2.4	29	1.9	7.1
04/26/94	34450	7.34	68	<5	4.6	26	1.1	6.5
05/27/94	34481	7.34	51	<5	2.6	20	1.7	4.6
06/23/94	34508	7.73	59	<5	1.2	30	2.3	6.3

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	Mg mg/l	Cl mg/l	So4 mg/l	No3 mg/l	TOTAL P mg/l	FLOW CFS	FLOW GPM	Al mg/l
03/12/92	3.6	1	8	0.1	0.03		30	
04/21/92	2.4	2	6	0.6	0.04	2.704	1214	
05/29/92	3.4	1	5	0.1	0.01			
06/03/92	4.0	3		42.2	0.03			
11/06/92	4.4	5	14	0.1	0.07			
01/23/92	4.5	4	9	0.2	0.01			
02/18/93	4.8	4	8	0.1	0.01		300	
03/04/93	4.7	4	9	0.1	0.02		300	
03/16/93	4.8	10	8	0.1	0.01		600	
04/06/93	3.5	8	5	0.6	0.02		662	
04/29/93	3.5	3	5	0.7	0.32		1194	
05/07/93	2.9	5	5	0.4	0.02		1876	
05/26/93	1.4	3	3	0.5	0.02		3947	0.13
06/10/93	2.1	6	3	0.2	0.03		1471	0.13
06/25/93	2.0	4	4	0.1	0.02		852	0.12
07/09/93	2.6	3	3	0.1	0.03			0.10
07/29/93	3.3	7	9	0.1	0.01		22	0.07
03/28/94	3.3	2	7	0.1	0.02		64	0.31
04/07/94	3.4	2	7	0.1	0.03		68	0.43
04/26/94	2.5	1	3	0.3	0.02		786	0.24
05/27/94	2.0	1	1	0.1	0.02		1179	0.14
06/23/94	3.0	0	5	0.1	0.02		81	0.23

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	As mg/l	Ba mg/l	Be mg/l	B mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l
03/12/92	0.004							0.21
04/21/92	0.006							0.28
05/29/92	0.014							0.08
06/03/92	0.010							0.06
11/06/92	0.008	0.31	0.01	0.1	0.01	0.05	0.02	0.13
01/23/92	0.006	0.28	0.01	0.1	0.01	0.05	0.02	0.04
02/18/93	0.005	0.27	0.01	0.1	0.01	0.05	0.02	0.02
03/04/93	0.006	0.28	0.01	0.1	0.01	0.05	0.02	0.02
03/16/93	0.005	0.32	0.01	0.1	0.01	0.05	0.02	0.05
04/06/93	0.003	0.25	0.01	0.1	0.01	0.05	0.02	0.08
04/29/93	0.015	0.27	0.01	0.1	0.01	0.05	0.02	0.11
05/07/93	0.110	0.25	0.02	0.1	0.01	0.05	0.02	0.10
05/26/93	0.015	0.16	0.01	0.1	0.01	0.05	0.02	0.08
06/10/93	0.009	0.18	0.01	0.1	0.01	0.05	0.02	0.09
06/25/93	0.008	0.20	0.01	0.1	0.01	0.05	0.02	0.08
07/09/93	0.010	0.17	0.01	0.1	0.01	0.05	0.02	0.07
07/29/93	0.008	0.20	0.01	0.1	0.01	0.05	0.02	0.06
03/28/94	0.007	0.20	0.01	0.1	0.01	0.05	0.02	0.15
04/07/94	0.006	0.19	0.01	0.1	0.01	0.05	0.02	0.24
04/26/94	0.007	0.19	0.01	0.1	0.01	0.05	0.02	0.35
05/27/94	0.013	0.14	0.01	0.1	0.01	0.05	0.02	<0.05
06/23/94	0.014	0.29	0.01	0.2	0.01	0.05	0.02	0.08

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	Pb mg/l	Mn mg/l	Hg mg/l	Ag mg/l	Se mg/l	Zn mg/l	D.O. mg/l
03/12/92							
04/21/92							
05/29/92							
06/03/92					0.001		
11/06/92	0.05	0.02	0.0050	0.02	0.001	0.02	
01/23/92	0.05	0.01	0.0005	0.02	0.001	0.02	
02/18/93	0.05	0.01	0.0005	0.02	0.001	0.02	13.50
03/04/93	0.05	0.01	0.0005	0.02	0.001	0.02	10.36
03/16/93	0.05	0.01	0.0005	0.02	0.001	0.02	
04/06/93	0.05	0.01	0.0005	0.02	0.001	0.02	8.20
04/29/93	0.05	0.04	0.0020	0.02	0.001	0.02	11.04
05/07/93	0.05	0.01	0.0005	0.02	0.001	0.02	9.63
05/26/93	0.05	0.01	0.0007	0.02	0.001	0.02	12.79
06/10/93	0.05	0.01	0.0005	0.02	0.001	0.02	11.05
06/25/93	0.05	0.01	0.0005	0.02	0.001	0.02	12.20
07/09/93	0.05	0.01	0.0005	0.02	0.001	0.02	
07/29/93	0.05	0.01	0.0005	0.02	0.001	0.02	9.19
03/28/94	0.05	0.01	0.0005	0.02	0.001	0.02	8.08
04/07/94	0.05	0.01	0.0005	0.02	0.001	0.02	6.92
04/26/94	0.05	0.01	0.0005	0.02	0.001	0.02	9.74
05/27/94	0.05	0.01	0.0005	0.02	0.001	0.02	10.39
06/23/94	0.05	0.01	0.0005	0.02	0.001	0.02	7.39

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	DATEVAL	pH	COND UMHO	TSS mg/l	TURB NTU	HCO3 mg/l	Na mg/l	Ca mg/l
04/11/95	34800	7.14	83	<5	1.6	34	2.43	8.23
04/29/95	34818	6.8	60	<5	2.46	32.5	1.91	8.45
05/30/95	34849	6.98	40	14	4.66	17.3	1.56	4.76
06/29/95	34879	6.89	62	<5	1.54	17.3	1.62	3.49
07/26/95	34906	6.93	80	<5	1.01	27.8	2.34	6.13
12/04/95	35037	7.73	119	<5	1.27	29.1	2.73	7.85

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-95

DATE	Mg mg/l	Cl mg/l	So4 mg/l	No3 mg/l	TOTAL P mg/l	FLOW CFS	FLOW GPM	Al mg/l
04/11/95	3.33	<1.5	4.76	0.35	0.02		825	0.32
04/29/95	3.31	<1.5	4.21	0.56	0.02		1046	0.33
05/30/95	1.69	<1.5	1.58	0.42	0.02		3823	0.42
06/29/95	1.47	<1.5	2.6	0.07	0.02		1190	<0.2
07/26/95	2.95	<1.5	3.41	<0.06	0.02		4.9	0.22
12/04/95	3.69	<1.5	9.59	<0.06	0.02		29.2	<0.08

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	As mg/l	Ba mg/l	Be mg/l	B mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Fe mg/l
04/11/95	0.008	0.21	0.01	0.1	0.01	0.05	0.02	0.17
04/29/95	0.007	0.21	0.01	0.2	0.01	0.05	0.02	0.24
05/30/95	0.008	0.17	0.01	0.2	0.01	0.05	0.02	0.44
06/29/95	0.01	0.12	0.01	0.2	0.01	0.05	0.02	0.13
07/26/95	0.011	0.18	0.01	0.2	0.01	0.05	0.02	0.18
12/04/95	0.008	0.22	0.01	0.01	0.01	0.05	0.02	<0.05

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS

NORTH FORK S-95

DATE	Pb mg/l	Mn mg/l	Hg mg/l	Ag mg/l	Se mg/l	Zn mg/l	D.O. mg/l
04/11/95	0.01	0.01	0.0005	0.02	0.001	0.02	9.7
04/29/95	0.01	0.01	0.0005	0.02	0.001	0.02	10.97
05/30/95	0.01	0.01	0.0005	0.02	0.001	0.02	10.26
06/29/95	0.01	0.01	0.0005	0.02	0.001	0.02	8.67
07/26/95	0.01	0.01	0.0005	0.02	0.001	0.02	6.95
12/04/95	0.01	0.01	0.0005	0.02	0.001	0.02	9.86

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	pH	COND UMHO	TSS Mg/l	TURB NTU	HCO3 Mg/l	Na Mg/l	Ca Mg/l	Mg Mg/l	Cl Mg/l	So4 Mg/l	No3 Mg/l
04/07/93	6.71	1415.00	8.00	14.00	34.00	6.10	131.00	132.00	16.00	640.00	8.10
04/30/93	7.43	1150.00	9.00	3.00	34.00	5.20	106.00	102.00	11.00	656.00	7.50
05/11/93	7.14	970.00	12.00	9.80	27.00	4.20	86.00	84.00	13.00	510.00	7.10
05/26/93	6.59	940.00	3.00	3.00	8.00	3.60	81.00	85.00	10.00	462.00	4.00
06/10/93	6.99	840.00	2.00	1.10	25.00	3.40	80.00	69.00	11.00	392.00	4.10
06/25/93	6.99	750.00	1.00	1.70	29.00	3.20	64.00	56.00	8.00	364.00	3.50
07/09/93	7.26	840.00	3.00	0.90	31.00	3.40	77.00	66.00	7.00	415.00	4.70
07/29/93	7.36	1140.00	2.00	0.70	34.00	5.10	130.00	99.00	7.00	741.00	6.40
08/09/93	7.12	1830.00	13.00	0.40	41.00	7.20	210.00	154.00	12.00	999.00	11.00
08/26/93	7.57	2500.00	2.00	0.20	48.00	5.90	258.00	165.00	10.00	1300.00	12.30
09/08/93	6.98	2600.00	2.00	0.40	41.00	8.40	270.00	232.00	17.00	1628.00	18.00
09/27/93	7.20	2700.00	2.00	0.30	46.00	12.00	322.00	249.00	15.00	1680.00	16.10
10/11/93	7.06	2280.00		0.20	57.00	10.20	268.00	217.00	9.00	1450.00	19.60
10/22/93	7.25	2020.00	5.00	0.30	48.00	8.90	235.00	190.00	8.00	1460.00	16.20
11/12/93	7.16	2050.00	5.00	0.40	45.00	9.40	230.00	191.00	9.00	1230.00	16.50
03/15/94	6.54	715.00	5.00	1.50	37.00	4.50	64.40	54.50	3.20	319.00	3.43
03/28/94	7.07	1060.00	5.00	0.60	40.40	5.18	94.30	87.40	4.46	513.00	5.92
04/08/94	7.00	1270.00	5.00	0.20	39.40	5.43	11.00	112.00	4.70	694.00	7.13
04/26/94	6.92	1730.00	5.00	0.71	35.00	5.99	162.00	180.00	4.34	1090.00	9.85
05/27/94	6.93	863.00	5.00	1.42	31.50	3.87	66.30	76.10	2.69	438.00	3.42

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	pH	COND UMHO	TSS Mg/l	TURB NTU	HCO3 Mg/l	Na Mg/l	Ca Mg/l	Mg Mg/l	Cl Mg/l	So4 Mg/l	No3 Mg/l
06/23/94	7.15	1710.00	5.00	0.22	44.10	7.65	186.00	198.00	4.74	1150.00	11.80
07/28/94	7.20	2560.00	5.00	0.41	44.60	10.40	315.00	318.00	8.68	1920.00	22.30
10/28/94	7.15	2850.00	5.00	0.24	48.20	11.40	306.00	324.00	9.51	1900.00	19.30

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	TOTAL P	FLOW CFS	FLOW GPM	Al Mg/l	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
04/07/93	0.01		1075.30		0.015	0.06	0.01	0.10	0.01	0.05	0.02	0.59
04/30/93	0.01		1398.50		0.014	0.08	0.01	0.10	0.01	0.05	0.02	0.21
05/11/93	0.08		3700.80		0.076	0.08	0.02	0.10	0.01	0.05	0.02	1.10
05/26/93	0.02			0.27	0.012	0.11	0.01	0.10	0.01	0.05	0.02	0.17
06/10/93	0.01		1277.30	0.15	0.005	0.10	0.01	0.10	0.01	0.05	0.02	0.05
06/25/93	0.01		756.20	0.18	0.005	0.11	0.01	0.10	0.01	0.05	0.02	0.08
07/09/93	0.01			0.11	0.005	0.09	0.01	0.10	0.01	0.05	0.02	0.06
07/29/93	0.01		1.00	0.13	0.005	0.06	0.01	0.10	0.01	0.05	0.02	0.10
08/09/93	0.02		1.00	0.13	0.005	0.04	0.01	0.10	0.01	0.05	0.02	0.07
08/26/93	0.01		1.00	0.06	0.005	0.03	0.01	0.10	0.01	0.05	0.02	0.02
09/08/93	0.01		1.00	0.08	0.005	0.03	0.01	0.10	0.01	0.05	0.02	0.02
09/27/93	0.01		5.00	0.20	0.005	0.02	0.01	0.10	0.01	0.05	0.02	0.02
10/11/93	0.01		20.00	0.26	0.005	0.01	0.01	0.30	0.01	0.03	0.01	0.07
10/22/93	0.01		11.20	0.23	0.005	0.01	0.01	0.20	0.01	0.03	0.01	0.05
11/12/93	0.01		11.70	0.13	0.005	0.01	0.01	0.20	0.01	0.03	0.01	0.05
03/15/94	0.07		286.00	0.26	0.005	0.04	0.01	0.10	0.01	0.01	0.01	0.14
03/28/94	0.05		128.00	0.10	0.005	0.03	0.01	0.10	0.01	0.01	0.01	0.05
04/08/94	0.03		110.00	0.06	0.005	0.02	0.01	0.10	0.01	0.01	0.01	0.68
04/26/94	0.02		953.00	0.05	0.005	0.04	0.01	0.10	0.01	0.01	0.01	0.18
05/27/94	0.01		860.00	0.28	0.010	0.06	0.01	0.17	0.01	0.01	0.01	0.06

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	TOTAL P	FLOW CFS	FLOW GPM	Al Mg/l	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
06/23/94	0.01		74.00	0.10	0.010	0.03	0.01	0.11	0.01	0.02	0.01	0.05
07/28/94	0.30		30.00	0.23	0.010	0.01	0.01	0.23	0.01	0.04	0.01	0.05
10/28/94	0.03		5.00	0.20	0.005	0.01	0.01	0.20	0.01	0.04	0.01	0.05

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
04/07/93	0.05	1.10	0.0005	0.02	0.001	0.17	9.28
04/30/93	0.05	0.80	0.0020	0.02	0.001	0.11	11.10
05/11/93	0.05	0.74	0.0005	0.02	0.001	0.10	11.40
05/26/93	0.05	0.58	0.0005	0.02	0.001	0.07	
06/10/93	0.05	0.37	0.0006	0.02	0.001	0.05	9.66
06/25/93	0.05	0.14	0.0005	0.02	0.001	0.03	13.78
07/09/93	0.05	0.05	0.0005	0.02	0.001	0.02	
07/29/93	0.05	0.04	0.0005	0.02	0.003	0.02	12.17
08/09/93	0.05	0.04	0.0005	0.02	0.004	0.04	12.62
08/26/93	0.05	0.01	0.0005	0.02	0.009	0.02	11.25
09/08/93	0.05	0.01	0.0005	0.02	0.004	0.02	8.16
09/27/93	0.05	0.14	0.0005	0.02	0.001	0.02	9.93
10/11/93	0.01	0.01	0.0002	0.01	0.068	0.01	10.88
10/22/93	0.01	0.01	0.0002	0.01	0.069	0.01	10.60
11/12/93	0.01	0.01	0.0003	0.01	0.066	0.01	9.12
03/15/94	0.01	0.01	0.0002	0.01	0.017	0.01	6.45
03/28/94	0.01	0.10	0.0006	0.01	0.023	0.01	8.12
04/08/94	0.01	0.08	0.0002	0.01	0.027	0.02	13.63
04/26/94	0.01	0.53	0.0002	0.01	0.062	0.06	
05/27/94	0.01	0.23	0.0002	0.01	0.025	0.04	8.63

INDEPENDENCE MINING COMPANY INC

WATER QUALITY ANALYSIS
S112 DRY CANYON

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
06/23/94	0.01	0.05	0.0002	0.17	0.068	0.03	11.04
07/28/94	0.01	0.01	0.0002	0.01	0.196	0.05	14.07
10/28/94	0.01	0.01	0.0002	0.01	0.169	0.01	

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l	Mg Mg/l	Cl Mg/l	So4 Mg/l	No3 Mg/l
06/12/91	7.06	266	1.00	3.30	29.00	2.00	26.00	13.00	0.70	75.40	2.70
07/25/91	7.15	507	7.00	1.00	50.00	0.70	50.50	20.60	1.20	200.00	0.01
09/13/91	7.30	680	5.00	1.00	32.00	5.60	78.00	31.00	6.00	210.00	6.80
06/12/91	7.06	266	1.00	3.30	29.00	2.00	26.00	13.00	0.70	75.00	2.70
07/25/91	7.15	507	7.00	1.00	50.00	0.70	50.50	20.60	1.20	200.00	0.10
09/13/91	7.30	680	5.00	1.00	32.00	5.60	78.00	31.00	6.00	210.00	6.80
10/23/91	7.20	870	5.00	1.40	47.00	6.50	122.00	34.00	8.00	408.00	8.60
11/19/91	7.40	800	1.00	4.00	46.00	5.60	95.00	41.00	11.00	320.00	8.60
03/12/92	7.24	440	2.00	1.40	36.00	4.30	43.80	25.30	4.00	150.00	3.70
04/21/92	7.54	670	1.00	2.80	28.00	4.60	63.00	43.00	4.00	274.00	6.00
05/22/92	7.65	530	5.00	0.60	34.00	3.30	61.50	30.70	5.00	211.00	4.20
06/03/92	8.42	640	20.00	3.60		3.60	76.90	40.90	6.00		2.00
09/25/92	7.51	1210	1.00	2.00	57.00	8.50	171.00	77.60	11.00	588.00	9.90
10/06/92	7.64	1230	5.00	1.50	60.00	7.60	170.00	81.80	10.00	590.00	11.10
11/06/92	7.47	155	26.00	3.40	43.00	9.00	205.00	121.00	13.00	945.00	14.70
01/28/93	6.96	980	1.00	0.10	40.00	5.30	112.00	63.00	11.00	475.00	7.80
02/18/93	6.83	930	1.00	0.20	36.00	5.70	113.00	65.00	9.00	452.00	5.80
03/04/93	7.24	950	1.00	0.40	44.00	5.70	115.00	65.00	9.00	510.00	6.80
03/16/93	7.19	550	1.00	1.50	40.00	4.40	72.00	42.00	15.00	253.00	4.30

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l	Mg Mg/l	Cl Mg/l	So4 Mg/l	No3 Mg/l
04/07/93	6.89	1400	5.00	7.50	31.00	5.40	125.00	120.00	13.00	611.00	8.10
04/30/93	7.40	1130	3.00	2.60	29.00	5.10	103.00	96.00	11.00	528.00	7.50
05/11/93	7.21	1010	5.00	6.00	27.00	4.30	87.00	84.00	12.00	510.00	6.90
05/26/93	7.33	910	3.00	2.30	22.00	3.50	80.00	82.00	8.00	420.00	4.40
06/10/93	7.07	500	1.00	1.00	28.00	3.60	79.00	68.00	11.00	407.00	4.20
06/25/93	7.03	740	9.00	3.00	25.00	3.00	64.00	53.00	7.00	353.00	3.50
07/09/93	7.36	850	8.00	1.00	30.00	3.50	77.00	62.00	5.00	407.00	4.30
07/29/93	7.16	1350	1.00	0.20	38.00	5.80	132.00	122.00	8.00	699.00	7.40
08/09/93	7.38	1360	2.00	0.60	36.00	5.80	162.00	108.00	9.00	777.00	7.30
08/27/93	7.96	1670	1.00	0.20	42.00	5.40	190.00	155.00	6.00	944.00	8.20
09/08/93	7.13	1850	3.00	0.50	36.00	7.20	231.00	232.00	13.00	1129.00	9.30
10/22/93	7.41	1950	5.00	1.10	37.00	8.70	256.00	170.00	8.00	1210.00	15.90
03/15/94	7.19	660	<5	0.90	37.00	4.57	68.00	54.90	3.25	331.00	3.48
03/28/94	7.79	987	<5	0.48	38.40	4.83	88.00	77.00	4.06	481.00	5.45
04/08/94	7.44	1150	<5	0.48	37.30	5.10	102.00	93.60	4.31	595.00	7.12
04/26/94	6.94	1550	<5	0.50	23.00	5.40	148.00	167.00	3.52	1000.00	8.90
05/27/94	7.27	915	<5	1.16	34.60	4.05	72.60	81.30	2.48	476.00	4.70

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	TOTAL P	FLOW CFS	FLOW GPM	Al Mg/l	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
06/12/91	0.10				0.008							0.13
07/25/91	0.10				0.017							0.21
09/13/91	0.05				0.018							0.04
06/12/91	0.10	3.81	1712.00		0.008							0.13
07/25/91	0.10											0.21
09/13/91	0.05											0.04
10/23/91	0.10											0.02
11/19/91	0.01											0.04
03/12/92	0.02		25.00		0.003							0.06
04/21/92	0.02		150.00		0.007							0.10
05/22/92	0.02		30.00		0.005							0.04
06/03/92	0.03	3.81	1712.00		0.011							0.07
09/25/92	0.02				0.019	0.08	0.01	0.10	0.01	0.05	0.02	0.17
10/06/92	0.02				0.017	0.07	0.01	0.10	0.01	0.05	0.02	0.08
11/06/92	0.04				0.007	0.04	0.01	0.10	0.01	0.05	0.02	0.15
01/28/93	0.01				0.001	0.03	0.01	0.10	0.01	0.05	0.02	0.02
02/18/93	0.01				0.001	0.03	0.01	0.10	0.01	0.05	0.02	0.02
03/04/93	0.01		5.00		0.001	0.02	0.01	0.10	0.01	0.05	0.02	0.02
03/16/93	0.02		1200.00		0.003	0.04	0.01	0.10	0.01	0.05	0.02	0.06

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	TOTAL P	FLOW CFS	FLOW GPM	Al Mg/l	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
04/07/93	0.01		874.70		0.120	0.06	0.01	0.10	0.01	0.05	0.02	0.44
04/30/93	0.01		1582.50		0.013	0.07	0.01	0.10	0.01	0.05	0.02	0.20
05/11/93	0.04		3056.30		0.035	0.08	0.02	0.10	0.01	0.05	0.02	0.60
05/26/93	0.02		3150.10	0.26	0.011	0.11	0.01	0.10	0.01	0.05	0.02	0.15
06/10/93	0.01		1108.50	0.15	0.005	0.10	0.01	0.10	0.01	0.05	0.02	0.05
06/25/93	0.01		543.90	0.16	0.005	0.11	0.01	0.10	0.01	0.05	0.02	0.08
07/09/93	0.01			0.12	0.005	0.09	0.01	0.10	0.01	0.05	0.02	0.06
07/29/93	0.01		26.90	0.06	0.005	0.05	0.01	0.10	0.01	0.05	0.02	0.02
08/09/93	0.01		5.00	0.10	0.006	0.06	0.01	0.10	0.01	0.05	0.02	0.10
08/27/93	0.01		5.00	0.06	0.005	0.05	0.01	0.10	0.01	0.05	0.02	0.02
09/08/93	0.01		0.00	0.12	0.005	0.05	0.01	0.10	0.01	0.05	0.02	0.02
10/22/93	0.03		10.00	0.36	0.007	0.02	0.01	0.30	0.01	0.03	0.01	0.05
03/15/94	0.02		222.00	0.17	0.035	0.02	0.01	0.10	0.01	0.01	0.01	0.10
03/28/94	0.02		192.00	0.10	0.005	0.03	0.01	0.10	0.01	0.01	0.01	0.05
04/08/94	0.02		325.00	0.11	0.006	0.06	0.01	0.10	0.01	0.01	0.01	0.05
04/26/94	0.01		616.00	0.05	0.005	0.04	0.01	0.10	0.01	0.01	0.01	0.13
05/27/94	0.01		585.00	0.23	0.01	0.05	0.01	0.17	0.01	0.01	0.01	0.05

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
06/12/91							
07/25/91							
09/13/91							
06/12/91							
07/25/91							
09/13/91							
10/23/91							
11/19/91							
03/12/92							
04/21/92							
05/22/92							
06/03/92					0.004		
09/25/92	0.0500	0.06	0.0005	0.02	0.013	0.02	
10/06/92	0.0005	0.04	0.0005	0.02	0.010	0.02	
11/06/92	0.0500	0.12	0.0005	0.02	0.005	0.03	
01/28/93	0.0500	0.10	0.0005	0.02	0.002	0.02	
02/18/93	0.0500	0.10	0.0005	0.02	0.001	0.02	10.53
03/04/93	0.0500	0.10	0.0005	0.02	0.002	0.02	10.23
03/16/93	0.0500	0.02	0.0005	0.02	0.001	0.02	

INDEPENDENCE MINING COMPANY INC.

WATER QUALITY ANALYSIS
NORTH FORK S-115
Spillway of Dry Canyon sediment dam

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
04/07/93	0.0500	1.10	0.0005	0.02	0.001	0.18	9.55
04/30/93	0.0500	0.78	0.0010	0.02	0.002	0.10	6.64
05/11/93	0.0500	0.73	0.0017	0.02	0.001	0.10	10.92
05/26/93	0.0500	0.57	0.0006	0.02	0.002	0.07	
06/10/93	0.0500	0.35	0.0005	0.02	0.001	0.05	10.26
06/25/93	0.0500	0.15	0.0005	0.02	0.001	0.03	12.81
07/09/93	0.0500	0.05	0.0005	0.02	0.001	0.02	
07/29/93	0.0500	0.03	0.0005	0.02	0.002	0.02	14.79
08/09/93	0.0540	0.03	0.0005	0.02	0.004	0.04	8.38
08/27/93	0.0500	0.01	0.0005	0.02	0.008	0.02	9.56
09/08/93	0.0500	0.02	0.0005	0.02	0.005	0.02	8.25
10/22/93	0.0100	0.01	0.0002	0.01	0.093	0.01	
03/15/94	0.0500	0.02	0.0002	0.01	0.010	0.01	11.43
03/28/94	0.0500	0.04	0.0002	0.01	0.010	0.01	9.93
04/08/94	0.0500	0.07	0.0002	0.01	0.010	0.01	7.34
04/26/94	0.0500	0.46	0.0002	0.01	0.010	0.04	
05/27/94	0.0500	0.21	0.0002	0.01	0.010	0.03	7.06

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	DATEVAL	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l
04/28/87	31895	7.7	66	16	6.2	29	3	6.4
05/14/87	31911	7.6	73	13	6.2	31	2	7.2
06/24/87	31952	7.4	103	18	14	46	2	8.6
07/22/87	31980	7.8	121	3	4.4	56	2	12.7
08/12/87	32001	7.8	190	2	1.5	78	4	21
09/16/87	32036	8	178	1	1.7	77	4	19.3
10/22/87	32072	8	169	1	0.74	73	3	19.9
11/24/87	32105	7.8		2	2	65	3	17
01/28/88	32170	7.7	140	1	1.8	53	4	14.5
02/17/88	32190	7.7	160	4	1.7	54	3	14
03/24/88	32226	7.5	115	11	6.5	39	3	10.8
04/14/88	32247	7.8	102	13	14	35	2	7.8
05/02/88	32265	7.5	99	6	5.5	32	2	8.2
06/06/88	32300	7.4	93	8	4.3	32	2	8.8
07/31/88	32355	7.7	140	1	1.8	56	2	13
08/23/88	32378	7.4	150	1	1.4	58	2	14.9
09/14/88	32400	7.6	160	1	1.3	65	3	15.2
10/12/88	32428	7.8	164	1	1.1	64	3	18.1
11/09/88	32456	7.5	320	3	8.2	63	4	28.1
04/19/89	32617	7.1	150	68	46	26	3	12.7
05/25/89	32653	7.6	88	12	12	31	3	13.6

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	DATEVAL	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l
06/08/89	32667	6.9	109	9	2.9	27	2	9.6
07/17/89	32706	7	170	2	2.5	42	2	15.6
08/23/89	32743	7.8	162	3	2.6	56	3	17.8
09/13/89	32764	6.9	167	1	3.4	60	3	20
10/17/89	32798	7.9	225	3	3	71	3	22
11/15/89	32827	7.7	210	5	2	62	3	23.5
12/12/89	32854	7.6	220	6	1.3	68	4	21.5
01/23/90	32896	7.6	210	1	0.5	60	4	20.3
02/13/90	32917	7.6	220	2	1	57	4.6	22.8
03/21/90	32953	7.6	170	7	6.2	41	3.3	18.8
04/18/90	32981	7.9	190	11	2.6	30	2.7	20.8
05/11/90	33004	7.2	170	3	2.4	32	2.3	17.8
07/20/90	33074	7.3	177	8	6.6	49	3.7	21.2
08/22/90	33107	7.6	250	4	2.8	61	4.2	31.3
09/29/90	33145	7.8	275	5	1.7	67	4.5	28.1
10/29/90	33175	8.3	240	1	4	72	4.4	27.7
11/09/90	33186	7.8	250	1	2	69	4.4	28.4
12/04/90	33211	7.3	240	1	0.7	68	4.6	27.8
01/04/90	33242	6.9	264	1	0.02	68	3.7	26.5
02/11/91	33280	7.7	262	5	2.4	66	4.6	25.7
03/27/91	33324	7.9	230	1	1.7	48	4.3	24.9

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	DATEVAL	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l
04/30/91	33358	6.8	307		1	40	1	25.7
05/16/91	33374	7.2	345	19.2	7.1	33	3.1	33
06/12/91	33401	6.68	394	66	46.5	16	1	40
06/19/91	33408	7.12		5	1		1	12.4
07/25/91	33444	7.36	235	3	1	54	0.7	21.9
08/05/91	33455	7.5	324	3	1.5	58	2.7	29.4
09/13/91	33494	7.3	510	1	1	58	4.8	55
10/23/91	33534	7.4	310	1	2.2	66	4.3	37
11/19/91	33561	7.7	450	1	0.9	58	4.7	47
12/20/91	33592	7.62	300	1	0.3	46	3	33
01/17/92	33620	7.81	340	1	0.3	48	4.2	41
03/12/92	33675	7.91	310	1	0.8	40	4.3	30.4
04/22/92	33716	7.7	420	8	7	30	4.2	37
05/22/92	33746	7.85	250	12	2.8	45	2.3	27.2
06/03/92	33758	7.8	240	8	3.4		2	26.7
07/07/92	33792	7.95	340	6	2	70	3.1	31.6
08/05/92	33821	7.78	280	29	3.2	79	3.1	30.7
09/25/92	33872	7.97	400	1	1.6	76	3.7	42
10/06/92	33883	7.88	360	10	2.5	76	3.5	38.8
11/06/92	33914	7.76	640	18	1.4	53	4.9	77.1
12/15/92	33953	7.45	490	21	1.7	43	3.9	49.7

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	DATEVAL	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l
01/28/93	33997	7.88	445	19	3.5	57	3.8	48
02/18/93	34018	7.74	420	4	0.8	55	3.9	50
03/03/93	34031	7.66	420	3	0.8	49	3.7	48
03/15/93	34043	7.82	340	8	1.4	48	3.3	38
04/08/93	34067	7.79	700	6	5.5	40	4	65
04/30/93	34089	7.51	550	20	9	30	3.7	52
05/11/93	34100	7.42	550	133	58	27	3.5	50
05/27/93	34116	7.58	400	19	6	26	2.3	35
06/10/93	34130	7.79	290	6	2.7	30	2.7	36
06/25/93	34145	7.68	300	15	2	35	2.5	28
07/09/93	34159	7.65	330	9	2.2	36	2.7	31
07/31/93	34181	7.05	390	50	30	53	3.6	41
08/09/93	34190	7.7	400	8	4	49	3.5	41
08/27/93	34208	8.29	430	11	3.3	64	3.4	45
09/08/93	34220	7.57	430	16	5.5	58	3.8	46
09/28/93	34240	7.45	480	6	1.4	63	4.3	49
10/13/93	34255	7.94	494	5	8.5	65	4.7	51
10/22/93	34264	7.82	512	5	3.1	63	4.7	53
11/12/93	34285	7.75	921	5	1.1	51	6.1	112
11/24/93	34297	7.73	762	5	0.8	60	5.7	89
12/10/93	34313	7.71	580	5	0.9	59	4.7	59

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	DATEVAL	pH	COND UMHO	TSS Mg/l	TURB NTU	Alk. Mg/l	Na Mg/l	Ca Mg/l
01/12/94	34346	7.61	600	5	0.8	63	5.5	87
01/27/94	34361	7.81	680	5	1.1	67	5.7	89
02/28/94	34393	7.77	610	5	1.1	73	5.3	79
03/16/94	34409	7.6	360	5	1.6	48	5.9	43
03/29/94	34422	7.32	290	5	1.4	50	4	47
04/08/94	34432	7.55	500	5	0.9	46	3.8	50
04/27/94	34451	7.66	980	5	3.4	37	4.8	83
05/27/94	34481	7.38	400	6	5.2	36	2.9	36
06/23/94	34508	7.87	50	27	16.6	62	3.9	57
07/28/94	34543	7.69	680	17	14.1	87	6	83
08/30/94	34576	7.73	750	6	2.8	94	7.4	89
09/28/94	34605	7.48	700	5	2.7	100	6.4	94
10/28/94	34635	7.78	460	5	1.1	73	4.9	76

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Mg Mg/l	Cl Mg/l	SO4 Mg/l	NO3 Mg/l	TOTAL P Mg/l	FLOW Mg/l	FLOW Mg/l	Al Mg/l
04/28/87	2.6	2	4	3.4	0.05			
05/14/87	2.8	1	5	0.34	0.03			
06/24/87	4.2	1	5	1	0.06	3.989		
07/22/87	5.1	2	7	0.6	0.03			
08/12/87	8.2	4	19	0.5	0.03			
09/16/87	8.1	2	13	0.5	0.04			
10/22/87	8.2	1	13	0.3	0.01			
11/24/87	6.9	2	15	0.8	0.02			
01/28/88	5.6	2	15	0.7	0.01			
02/17/88	5.6	1	17	0.7	0.02			
03/24/88	4	1	16	1.1	0.05			
04/14/88	3	1	7	3.6	0.06			
05/02/88	3	1	6	2.2	0.04			
06/06/88	3.1	1	6	2.3	0.04			
07/31/88	5	8	5	0.9	0.04			
08/23/88	5.9	2	7	0.8	0.03	0.231	103.67	
09/14/88	6.4	3	9	0.4	0.1	0.18	80.78	
10/12/88	7.3	7	17	0.1	0.01			
11/09/88	11.5	31	23	0.6	0.03	0.186	83.48	
04/19/89	4.9	5	30	6.3	0.24	29.242	13123.81	
05/25/89	4.2	5	17	5.4	0.31	15.56	6983.33	

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Mg Mg/l	Cl Mg/l	SO4 Mg/l	NO3 Mg/l	TOTAL P Mg/l	FLOW Mg/l	FLOW Mg/l	Al Mg/l
06/08/89	3.3	2	15	2.5	0.15	18.517	8310.43	
07/17/89	4.7	14	13	2.2	0.01	2.38	1068.14	
08/23/89	5.8	6	11	1.7	0.07	0.593	266.14	
09/13/89	6.8	8	16	1.5	0.04	0.485	217.67	
10/17/89	8.1	11	19	1.2	0.03	0.387	173.69	
11/15/89	8.6	13	23	1.6	0.03	0.799	358.59	
12/12/89	8.5	9	24	1.8	0.01			
01/23/90	7.9	10	26	0.55	0.02			
02/13/90	7.7	10	23	2.7	0.02			
03/21/90	6.8	10	25	5	0.01	3.025	1357.62	
04/18/90	8	5	47	6.5	0.04	7.987	3584.57	
05/11/90	6.7	4	35	7.2	0.03	6.362	2855.27	
07/20/90	7	4	29	2.5	0.05			
08/22/90	11	27	35	0.6	0.02			
09/29/90	10	14	36	1.8	0.02			
10/29/90	11	17	35	2.8	0.01			
11/09/90	11	21	35	0.4	0.02			
12/04/90	11	18	36	0.8	0.02			
01/04/90	12	13.8	38	0.51	0.06			
02/11/91	12	15	35.3	0.76	0.1			
03/27/91	10	14	41	1.2	0.02			

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Mg Mg/l	Cl Mg/l	SO4 Mg/l	NO3 Mg/l	TOTAL P Mg/l	FLOW Mg/l	FLOW Mg/l	Al Mg/l
04/30/91	13	13.5	22	1	0.08			
05/16/91	19	7.5	106	15.5	0.1			
06/12/91	22	3.3	154	1.61	0.3			
06/19/91	8.2	1.8	49	1.02	0.12			
07/25/91	8.8	8.6	53.4	0.52	0.1			
08/05/91	18	24.6	74	0.45	0.1			
09/13/91	19	35	140	1.9	0.02			
10/23/91	16.1	16	80	0.1	0.07			
11/19/91	21	12	130	1.9	0.01	1.78	798.9	
12/20/91	16	17	65	1.4	0.01			
01/17/92	18	12	92	1.6	0.02	0.82	368	
03/12/92	15.6	15	79	1.4	0.02	1.752	786.3	
04/22/92	24	10	154	2.7	0.03			
05/22/92	13.4	9	69	0.8	0.03	3.808	1709	
06/03/92	13.6	9		0.7	0.03	1.977	887.3	
07/07/92	16.9	31	74	0.4	0.03			
08/05/92	14.9	18	41	0.2	0.06	0.205	92	
09/25/92	22.6	40	59	0.1	0.02	0.517	232	
10/06/92	19.3	30	71	0.1	0.03	0.457	205.1	
11/06/92	38.8	30	284	2	0.17	0.947	425	
12/15/92	24.6	18	160	1.6	0.01			

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Mg Mg/l	Cl Mg/l	SO4 Mg/l	NO3 Mg/l	TOTAL P Mg/l	FLOW Mg/l	FLOW Mg/l	Al Mg/l
01/28/93	24	15	132	1.5	0.03			
02/18/93	25	13	155	1.1	0.01		1500	0.01
03/03/93	23	13	158	2.6	0.01		1500	
03/15/93	20	20	113	1.6	0.01		1800	
04/08/93	52	17	261	4.9	0.02		2275.4	
04/30/93	38	12	239	3.6	0.04		4724.5	
05/11/93	35	10	192	3.7	0.2		13058	
05/27/93	26	6	151	2.5	0.06		16946	0.36
06/10/93	25	8	138	2.9	0.03		7103.2	0.19
06/25/93	18	8	104	1.6	0.01		3624.1	0.16
07/09/93	19	7	109	1.5	0.03			0.12
07/31/93	26	8	119	5.1	0.05			0.28
08/09/93	22	9	115	1.3	0.02		704.6	0.17
08/27/93	22	9	136	1.3	0.01		494.1	0.17
09/08/93	24	11	138	1.2	0.03		312.4	0.15
09/28/93	27	10	154	0.8	0.01		275.6	0.14
10/13/93	28	13	160	0.8	0.03		409.8	0.39
10/22/93	28	8	176	0.9	0.03		357.2	0.4
11/12/93	59	8	438	1.5	0.03		433.1	0.16
11/24/93	46	7	326	1.1	0.03		357	0.27
12/10/93	31	7	209	1.1	0.03		326.7	0.28

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Mg Mg/l	Cl Mg/l	SO4 Mg/l	NO3 Mg/l	TOTAL P Mg/l	FLOW Mg/l	FLOW Mg/l	Al Mg/l
01/12/94	44	6	306	1.2	0.03		200	0.33
01/27/94	47	5	301	1	0.01		607	0.29
02/28/94	42	5	299	1.1	0.01		377	0.31
03/16/94	25	6	151	1.6	0.03		920	0.15
03/29/94	28	8	173	1.5	0.02		846	0.11
04/08/94	32	7	200	1.9	0.02		1293	0.13
04/27/94	60	7	420	3.7	0.01		3310	0.06
05/27/94	27	4	171	1.6	0.03		5555	0.34
06/23/94	35	5	201	0.9	0.12		931	0.45
07/28/94	48	4	294	1.1	0.04		430	0.68
08/30/94	50	4	338	0.5	0.03		246	0.35
09/28/94	55	5	341	0.3	0.03		349	0.33
10/28/94	31	7	293	0.1	0.03		160	0.2

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
04/28/87	0.015							0.21
05/14/87	0.02							0.14
06/24/87	0.029							0.48
07/22/87	0.021							0.17
08/12/87	0.016							0.12
09/16/87	0.013							0.02
10/22/87	0.01							0.03
11/24/87	0.021							0.09
01/28/88	0.006							0.13
02/17/88	0.006							0.09
03/24/88	0.014							0.31
04/14/88	0.016							0.22
05/02/88	0.013							0.11
06/06/88	0.021							0.17
07/31/88	0.017							0.06
08/23/88	0.015							0.04
09/14/88	0.01							0.09
10/12/88	0.012							0.09
11/09/88	0.006							0.18
04/19/89	0.032							0.53
05/25/89	0.002							0.06

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
06/08/89	0.003							0.16
07/17/89	0.003							0.15
08/23/89	0.003							0.18
09/13/89	0.002							0.2
10/17/89	0.008							0.17
11/15/89	0.01							0.15
12/12/89	0.009							0.1
01/23/90	0.009							0.05
02/13/90	0.006							0.04
03/21/90	0.011							0.22
04/18/90	0.014							0.23
05/11/90	0.013							0.18
07/20/90	0.021							0.2
08/22/90	0.015							0.18
09/29/90	0.015							0.19
10/29/90	0.01							0.12
11/09/90	0.009							0.12
12/04/90	0.008							0.11
01/04/90	0.006							0.07
02/11/91	0.006							0.17
03/27/91	0.006							0.13

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
04/30/91	0.012							
05/16/91	0.025							0.58
06/12/91	0.086							1.6
06/19/91	0.018							0.1
07/25/91	0.011							0.21
08/05/91	0.017							0.23
09/13/91	0.006							0.28
10/23/91	0.01							0.3
11/19/91	0.006							0.12
12/20/91	0.006							0.09
01/17/92	0.005							0.08
03/12/92	0.005							0.08
04/22/92	0.009							0.27
05/22/92	0.014							0.22
06/03/92	0.015							0.24
07/07/92	0.017							0.27
08/05/92	0.03							1
09/25/92	0.012	0.32	0.01	0.1	0.01	0.05	0.02	0.24
10/06/92	0.014	0.28	0.01	0.1	0.01	0.05	0.02	0.23
11/06/92	0.007	0.2	0.01	0.1	0.01	0.05	0.02	0.26
12/15/92	0.005	0.16	0.01	0.1	0.01	0.05	0.02	0.35

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
01/28/93	0.008	0.17	0.01	0.1	0.01	0.05	0.02	0.33
02/18/93	0.15	0.01	0.01	0.1	0.01	0.05	0.02	0.1
03/03/93	0.005	0.14	0.01	0.1	0.01	0.05	0.02	0.09
03/15/93	0.008	0.17	0.01	0.1	0.01	0.05	0.02	0.36
04/08/93	0.09	0.19	0.01	0.01	0.01	0.05	0.02	0.27
04/30/93	0.036	0.2	0.01	0.1	0.01	0.05	0.02	0.5
05/11/93	0.14	0.15	0.02	0.1	0.01	0.05	0.02	2.5
05/27/93	0.036	0.16	0.01	0.1	0.01	0.05	0.02	0.37
06/10/93	0.014	0.17	0.01	0.1	0.01	0.05	0.02	0.22
06/25/93	0.16	0.17	0.01	0.1	0.01	0.05	0.02	0.21
07/09/93	0.014	0.16	0.01	0.1	0.01	0.05	0.02	0.19
07/31/93	0.035	0.22	0.01	0.1	0.01	0.05	0.02	0.18
08/09/93	0.02	0.18	0.01	0.1	0.01	0.05	0.02	0.3
08/27/93	0.015	0.19	0.01	0.1	0.01	0.05	0.02	0.3
09/08/93	0.013	0.19	0.01	0.1	0.01	0.05	0.02	0.3
09/28/93	0.008	0.22	0.01	0.1	0.01	0.05	0.02	0.26
10/13/93	0.05	0.19	0.01	0.2	0.01	0.01	0.01	0.35
10/22/93	0.015	0.17	0.01	0.2	0.01	0.01	0.01	0.26
11/12/93	0.005	0.1	0.01	0.1	0.01	0.01	0.01	0.15
11/24/93	0.005	0.09	0.01	0.1	0.01	0.01	0.01	0.05
12/10/93	0.006	0.08	0.01	0.2	0.01	0.01	0.01	0.07

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	As Mg/l	Ba Mg/l	Be Mg/l	B Mg/l	Cd Mg/l	Cr Mg/l	Cu Mg/l	Fe Mg/l
01/12/94	0.005	0.08	0.01	0.2	0.01	0.01	0.01	0.05
01/27/94	0.008	0.08	0.01	0.2	0.01	0.01	0.01	0.15
02/28/94	0.009	0.07	0.01	0.2	0.01	0.01	0.01	1.06
03/16/94	0.008	0.07	0.01	0.1	0.01	0.01	0.01	0.17
03/29/94	0.005	0.08	0.01	0.1	0.01	0.01	0.01	0.09
04/08/94	0.006	0.07	0.01	0.1	0.01	0.01	0.01	0.13
04/27/94	0.011	0.1	0.01	0.1	0.01	0.01	0.01	0.29
05/27/94	0.025	0.11	0.01	0.2	0.01	0.01	0.01	0.31
06/23/94	0.032	0.17	0.01	0.1	0.01	0.01	0.01	0.84
07/28/94	0.025	0.16	0.01	0.1	0.01	0.01	0.01	0.55
08/30/94	0.016	0.11	0.01	0.3	0.01	0.01	0.01	0.27
09/28/94	0.011	0.11	0.01	0.4	0.01	0.01	0.01	0.35
10/28/94	0.008	0.1	0.01	0.2	0.01	0.01	0.01	0.12

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
04/28/87							
05/14/87							
06/24/87							
07/22/87							
08/12/87							
09/16/87							
10/22/87							
11/24/87							
01/28/88							
02/17/88							
03/24/88							
04/14/88							
05/02/88							
06/06/88							
07/31/88							
08/23/88							
09/14/88							
10/12/88							
11/09/88							
04/19/89							
05/25/89							

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
06/08/89							
07/17/89							
08/23/89							
09/13/89							
10/17/89							
11/15/89							
12/12/89							
01/23/90							
02/13/90							
03/21/90							
04/18/90							
05/11/90							
07/20/90							
08/22/90							
09/29/90							
10/29/90							
11/09/90							
12/04/90							
01/04/90							
02/11/91							
03/27/91							

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

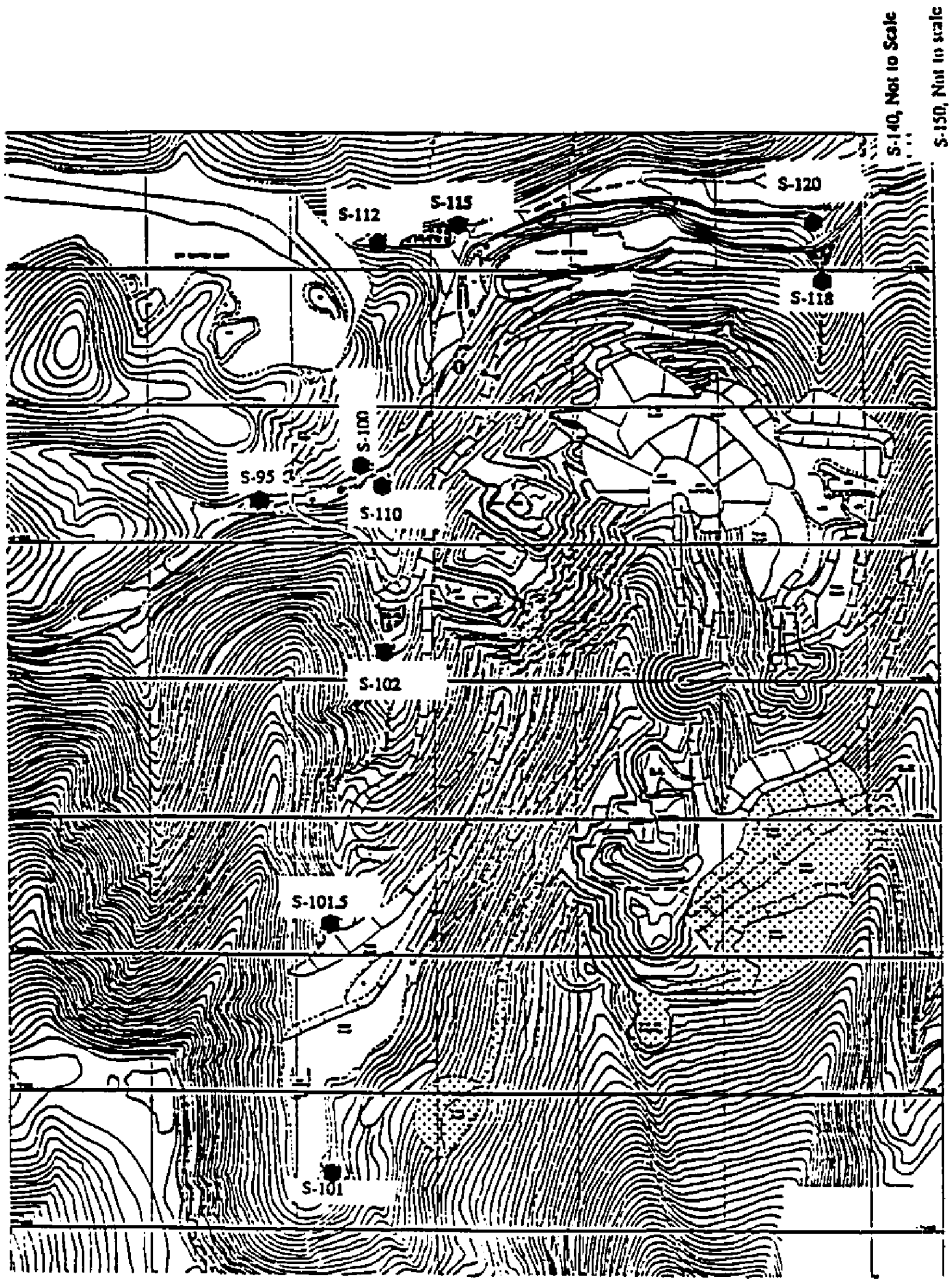
DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
04/30/91							
05/16/91							
06/12/91							
06/19/91							
07/25/91							
08/05/91							
09/13/91							
10/23/91							
11/19/91							
12/20/91							
01/17/92							
03/12/92							
04/22/92							
05/22/92							
06/03/92					0.001		
07/07/92					0.001		
08/05/92					0.001		
09/25/92	0.05	0.08	0.0005	0.02	0.001	0.02	
10/06/92	0.0005	0.08	0.0005	0.02	0.001	0.02	
11/06/92	0.05	0.2	0.0005	0.02	0.001	0.02	
12/15/92	0.05	0.06	0.0005	0.02	0.001	0.02	

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
01/28/93	0.05	0.06	0.0005	0.02	0.001	0.02	
02/18/93	0.05	0.03	0.0005	0.02	0.001	0.02	10.84
03/03/93	0.05	0.03	0.0005	0.02	0.001	0.02	11.5
03/15/93	0.05	0.06	0.0005	0.02	0.001	0.02	
04/08/93	0.05	0.2	0.0005	0.02	0.001	0.02	9.54
04/30/93	0.05	0.21	0.0036	0.02	0.001	0.03	9.42
05/11/93	0.05	0.49	0.0013	0.02	0.002	0.07	10.75
05/27/93	0.05	0.19	0.001	0.02	0.001	0.03	13.25
06/10/93	0.05	0.11	0.0005	0.02	0.002	0.02	8.6
06/25/93	0.05	0.05	0.0005	0.02	0.001	0.02	10.65
07/09/93	0.05	0.04	0.0005	0.02	0.001	0.02	
07/31/93	0.05	0.01	0.0005	0.02	0.001	0.02	
08/09/93	0.05	0.05	0.0005	0.02	0.001	0.02	8.75
08/27/93	0.05	0.06	0.0005	0.02	0.001	0.02	10.28
09/08/93	0.05	0.07	0.0005	0.02	0.001	0.04	9.79
09/28/93	0.05	0.06	0.0005	0.02	0.001	0.02	9.7
10/13/93	0.03	0.06	0.0002	0.01	0.05	0.01	9.34
10/22/93	0.01	0.05	0.0002	0.01	0.05	0.01	10.2
11/12/93	0.01	0.1	0.0002	0.01	0.007	0.01	9.14
11/24/93	0.01	0.06	0.0002	0.01	0.009	0.01	7.01
12/10/93	0.01	0.05	0.0002	0.01	0.005	0.01	12.55

INDEPENDENCE MINING COMPANY INC
WATER QUALITY ANALYSIS
NORTH FORK S-140
(below confluence w/ Cole Canyon)

DATE	Pb Mg/l	Mn Mg/l	Hg Mg/l	Ag Mg/l	Se Mg/l	Zn Mg/l	D.O. Mg/l
01/12/94	0.01	0.04	0.0002	0.01	0.005	0.01	8
01/27/94	0.01	0.04	0.0002	0.01	0.007	0.01	8.41
02/28/94	0.01	0.04	0.0002	0.01	0.005	0.01	8.69
03/16/94	0.01	0.03	0.0002	0.01	0.006	0.01	11.16
03/29/94	0.01	0.02	0.0002	0.01	0.005	0.01	12.18
04/08/94	0.01	0.02	0.0005	0.01	0.01	0.01	8.46
04/27/94	0.01	0.08	0.0002	0.01	0.02	0.01	12.1
05/27/94	0.01	0.05	0.0002	0.01	0.01	0.01	9.56
06/23/94	0.01	0.11	0.0002	0.01	0.007	0.01	9.45
07/28/94	0.01	0.1	0.0002	0.01	0.005	0.01	10.91
08/30/94	0.01	0.06	0.0002	0.01	0.005	0.01	10.47
09/28/94	0.01	0.07	0.0002	0.01	0.005	0.01	
10/28/94	0.01	0.06	0.0002	0.01	0.005	0.01	



Facility and Monitoring Station Locations.

(Schafer & Associates, 1994)

Station Identifier	Location	Start Date
S95	North Fork Humboldt above haul road	03/12/92
S-100	North Fork Humboldt below haul road	04/14/93
S-101	Sammy Creek above Sammy Creek dump	08/14/91
S101.5	Sammy Creek below Sammy Creek dump	05/29/92
S102	Sammy Creek: below dump, above sediment pond	08/14/91
S110	Sammy Creek at mouth	06/15/86
S112	Dry Canyon: below dump, above sediment pond	04/07/93
S115	Dry Canyon at mouth	06/12/91
S118	Water Canyon: below dump, above sediment pond	03/12/92
S120	Water Canyon below sediment pond	04/28/87
S140	North Fork Humboldt	04/14/86
S150	North Fork Humboldt	04/14/86

(After Schafer and Associates, 1994)

APPENDIX II

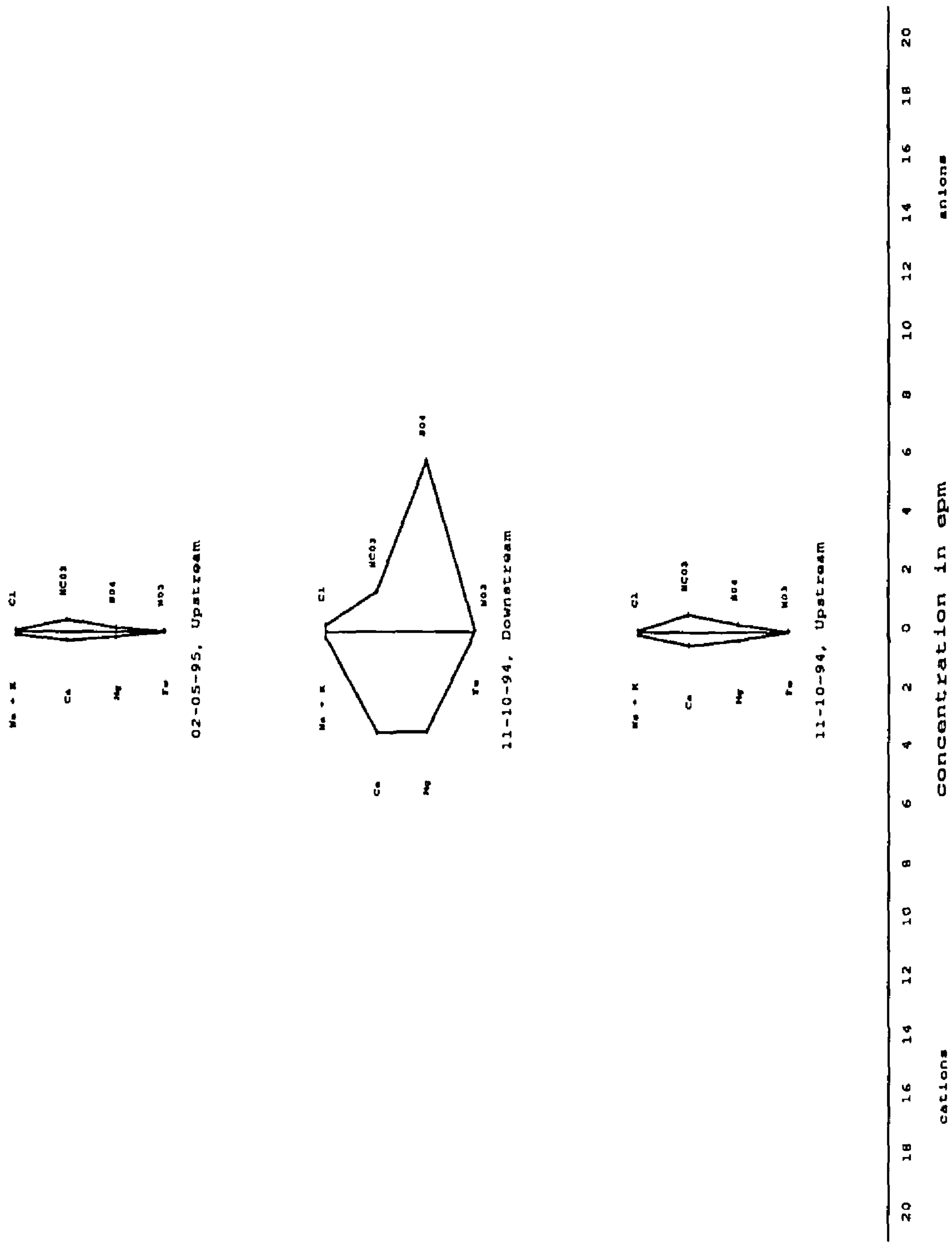
LISTING OF LABORATORY METHODS

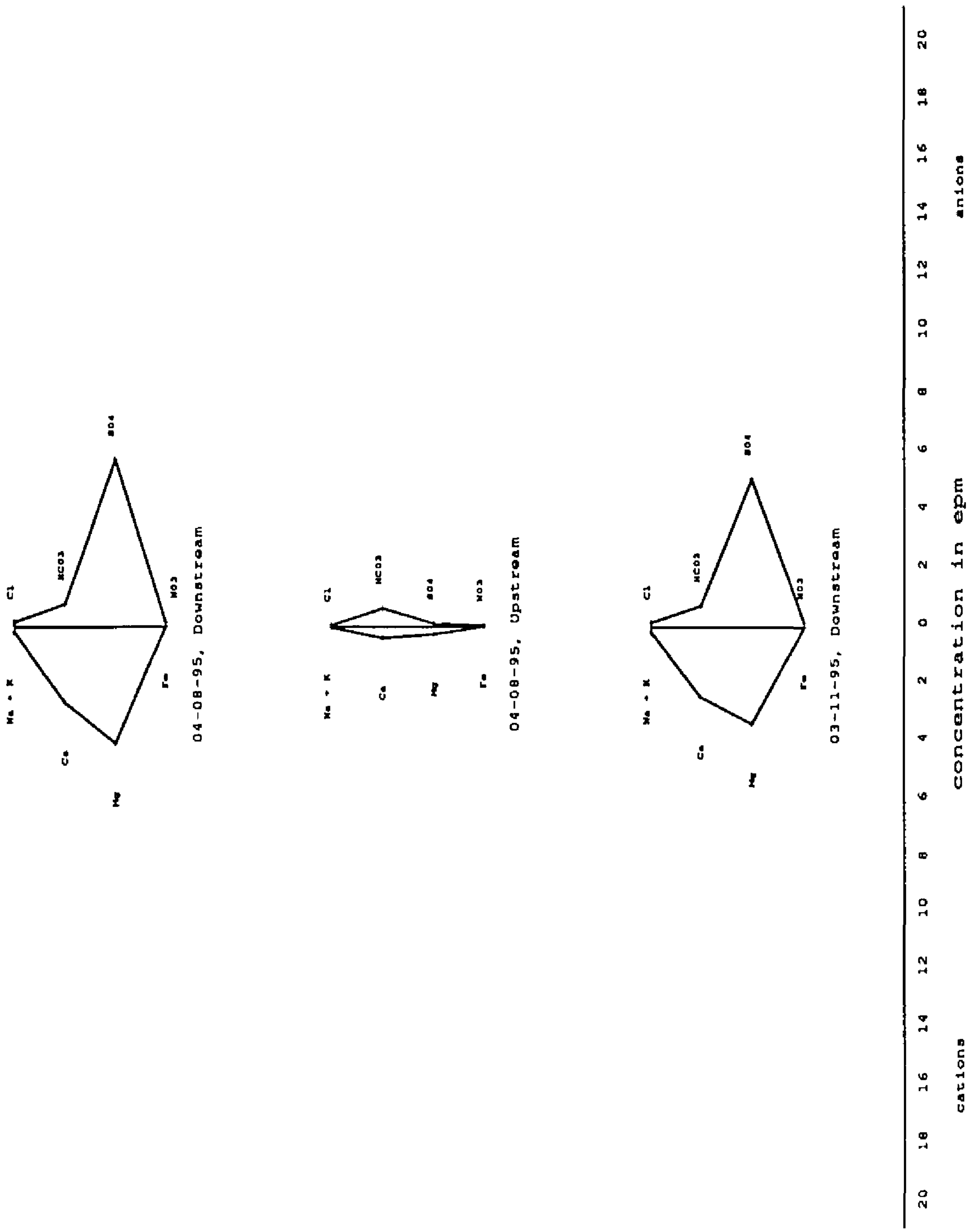
Constituent	Technique	Reference	Method
TDS	Gravimetric	EPA-600/4-79-020	160.1
TSS	Gravimetric	EPA-600/4-79-020	160.2
pH	Electrometric	EPA-600/4-79-020	150.1
EC	Specific Conductance	EPA-600/4-79-020	120.1
Alkalinity	Electrometric Titration	USGS TWRI	
Chloride	Ion Chromatography	EPA-600/4-84-017	300.0
Sulfate	Ion Chromatography	EPA-600/4-84-017	300.0
Sodium	Atomic Adsorption	EPA-600/4-79-020	273.1
Potassium	Atomic Adsorption	EPA-600/4-79-020	258.1
Calcium	Atomic Adsorption	EPA-600/4-79-020	215.1
Magnesium	Atomic Adsorption	EPA-600/4-79-020	242.1
Silica	Colorimetric	USGS TWRI	
Nitrate	Ion Chromatography	EPA-600/4-84-017	300.0
Silver	Atomic Adsorption	EPA-600/4-79-020	272.1
Aluminum	Atomic Adsorption	EPA-600/4-79-020	202.1
Arsenic	Atomic Adsorption	USGS TWRI	
Barium	Atomic Adsorption	EPA-600/4-79-020	208.1
Beryllium	Atomic Adsorption	EPA-600/4-79-020	210.1
Cadmium	Atomic Adsorption	EPA-600/4-79-020	213.1
Chromium	Atomic Adsorption	EPA-600/4-79-020	218.1
Copper	Atomic Adsorption	EPA-600/4-79-020	220.1
Iron	Atomic Adsorption	EPA-600/4-79-020	236.1
Mercury	Cold Vapor	EPA-600/4-49-020	245.1
Lithium	Atomic Adsorption	USGS TWRI	
Manganese	Atomic Adsorption	EPA-600/4-79-020	243.1
Nickel	Atomic Adsorption	EPA-600/4-79-020	249.1
Lead	Atomic Adsorption	EPA-600/4-79-020	239.1
Selenium	Atomic Adsorption	UGSS TWRI	
Strontium	Atomic Adsorption	USGS TWRI	
Titanium	Atomic Adsorption	EPA-600/4-79-020	283.1
Thallium	ICP	EPA-600/4-79-020	200.7
Vanadium	Atomic Adsorption	EPA-600/4-79-020	286.1
Zinc	Atomic Adsorption	EPA-600/4-79-020	289.1
Boron	ICP	EPA-600/4-79-020	200.7
Flouride	Potentiometric	EPA-600/4-79-020	340.2
TOC	Combustion	EPA-600/4-79-020	415.1

EPA- source listings refer to EPA publication numbers.
USGS TWRI listings refer to "Techniques of Water Resources Investigations of the United States Geological Survey, Methods for the Determination of Inorganic Substances in Water and Fluvial Sediments", Fishmann, M. J., and Friedman, L. C., editors, USGS, Denver, CO, 1985.

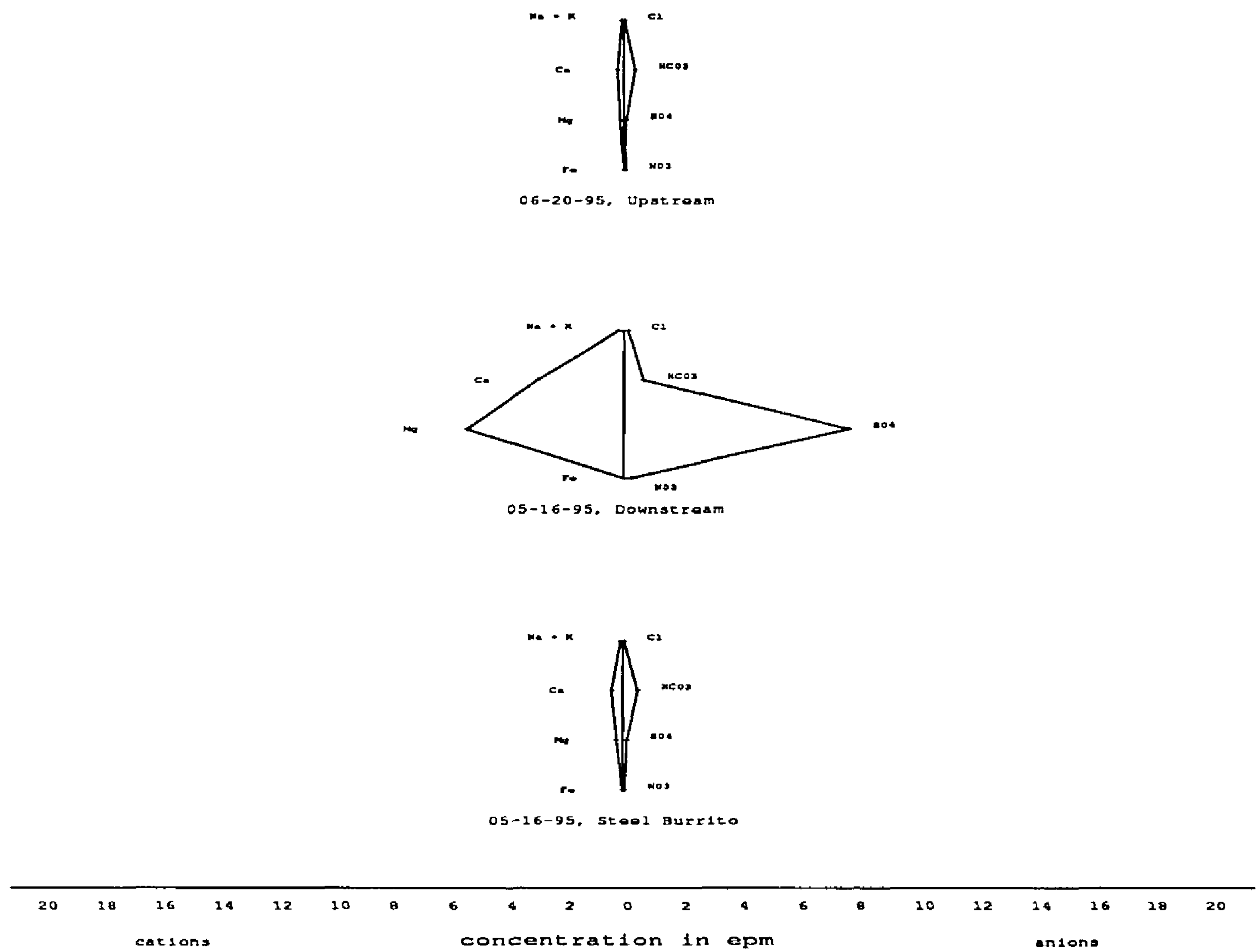
APPENDIX III

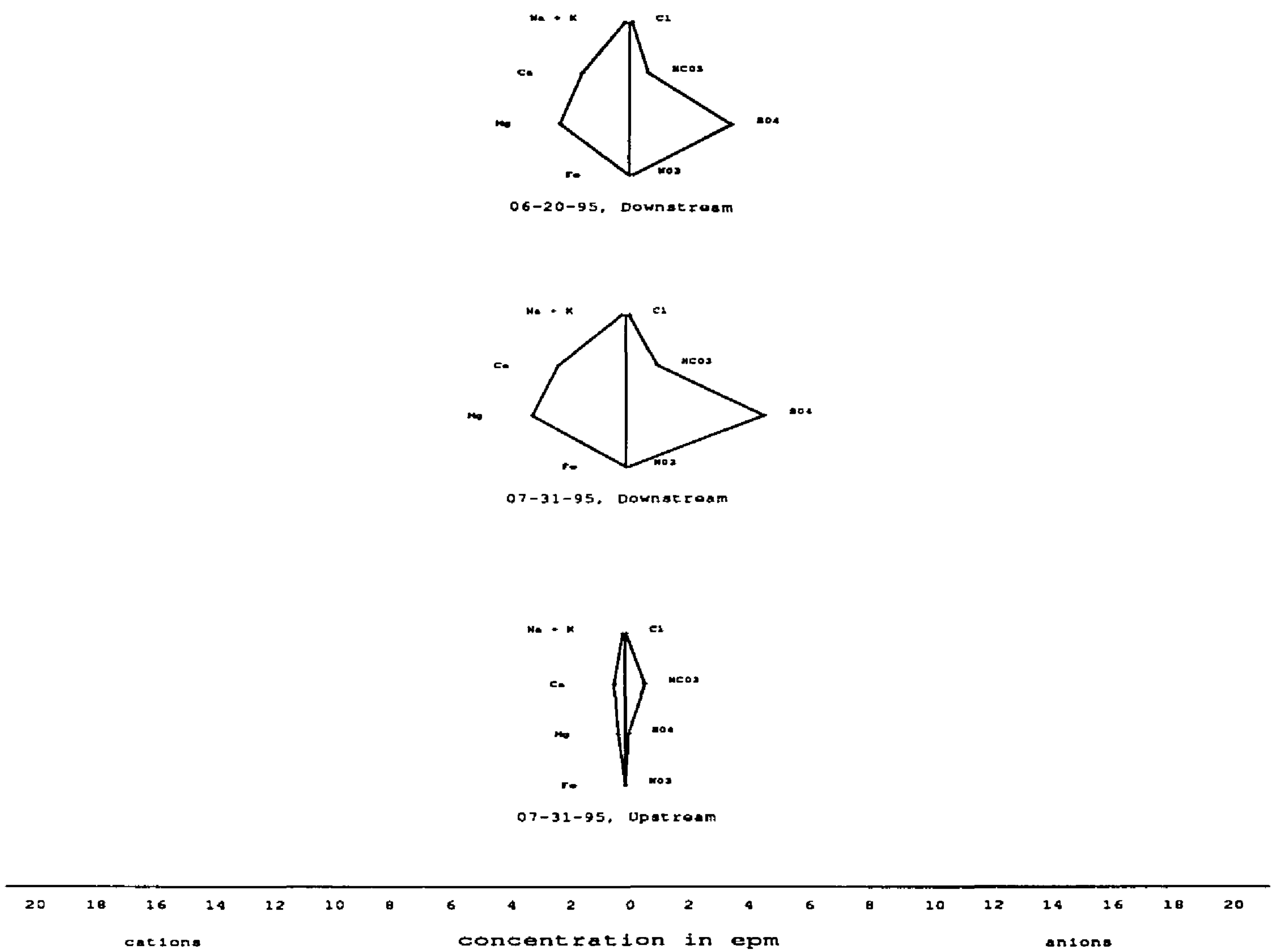
STIFF DIAGRAMS FROM CHEMICAL ANALYSES

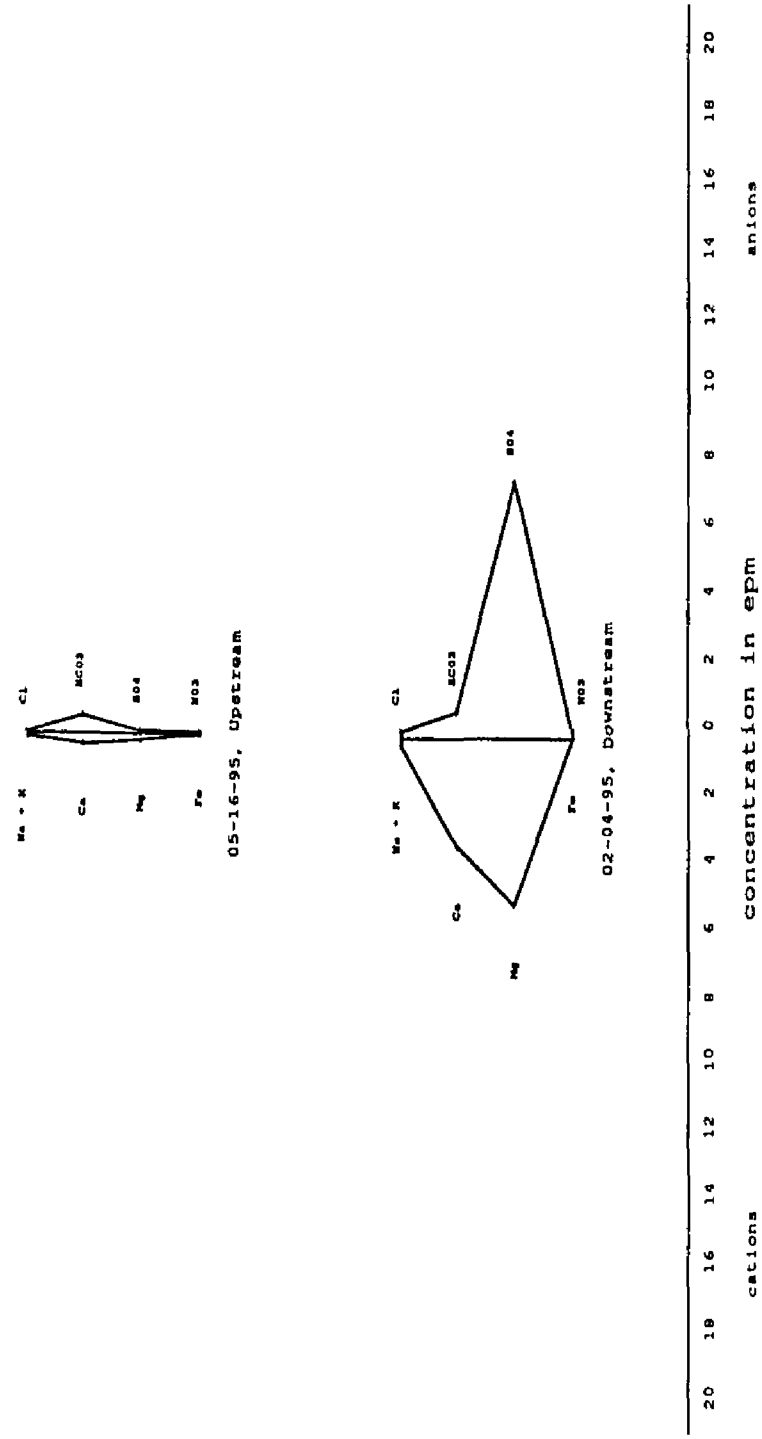

02-05-95, Upstream
11-10-94, Downstream
11-10-94, Upstream
Cl
HCO3
SO4
NO3
Na + K
Ca
Mg
Fe
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
anions
cations
concentration in epm



Cl
HCO3
SO4
NO3
Na + K
Ca
Mg
Fe
04-08-95, Downstream
04-08-95, Upstream
03-11-95, Downstream
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
cations
anions
concentration in epm


Na + K
Cl
Ca
HCO3
Mg
SO4
Fe
NO3
06-20-95, Upstream
05-16-95, Downstream
05-16-95, Steel Burrito
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
cations
concentration in epm
anions


Na + K
Cl
Ca
HCO3
Mg
SO4
Fe
NO3
06-20-95, Downstream
07-31-95, Downstream
07-31-95, Upstream
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
cations
concentration in epm
anions



Cl
HCO3
SO4
NO3
Na + K
Ca
Mg
Fe
05-16-95, Upstream
02-04-95, Downstream
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
cations
anions
concentration in epm

APPENDIX IV

RESULTS OF STATISTICAL TESTS

Constituent/Parameter	Alpha	Delta Hat
Ba	0.001	-0.1015
Se	0.004	0.008*
Sr	0.001	0.073
EC (field)	0.001	600
EC (laboratory)	0.001	580.5
HCO3	0.004	15.85
Cl	0.001	4.39
SO4	0.001	271.81
NO3 (total)	0.002	7.72
Na	0.001	1.77
K	0.001	0.57
Ca	0.001	45.45
Mg	0.001	39.07
NO3 (as N)	0.002	1.74
F	0.001	0.057
Mn	0.001	0.07*
TSS	0.267	
Temperature	0.183	
SiO2	0.051	
pH (field)	0.051	
DO	0.365	
As	0.147	
Fe	0.527	
Zn	0.527	
Al	0.183	
B	0.365	

"Delta Hat" values indicate the estimated magntude of change difference between the upstream and downstream data sets for each constituent/parameter. Positive values indicate increasing concentration or value from upstream to downstream, negative values indicate a decrease. All delta hat values are in units of mg/L except those for field and laboratory EC, which are in units of µS/cm. Values followed by asterisks were calculated from data sets which inclueded laboratory non-detects. One-half the detection limit was substituted for non-detect values to allow calculation of the delta hat value.

APPENDIX V

DAILY AVERAGE VALUES FOR STAGE AND EC, WITH EXTRAPOLATED VALUES FOR DISCHARGE AND MASS LOADING

DATE	STAGE (cm)	DISCH S (m^3/s)	DISCH N (m^3/s)	DISCH T (m^3/s)	EC (µS/cm)	TDS (mg/L)	DAILY LD (t)
02/04/95	16.86	0.10	0.15	0.25	797	566	12.2
02/05/95	17.39	0.11	0.16	0.26	796	565	12.9
02/06/95	16.63	0.10	0.15	0.24	795	564	11.9
02/07/95	14.98	0.08	0.12	0.20	715	508	8.9
02/08/95	14.21	0.07	0.12	0.19	698	496	8.0
02/09/95	13.41	0.06	0.11	0.17	680	483	7.0
02/10/95	12.68	0.06	0.10	0.15	677	481	6.4
02/11/95	12.20	0.05	0.09	0.14	661	469	5.8
02/12/95	11.80	0.05	0.09	0.14	666	473	5.5
02/13/95	11.00	0.04	0.08	0.12	699	496	5.2
02/14/95	9.78	0.03	0.07	0.10	735	522	4.4
02/15/95	9.15	0.03	0.06	0.09	832	591	4.5
02/16/95	7.85	0.02	0.05	0.07	836	594	3.5
02/17/95	7.12	0.02	0.04	0.06	880	625	3.1
02/18/95	6.78	0.02	0.04	0.05	868	616	2.8
02/19/95	7.35	0.02	0.04	0.06	826	586	3.1
02/20/95	9.01	0.03	0.06	0.09	755	536	4.0
02/21/95	10.61	0.04	0.07	0.11	748	531	5.2
02/22/95	12.23	0.05	0.09	0.14	747	530	6.6
02/23/95	12.77	0.06	0.10	0.16	732	520	7.0
02/24/95	13.39	0.06	0.11	0.17	707	502	7.3
02/25/95	13.80	0.07	0.11	0.18	678	481	7.4
02/26/95	13.64	0.06	0.11	0.17	697	495	7.4
02/27/95	13.05	0.06	0.10	0.16	715	508	7.1
02/28/95	12.59	0.06	0.10	0.15	713	506	6.6
03/01/95	12.25	0.05	0.09	0.14	728	517	6.5
03/02/95	11.54	0.05	0.08	0.13	744	528	6.0
03/03/95	12.44	0.05	0.09	0.15	739	525	6.7
03/04/95	11.25	0.04	0.08	0.12	748	531	5.7
03/05/95	10.26	0.04	0.07	0.11	803	570	5.3
03/06/95	8.98	0.03	0.06	0.09	818	581	4.3
03/07/95	8.71	0.03	0.06	0.08	817	580	4.1
03/08/95	8.64	0.03	0.05	0.08	780	554	3.8
03/09/95	10.68	0.04	0.08	0.11	750	533	5.3
03/10/95	16.47	0.10	0.14	0.24	652	463	9.6
03/11/95	21.56	0.17	0.22	0.38	569	404	13.3
03/12/95	14.84	0.08	0.12	0.20	630	447	7.7
03/13/95	12.96	0.06	0.10	0.16	653	464	6.4
03/14/95	13.56	0.06	0.11	0.17	792	562	8.3
03/15/95	13.57	0.06	0.11	0.17	734	521	7.7
03/16/95	13.08	0.06	0.10	0.16	745	529	7.4
03/17/95	12.87	0.06	0.10	0.16	741	526	7.1
03/18/95	12.76	0.06	0.10	0.15	729	518	6.9
03/19/95	12.35	0.05	0.09	0.15	725	515	6.5
03/20/95	12.50	0.05	0.10	0.15	715	508	6.6
03/21/95	12.08	0.05	0.09	0.14	627	445	5.4
03/22/95	11.35	0.04	0.08	0.13	630	447	4.9
03/23/95	10.90	0.04	0.08	0.12	645	458	4.7
03/24/95	10.47	0.04	0.07	0.11	590	419	4.0
03/25/95	10.11	0.03	0.07	0.10	607	431	3.9
03/26/95	9.48	0.03	0.06	0.09	604	429	3.5
03/27/95	8.98	0.03	0.06	0.09	675	479	3.5
03/28/95	8.75	0.03	0.06	0.08	698	496	3.5

03/29/95	8.41	0.02	0.05	0.08	791	562	3.7
03/30/95	8.19	0.02	0.05	0.07	837	594	3.8
03/31/95	8.25	0.02	0.05	0.07	828	588	3.8
04/01/95	7.83	0.02	0.05	0.07	812	577	3.4
04/02/95	8.07	0.02	0.05	0.07	892	633	3.9
04/03/95	8.12	0.02	0.05	0.07	884	628	3.9
04/04/95	8.83	0.03	0.06	0.08	768	545	3.9
04/05/95	9.08	0.03	0.06	0.09	803	570	4.3
04/06/95	9.57	0.03	0.06	0.10	770	547	4.5
04/07/95	9.78	0.03	0.07	0.10	675	479	4.1
04/08/95	9.54	0.03	0.06	0.09	631	448	3.7
04/09/95	10.69	0.04	0.08	0.11	654	464	4.6
04/10/95	10.35	0.04	0.07	0.11	653	464	4.3
04/11/95	10.39	0.04	0.07	0.11	652	463	4.4
04/12/95	10.90	0.04	0.08	0.12	651	462	4.7
04/13/95	13.61	0.06	0.11	0.17	647	459	6.9
04/14/95	12.13	0.05	0.09	0.14	642	456	5.6
04/15/95	14.48	0.07	0.12	0.19	670	476	7.9
04/16/95	15.20	0.08	0.13	0.21	668	474	8.6
04/17/95	18.37	0.12	0.17	0.29	671	476	11.9
04/18/95	16.33	0.09	0.14	0.24	673	478	9.8
04/19/95	16.39	0.09	0.14	0.24	676	480	9.9
04/20/95	11.85	0.05	0.09	0.14	677	481	5.7
04/21/95	14.45	0.07	0.12	0.19	676	480	7.9
04/22/95	20.89	0.16	0.21	0.36	669	475	14.8
04/23/95	22.42	0.18	0.23	0.41	684	486	17.2
04/24/95	24.40	0.22	0.26	0.47	656	466	19.1
04/25/95	21.67	0.17	0.22	0.39	665	472	15.7
04/26/95	22.83	0.19	0.23	0.42	689	489	17.9
04/27/95	24.41	0.22	0.26	0.47	690	490	20.1
04/28/95	19.45	0.13	0.18	0.32	672	477	13.2
04/29/95	16.17	0.09	0.14	0.23	659	468	9.4
04/30/95	20.02	0.14	0.19	0.34	638	453	13.2
05/01/95	20.69	0.15	0.20	0.36	628	446	13.7
05/02/95	18.16	0.12	0.17	0.28	609	432	10.6
05/03/95	20.30	0.15	0.20	0.34	616	437	13.0
05/04/95	20.33	0.15	0.20	0.35	647	459	13.7
05/05/95	17.84	0.11	0.16	0.28	645	458	10.9
05/06/95	16.60	0.10	0.15	0.24	646	459	9.6
05/07/95	18.16	0.12	0.17	0.28	650	462	11.3
05/08/95	22.75	0.19	0.23	0.42	655	465	16.9
05/09/95	22.93	0.19	0.24	0.43	651	462	17.0
05/10/95	23.04	0.19	0.24	0.43	639	454	16.8
05/11/95	17.51	0.11	0.16	0.27	624	443	10.2
05/12/95	17.81	0.11	0.16	0.27	620	440	10.4
05/13/95	20.16	0.15	0.19	0.34	650	462	13.6
05/14/95	21.28	0.16	0.21	0.37	655	465	15.0
05/15/95	21.53	0.17	0.22	0.38	658	467	15.4
05/16/95	19.72	0.14	0.19	0.33	660	469	13.3
05/17/95	19.23	0.13	0.18	0.31	661	469	12.7
05/18/95	19.01	0.13	0.18	0.31	659	468	12.4
05/19/95	18.63	0.12	0.17	0.30	663	471	12.1
05/20/95	18.88	0.13	0.18	0.30	642	456	12.0
05/21/95	18.81	0.13	0.18	0.30	611	434	11.3
05/22/95	18.45	0.12	0.17	0.29	601	427	10.8
05/23/95	18.27	0.12	0.17	0.29	603	428	10.6

05/24/95	17.84	0.11	0.16	0.28	629	447	10.6
05/25/95	18.37	0.12	0.17	0.29	616	437	10.9
05/26/95	18.69	0.12	0.17	0.30	605	430	11.1
05/27/95	18.91	0.13	0.18	0.30	597	424	11.1
05/28/95	18.76	0.13	0.17	0.30	607	431	11.2
05/29/95	19.25	0.13	0.18	0.31	604	429	11.6
05/30/95	19.30	0.13	0.18	0.32	607	431	11.7
05/31/95	19.00	0.13	0.18	0.31	623	442	11.7
06/01/95	19.26	0.13	0.18	0.31	603	428	11.6
06/02/95	18.70	0.12	0.17	0.30	607	431	11.1
06/03/95	18.79	0.13	0.18	0.30	563	400	10.4
06/04/95	19.35	0.13	0.18	0.32	551	391	10.7
06/05/95	17.85	0.11	0.16	0.28	554	393	9.4
06/06/95	17.68	0.11	0.16	0.27	526	373	8.7
06/07/95	17.32	0.11	0.16	0.26	539	383	8.6
06/08/95	17.53	0.11	0.16	0.27	525	373	8.6
06/09/95	18.86	0.13	0.18	0.30	539	383	10.0
06/10/95	19.16	0.13	0.18	0.31	613	435	11.7
06/11/95	20.88	0.16	0.21	0.36	522	371	11.6
06/12/95	20.38	0.15	0.20	0.35	487	346	10.4
06/13/95	19.80	0.14	0.19	0.33	489	347	9.9
06/14/95	19.18	0.13	0.18	0.31	483	343	9.2
06/15/95	19.13	0.13	0.18	0.31	466	331	8.9
06/16/95	19.59	0.14	0.19	0.32	480	341	9.5
06/17/95	19.33	0.13	0.18	0.32	470	334	9.1
06/18/95	19.63	0.14	0.19	0.32	475	337	9.5
06/19/95	19.80	0.14	0.19	0.33	517	367	10.5
06/20/95	21.53	0.17	0.22	0.38	565	401	13.2
06/21/95	20.82	0.16	0.20	0.36	560	398	12.4
06/22/95	20.80	0.15	0.20	0.36	560	398	12.3
06/23/95	23.48	0.20	0.24	0.44	554	393	15.1
06/24/95	21.78	0.17	0.22	0.39	549	390	13.1
06/25/95	22.19	0.18	0.22	0.40	548	389	13.5
06/26/95	21.11	0.16	0.21	0.37	548	389	12.4
06/27/95	20.88	0.16	0.21	0.36	549	390	12.2
06/28/95	19.98	0.14	0.19	0.33	548	389	11.3
06/29/95	20.53	0.15	0.20	0.35	548	389	11.8
06/30/95	22.61	0.18	0.23	0.42	549	390	14.0
07/01/95	21.74	0.17	0.22	0.39	548	389	13.0
07/02/95	22.02	0.17	0.22	0.40	548	389	13.3
07/03/95	22.53	0.18	0.23	0.41	548	389	13.9
07/04/95	22.14	0.18	0.22	0.40	549	390	13.5
07/05/95	21.12	0.16	0.21	0.37	549	390	12.4
07/06/95	20.76	0.15	0.20	0.36	550	391	12.1
07/07/95	21.09	0.16	0.21	0.37	550	391	12.4
07/08/95	20.97	0.16	0.21	0.36	550	391	12.3
07/09/95	21.00	0.16	0.21	0.37	550	391	12.3
07/10/95	20.48	0.15	0.20	0.35	550	391	11.8
07/11/95	19.92	0.14	0.19	0.33	550	391	11.2
07/12/95	19.60	0.14	0.19	0.32	550	391	10.9
07/13/95	19.32	0.13	0.18	0.32	549	390	10.6
07/14/95	18.78	0.13	0.18	0.30	549	390	10.1
07/15/95	19.01	0.13	0.18	0.31	550	391	10.4
07/16/95	18.80	0.13	0.18	0.30	550	391	10.2
07/17/95	18.39	0.12	0.17	0.29	550	391	9.8
07/18/95	18.29	0.12	0.17	0.29	550	391	9.7

07/19/95	17.83	0.11	0.16	0.27	550	391	9.3
07/20/95	17.44	0.11	0.16	0.26	550	391	8.9
07/21/95	16.86	0.10	0.15	0.25	550	391	8.4
07/22/95	16.53	0.10	0.14	0.24	549	390	8.1
07/23/95	16.28	0.09	0.14	0.23	550	391	7.9
07/24/95	15.90	0.09	0.14	0.23	549	390	7.6
07/25/95	15.58	0.09	0.13	0.22	548	389	7.3
07/26/95	15.15	0.08	0.13	0.21	547	388	7.0
07/27/95	15.11	0.08	0.13	0.21	548	389	6.9
07/28/95	14.63	0.07	0.12	0.20	550	391	6.6
07/29/95	14.17	0.07	0.11	0.19	550	391	6.2
07/30/95	13.97	0.07	0.11	0.18	545	387	6.0
07/31/95	14.09	0.07	0.11	0.18	545	387	6.1

Explanation:
Stage: Daily average stage value, southern channel
Disch S: Estimated daily average discharge, southern channel
Disch N: Estimated daily average discharge, northern channel
Disch T: Estimated daily average discharge, combined northern and southern channels
Disch T may not appear to equal Disch S+Disch N due to rounding.
EC: Daily Average EC value
TDS: Estimated TDS concentration
Daily LD: Estimated daily load of dissolved solids (metric tons)

APPENDIX VI

STAGE-DISCHARGE DATA

Date	Northern Channel (DS) Discharge (m^3/s)	Stage (cm)	Southern Channel (DS) Discharge (m^3/s)	Stage (cm)	Upstream Discharge (m^3/s)	Stage (cm)
02/04/95	0.093	11	0.065	18	0.016	16
03/11/95	0.169	19	0.102	20	-	-
04/08/95	0.143	18	0.104	15	0.035	16
04/14/95	0.151	17	0.087	13	-	-
05/16/95	0.288	21	0.206	21	0.238	15
06/20/95	0.274	14	0.283	24	0.166	17
07/31/95	-	4	0.050	14	-	5

Flow too low to measure in the Northern Channel (Downstream), and Upstream 7/31/95.
Upstream site not visited 3/11/95 and 4/14/95.

APPENDIX VII

OUTPUT OF PHREEQE MODEL RUNS

```
         DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1Historical S140 Speciation 8-12-87
0000000000 0 0         0.00000
ELEMENTS
C          15        0.61017E+02
            0        0.00000E+00
SOLUTION 1
S140 Water, 8-12-87
11 15 2     7.80      4.50      20.0      1.00
6   4.000D+00   4  2.100D+01   5  8.200D+00  14  4.000D+00  16  1.900D+01  17  5.000D-01
10  2.000D-01   8  1.200D-01  13  7.000D+00  15  7.800D+01   7  7.000D-01
1SOLUTION NUMBER 1
S140 Water, 8-12-87
```

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	5.240269D-04	-3.2806
Mg	3.373301D-04	-3.4719
Na	1.740150D-04	-3.7594
K	1.790445D-05	-4.7470
Fe	2.149034D-06	-5.6678
Al	7.413544D-06	-5.1300
Si	1.165196D-04	-3.9336
Cl	1.128415D-04	-3.9475
TOT ALK	1.278513D-03	-2.8933
S	1.978180D-04	-3.7037
N	8.065030D-06	-5.0934

----DESCRIPTION OF SOLUTION---

```
                PH =   7.8000
                PE =   4.5000
      ACTIVITY H2O =   1.0000
  IONIC STRENGTH =     0.0028
       TEMPERATURE =  20.0000
ELECTRICAL BALANCE =   1.5207D-04
              THOR =   6.3262D-03
  TOTAL ALKALINITY =   1.2785D-03
        ITERATIONS =  12
      TOTAL CARBON =   1.2832D-03
```

DISTRIBUTION OF SPECIES

ISPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1 H+	1.0	1.672E-08	-7.777	1.585E-08	-7.800	9.480E-01	-0.023
2 E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3 H2O	0.0	1.000E+00	0.000	1.000E+00	0.000	1.000E+00	0.000
4 Ca+2	2.0	5.054E-04	-3.296	4.031E-04	-3.395	7.976E-01	-0.098
5 Mg+2	2.0	3.253E-04	-3.488	2.600E-04	-3.585	7.992E-01	-0.097
6 Na+	1.0	1.789E-05	-4.747	1.688E-05	-4.773	9.435E-01	-0.025
8 Fe+2	2.0	2.821E-08	-7.550	2.255E-08	-7.647	7.996E-01	-0.097
10 Al+3	3.0	1.108E-13	-12.956	6.850E-14	-13.164	6.184E-01	-0.209
13 H4SiO4	0.0	1.156E-04	-3.937	1.156E-04	-3.937	1.001E+00	0.000
14 Cl-	1.0	1.128E-04	-3.948	1.065E-04	-3.973	9.435E-01	-0.025
15 CO3-2	-2.0	3.850E-06	-5.415	3.072E-06	-5.513	7.979E-01	-0.098
16 SO4-2	-2.0	1.791E-04	-3.747	1.427E-04	-3.846	7.965E-01	-0.099
17 NO3-	-1.0	1.371E-39	-38.863	1.293E-39	-38.888	9.430E-01	-0.025

31	OH-	-1.0	4.540E-07	-6.343	4.283E-07	-6.368	9.435E-01	-0.025
33	H2 AQ	0.0	1.869E-28	-27.728	1.871E-28	-27.728	1.001E+00	0.000
34	HCO3-	-1.0	1.223E-03	-2.913	1.156E-03	-2.937	9.451E-01	0.025
35	H2CO3	0.0	4.411E-05	-4.355	4.414E-05	-4.355	1.001E+00	0.000
49	N2 AQ	0.0	4.033E-06	-5.394	4.035E-06	-5.394	1.001E+00	0.000
77	CaHCO3+	1.0	5.778E-06	-5.238	5.461E-06	-5.263	9.451E-01	-0.025
78	CaSO4	0.0	1.094E-05	-4.961	1.094E-05	-4.961	1.001E+00	0.000
87	MgHCO3+	1.0	3.653E-06	-5.437	3.448E-06	-5.462	9.440E-01	0.025
88	MgSO4	0.0	7.622E-06	-5.118	7.627E-06	-5.118	1.001E+00	0.000
115	Fe+3	3.0	8.335E-17	-16.079	5.155E-17	-16.288	6.184E-01	-0.209
118	FeOH2+	1.0	2.841E-07	-6.547	2.681E-07	-6.572	9.440E-01	-0.025
119	FeOH3	0.0	1.745E-06	-5.758	1.746E-06	-5.758	1.001E+00	0.000
120	FeOH4-	-1.0	8.676E-08	-7.062	8.190E-08	-7.087	9.440E-01	-0.025
153	AlOH4-	-1.0	7.341E-06	-5.134	6.930E-06	-5.159	9.440E-01	-0.025

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-8.9072	-8.4533	-0.4539
Aragonit	-8.9072	-8.3059	-0.6013
Dolomite	-18.0049	-16.9720	-1.0329
Siderite	-13.1594	-10.8590	-2.3004
Gypsum	-7.2403	-4.5811	-2.6592
Anhydrit	-7.2402	-4.3438	-2.8964
SiO2 (a)	-3.9368	-2.7536	-1.1832
Chalcedy	-3.9368	-3.6104	-0.3265
Quartz	-3.9368	-4.0553	0.1184
Gibbs(c)	10.2357	8.3951	1.8406
Al(OH)3a	10.2357	11.1313	-0.8957
Kaolinit	12.5976	7.8763	4.7213
Albite	-20.7546	-18.3258	-2.4288
Anorth	-21.5867	-19.8588	-1.7280
Kspar	-21.7424	-20.9583	-0.7841
Kmica	21.9238	13.4453	8.4785
Chlorite	68.7355	70.2740	-1.5386
Ca-Mont	-42.6293	-45.7568	3.1275
Talc	20.2973	21.9785	-1.6812
Illite	-38.7651	-40.9507	2.1856
Chrysotl	28.1710	32.8310	-4.6600
Sepiol c	12.2192	15.8938	-3.6746
Sepiol d	12.2192	18.6600	-6.4408
Hematite	14.2243	-3.6224	17.8467
Goethite	7.1122	-1.0000	8.1122
Fe(OH)3a	7.1121	4.8910	2.2211
Pyrite	-134.3342	-18.6203	-115.7139
FeS ppt	-75.4905	-3.9150	-71.5755
Mackinit	-75.4905	-4.6480	-70.8425
PCO2	-4.3552	-1.4069	-2.9483
O2 gas	-38.5652	-2.9369	-35.6283
H2 gas	-27.7280	-3.1280	-24.6000
N2 gas	-5.3941	-3.2430	-2.1511
H2S gas	-76.3834	-0.9399	-75.4436
CH4 gas	-77.6784	-2.8178	-74.8606
NH3 gas	-33.0807	1.8721	-34.9528
Melanter	-11.4926	-2.2717	-9.2209
Alunite	-5.1570	-0.7718	-4.3852
K-Jarosi	-14.5275	-8.8189	-5.7086

```
     DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1S140 Formation from Upstream Water (Historical)
0050002000 0 0         0.00000
ELEMENTS
C          15        0.61017E+02
            0        0.00000E+00
SOLUTION 1 S95 Water, 3-12-92
11 15 2     7.58      4.50      20.0      1.00
 6  3.300D+00   4  7.600D+00   5  3.600D+00  14  1.000D+00  16  8.000D+00  17  1.000D-01
10  5.000D-01   8  2.100D-01  13  7.000D+00  15  3.000D+01   7  5.000D-01
MINERALS
Calcite    2      4.0      -8.5      -2.3         1            -0.454
  15   1.00
   4   1.00
-1.7191E+02 -7.7993E-02  2.8393E+03  7.1595E+01  0.0000E+00
Dolomite   3      8.0      -17.      -9.4         0            -1.033
   4   1.00       5   1.00      15   2.00
PCO2       1      4.0      -1.5      -4.8         1            -2.948
  35   1.00
1.0839E+02  1.9851E-02 -6.9195E+03 -4.0452E+01  6.6936E+05
Gypsum     3      6.0      -4.6     -0.11         1            -2.659
   4   1.00
  16   1.00
   3   2.00
6.8240E+01  0.0000E+00 -3.2215E+03 -2.5063E+01  0.0000E+00
   0      0.        0.        0.        0              0.000
1SOLUTION NUMBER 1 S95 Water, 3-12-92


                        TOTAL MOLALITIES OF ELEMENTS
                        ----- ---------- -- --------
                ELEMENT          MOLALITY         LOG MOLALITY
                Ca              1.896325D-04         -3.7221
                Mg              1.480842D-04         -3.8295
                Na              1.435508D-04         -3.8430
                K               1.278786D-05         -4.8932
                Fe              3.760506D-06         -5.4248
                Al              1.853236D-05         -4.7321
                Si              1.165102D-04         -3.9336
                Cl              2.820810D-05         -4.5496
                TOT ALK         4.916958D-04         -3.3083
                S               8.328504D-05         -4.0794
                N               1.612875D-06         -5.7924

                        ----DESCRIPTION OF SOLUTION----
                                    PH = 7.5800
                                    PE =   4.5000
                          ACTIVITY H2O =   1.0000
                        IONIC STRENGTH =   0.0011
                           TEMPERATURE =  20.0000
                    ELECTRICAL BALANCE =   2.0486D-04
                                 THOR  =   2.2642D-03
                       TOTAL ALKALINITY =   4.9170D-04
                            ITERATIONS =  12
                          TOTAL CARBON =   4.3835D-04

                              ----------------------
                              DISTRIBUTION OF SPECIES
                              ----------------------
  I SPECIES     Z    MOLALITY  LOG MOLAL   ACTIVITY  LOG ACT     GAMMA    LOG GAM
   1 H+        1.0  2.726E-08   -7.564   2.630E-08  -7.580  9.649E-01  -0.016
   2 E-       -1.0  3.162E-05   -4.500   3.162E-05  -4.500  1.000E+00   0.000
```

3	H2O	0.0	1.000E+00	0.000	1.000E+00	0.000	1.000E+00	0.000
4	Ca+2	2.0	1.866E-04	-3.729	1.609E-04	-3.794	8.620E-01	-0.064
5	Mg+2	2.0	1.456E-04	-3.837	1.257E-04	-3.901	8.628E-01	-0.064
6	Na+	1.0	1.435E-04	-3.843	1.382E-04	-3.859	9.633E-01	-0.016
7	K+	1.0	1.278E-05	-4.893	1.231E-05	-4.910	9.629E-01	-0.016
8	Fe+2	2.0	1.883E-07	-6.725	1.625E-07	-6.789	8.630E-01	-0.064
10	Al+3	3.0	1.813E-12	-11.742	1.314E-12	-11.881	7.250E-01	-0.140
13	H4SiO4	0.0	1.159E-04	-3.936	1.160E-04	-3.936	1.000E+00	0.000
14	Cl-	-1.0	2.821E-05	-4.550	2.716E-05	-4.566	9.629E-01	-0.016
15	CO3-2	-2.0	7.353E-07	-6.134	6.340E-07	-6.198	8.622E-01	-0.064
16	SO4-2	-2.0	7.937E-05	-4.100	6.838E-05	-4.165	8.616E-01	-0.065
17	NO3-	-1.0	2.875E-41	-40.541	2.768E-41	-40.558	9.627E-01	-0.017
31	OH-	-1.0	2.681E-07	-6.572	2.581E-07	-6.588	9.629E-01	-0.016
33	H2 AQ	0.0	5.151E-28	-27.288	5.152E-28	-27.288	1.000E+00	0.000
34	HCO3-	-1.0	4.109E-04	-3.386	3.959E-04	-3.402	9.636E-01	-0.016
35	H2CO3	0.0	2.508E-05	-4.601	2.509E-05	-4.600	1.000E+00	0.000
49	N2 AQ	0.0	8.064E-07	-6.093	8.066E-07	-6.093	1.000E+00	0.000
78	CaSO4	0.0	2.092E-06	-5.679	2.093E-06	-5.679	1.000E+00	0.000
88	MgSO4	0.0	1.767E-06	-5.753	1.767E-06	-5.753	1.000E+00	0.000
115	Fe+3	3.0	5.122E-16	-15.291	3.713E-16	-15.430	7.250E-01	-0.140
118	FeOH2+	1.0	7.283E-07	-6.138	7.014E-07	-6.154	9.631E-01	-0.016
119	FeOH3	0.0	2.751E-06	-5.560	2.752E-06	-5.560	1.000E+00	0.000
120	FeOH4-	-1.0	8.077E-08	-7.093	7.779E-08	-7.109	9.631E-01	-0.016
152	AlOH3	0.0	2.599E-07	-6.585	2.600E-07	-6.585	1.000E+00	0.000
153	AlOH4-	-1.0	1.820E-05	-4.740	1.753E-05	-4.756	9.631E-01	-0.016

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-9.9915	-8.4533	-1.5382
Aragonit	-9.9915	-8.3059	-1.6856
Dolomite	-20.0902	-16.9720	-3.1182
Siderite	-12.9871	-10.8590	-2.1282
Gypsum	-7.9586	-4.5811	-3.3775
Anhydrit	-7.9586	-4.3438	-3.6148
SiO2 (a)	-3.9356	-2.7536	-1.1820
Chalcedy	-3.9356	-3.6104	-0.3252
Quartz	-3.9356	-4.0553	0.1197
Gibbs(c)	10.8587	8.3951	2.4636
Al(OH)3a	10.8587	11.1313	-0.2726
Kaolinit	13.8462	7.8763	5.9698
Albite	-20.4225	-18.3258	-2.0968
Anorth	-21.1772	-19.8588	-1.3184
Kspar	-21.4729	-20.9583	-0.5145
Kmica	23.4394	13.4453	9.9941
Chlorite	66.2064	70.2740	-4.0676
Ca-Mont	-41.3116	-45.7568	4.4452
Talc	18.0350	21.9785	-3.9435
Illite	-37.7310	-40.9507	3.2197
Chrysotl	25.9062	32.8310	-6.9248
Sepiol c	10.7115	15.8938	-5.1823
Sepiol d	10.7115	18.6600	-7.9485
Hematite	14.6195	-3.6224	18.2419
Goethite	7.3097	-1.0000	8.3097
Fe(OH)3a	7.3097	4.8910	2.4187
Pyrite	-130.5955	-18.6203	-111.9752
FeS ppt	-73.1923	-3.9150	-69.2773
Mackinit	-73.1923	-4.6480	-68.5443
PCO2	-4.6005	-1.4069	-3.1936
O2 gas	-39.4452	-2.9369	-36.5083
H2 gas	-27.2880	-3.1280	-24.1600
N2 gas	-6.0933	-3.2430	-2.8503
H2S gas	-74.5029	-0.9399	-73.5630
CH4 gas	-76.1638	-2.8178	-73.3459
NH3 gas	-32.7702	1.8721	-34.6424
Melanter	-10.9543	-2.2717	-8.6826

Alunite	-3.4038	-0.7718	-2.6321
K-Jarosi	-14.0507	-8.8189	-5.2317

1STEP NUMBER 1
0-------------

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	1.896325D-04	-3.7221
Mg	1.480842D-04	-3.8295
Na	1.435508D-04	-3.8430
K	1.278786D-05	-4.8932
Fe	3.760506D-06	-5.4248
Al	1.853236D-05	-4.7321
Si	1.165102D-04	-3.9336
Cl	2.820810D-05	-4.5496
C	4.383489D-04	-3.3582
S	8.328504D-05	-4.0794
N	1.612875D-06	-5.7924

----PHASE BOUNDARIES----

PHASE	DELTA PHASE*	LOG IAP	LOG KT	LOG IAP/KT
Calcite	3.290877D-05	-8.9072	-8.4533	-0.4539
Dolomite	1.906226D-04	-18.0049	-16.9720	-1.0329
PCO2	4.263109D-04	-4.3552	-1.4069	-2.9483
Gypsum	1.130290D-04	-7.2403	-4.5811	-2.6592

* NEGATIVE DELTA PHASE INDICATES PRECIPITATION
AND POSITIVE DELTA PHASE INDICATES DISSOLUTION.

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-8.9072	-8.4533	-0.4539
Aragonit	-8.9072	-8.3059	-0.6013
Dolomite	-18.0049	-16.9720	-1.0329
Siderite	-12.9152	-10.8590	-2.0562
Gypsum	-7.2403	-4.5811	-2.6592
Anhydrit	-7.2403	-4.3438	-2.8964
SiO2 (a)	-3.9369	-2.7536	-1.1833
Chalcedy	-3.9369	-3.6104	-0.3265
Quartz	-3.9369	-4.0553	0.1184
Gibbs(c)	10.6351	8.3951	2.2400
Al(OH)3a	10.6351	11.1313	-0.4962
Kaolinit	13.3965	7.8763	5.5201
Albite	-20.4399	-18.3258	-2.1142
Anorth	-20.7879	-19.8588	-0.9291
Kspar	-21.4904	-20.9583	-0.5320
Kmica	22.9748	13.4453	9.5294
Chlorite	69.5342	70.2740	-0.7399
Ca-Mont	-41.6987	-45.7568	4.0581
Talc	20.2971	21.9785	-1.6814
Illite	-37.9348	-40.9507	3.0159
Chrysotl	28.1708	32.8310	-4.6602
Sepiol c	12.2191	15.8938	-3.6747
Sepiol d	12.2191	18.6600	-6.4409
Hematite	14.7101	-3.6224	18.3324
Goethite	7.3550	-1.0000	8.3550
Fe(OH)3a	7.3550	4.8910	2.4640
Pyrite	-134.0713	-18.6203	-115.4511
FeS ppt	-75.2356	-3.9150	-71.3206
Mackinit	-75.2356	-4.6480	-70.5876
PCO2	-4.3552	-1.4069	-2.9483
O2 gas	-38.5706	-2.9369	-35.6336
H2 gas	-27.7253	-3.1280	-24.5973
N2 gas	-6.0932	-3.2430	-2.8501

H2S gas	-76.3728	-0.9399	-75.4329
CH4 gas	-77.6677	-2.8178	-74.8499
NH3 gas	-33.4261	1.8721	-35.2983
Melanter	-11.2484	-2.2717	-8.9767
Alunite	-4.1060	-0.7718	-3.3343
K-Jarosi	-13.9463	-8.8189	-5.1274

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	5.261928D-04	-3.2789
Mg	3.387068D-04	-3.4702
Na	1.435508D-04	-3.8430
K	1.278786D-05	-4.8932
Fe	3.760506D-06	-5.4248
Al	1.853236D-05	-4.7321
Si	1.165102D-04	-3.9336
Cl	2.820810D-05	-4.5496
C	1.278814D-03	-2.8932
S	1.963140D-04	-3.7070
N	1.612875D-06	-5.7924

----DESCRIPTION OF SOLUTION----

PH =	7.7987
PE =	4.5000
ACTIVITY H2O =	1.0000
IONIC STRENGTH =	0.0027
TEMPERATURE =	20.0000
ELECTRICAL BALANCE =	2.0486D-04
THOR =	6.3044D-03
TOTAL ALKALINITY =	1.3199D-03
ITERATIONS =	14

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	1.676E-08	-7.776	1.590E-08	-7.799	9.484E-01	-0.023
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	1.000E+00	0.000	1.000E+00	0.000	1.000E+00	0.000
4	Ca+2	2.0	5.076E-04	-3.295	4.056E-04	-3.392	7.991E-01	-0.097
5	Mg+2	2.0	3.267E-04	-3.486	2.616E-04	-3.582	8.007E-01	-0.097
6	Na+	1.0	1.434E-04	-3.844	1.355E-04	-3.868	9.448E-01	-0.025
7	K+	1.0	1.278E-05	-4.894	1.206E-05	-4.919	9.440E-01	-0.025
8	Fe+2	2.0	4.971E-08	-7.304	3.982E-08	-7.400	8.011E-01	-0.096
10	Al+3	3.0	2.794E-13	-12.554	1.734E-13	-12.761	6.208E-01	-0.207
13	H4SiO4	0.0	1.156E-04	-3.937	1.156E-04	-3.937	1.001E+00	0.000
14	Cl-	-1.0	2.821E-05	-4.550	2.663E-05	-4.575	9.440E-01	-0.025
15	CO3-2	-2.0	3.819E-06	-5.418	3.053E-06	-5.515	7.994E-01	-0.097
16	SO4-2	-2.0	1.776E-04	-3.750	1.418E-04	-3.848	7.981E-01	-0.098
17	NO3-	-1.0	6.018E-40	-39.221	5.678E-40	-39.246	9.435E-01	-0.025
31	OH-	-1.0	4.524E-07	-6.344	4.270E-07	-6.370	9.439E-01	-0.025
33	H2 AQ	0.0	1.881E-28	-27.726	1.882E-28	-27.725	1.001E+00	0.000
34	HCO3-	-1.0	1.219E-03	-2.914	1.152E-03	-2.938	9.456E-01	-0.024
35	H2CO3	0.0	4.411E-05	-4.355	4.414E-05	-4.355	1.001E+00	0.000
49	N2 AQ	0.0	8.064E-07	-6.093	8.069E-07	-6.093	1.001E+00	0.000
77	CaHCO3+	1.0	5.793E-06	-5.237	5.478E-06	-5.261	9.456E-01	-0.024
78	CaSO4	0.0	1.093E-05	-4.961	1.094E-05	-4.961	1.001E+00	0.000
87	MgHCO3+	1.0	3.662E-06	-5.436	3.458E-06	-5.461	9.445E-01	-0.025
88	MgSO4	0.0	7.621E-06	-5.118	7.626E-06	-5.118	1.001E+00	0.000
115	Fe+3	3.0	1.466E-16	-15.834	9.101E-17	-16.041	6.208E-01	-0.207
118	FeOH2+	1.0	4.982E-07	-6.303	4.705E-07	-6.327	9.445E-01	-0.025
119	FeOH3	0.0	3.053E-06	-5.515	3.055E-06	-5.515	1.001E+00	0.000
120	FeOH4-	-1.0	1.512E-07	-6.820	1.428E-07	-6.845	9.445E-01	-0.025
153	AlOH4-	-1.0	1.835E-05	-4.736	1.733E-05	-4.761	9.445E-01	-0.025

```
          DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1S112 water formation
0000000000 0 0         0.00000
ELEMENTS
C          15        0.61017E+02
            0        0.00000E+00
SOLUTION 1 S112 Water
   10 15 2     7.00      4.50      3.20      1.00
        14  4.700D+00  16  6.940D+02  17  7.130D+00   6  5.430D+00   7  1.890D+00
         4  1.130D+02   5  1.120D+02   8  6.760D-01  10  6.300D-02  15  3.940D+01
1SOLUTION NUMBER 1
 S112 Water
```

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	2.822122D-03	-2.5494
Mg	4.611290D-03	-2.3362
Na	2.364230D-04	-3.6263
K	4.838246D-05	-4.3153
Fe	1.211635D-05	-4.9166
Al	2.337220D-06	-5.6313
Cl	1.326997D-04	-3.8771
TOT ALK	6.463529D-04	-3.1895
S	7.231606D-03	-2.1408
N	1.151035D-04	-3.9389

----DESCRIPTION OF SOLUTION----

PH =	7.0000
PE =	4.5000
ACTIVITY H2O =	0.9998
IONIC STRENGTH =	0.0237
TEMPERATURE =	3.2000
ELECTRICAL BALANCE =	-5.9556D-05
THOR =	4.6701D-02
TOTAL ALKALINITY =	6.4635D-04
ITERATIONS =	15
TOTAL CARBON =	8.2164D-04

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	1.128E-07	-6.948	1.000E-07	-7.000	8.864E-01	-0.052
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	9.998E-01	0.000	9.998E-01	0.000	1.000E+00	0.000
4	Ca+2	2.0	2.170E-03	-2.664	1.251E-03	-2.903	5.765E-01	-0.239
5	Mg+2	2.0	3.704E-03	-2.431	2.163E-03	-2.665	5.840E-01	-0.234
6	Na+	1.0	2.331E-04	-3.632	2.023E-04	-3.694	8.679E-01	-0.062
7	K+	1.0	4.758E-05	-4.323	4.103E-05	-4.387	8.624E-01	-0.064
8	Fe+2	2.0	9.634E-06	-5.016	5.624E-06	-5.250	5.838E-01	-0.234
10	Al+3	3.0	5.881E-09	-8.231	1.986E-09	-8.702	3.377E-01	-0.472
14	Cl-	-1.0	1.327E-04	-3.877	1.144E-04	-3.941	8.624E-01	-0.064
15	CO3-2	-2.0	2.448E-07	-6.611	1.411E-07	-6.851	5.764E-01	-0.239
16	SO4-2	-2.0	5.687E-03	-2.245	3.242E-03	-2.489	5.701E-01	-0.244
17	NO3-	-1.0	7.633E-51	-50.117	6.556E-51	-50.183	8.589E-01	-0.066
31	OH-	-1.0	1.812E-08	-7.742	1.561E-08	-7.807	8.617E-01	-0.065
33	H2 AQ	0.0	8.899E-27	-26.051	8.948E-27	-26.048	1.005E+00	0.002
34	HCO3-	-1.0	6.159E-04	-3.211	5.366E-04	-3.270	8.713E-01	-0.060
35	H2CO3	0.0	1.841E-04	-3.735	1.851E-04	-3.733	1.005E+00	0.002
49	N2 AQ	0.0	5.755E-05	-4.240	5.787E-05	-4.238	1.005E+00	0.002
78	CaSO4	0.0	6.461E-04	-3.190	6.496E-04	-3.187	1.005E+00	0.002

87	MgHCO3+	1.0	1.502E-05	-4.823	1.301E-05	-4.886	8.663E-01	-0.062
88	MgSO4	0.0	8.921E-04	-3.050	8.970E-04	-3.047	1.005E+00	0.002
96	NaSO4-	-1.0	3.269E-06	-5.486	2.832E-06	-5.548	8.663E-01	-0.062
100	KSO4-	-1.0	8.057E-07	-6.094	6.979E-07	-6.156	8.663E-01	-0.062
107	FeHCO3+	1.0	1.954E-07	-6.709	1.692E-07	-6.772	8.663E-01	-0.062
108	FeSO4	0.0	2.098E-06	-5.678	2.109E-06	-5.676	1.005E+00	0.002
115	Fe+3	3.0	1.386E-14	-13.858	4.681E-15	-14.330	3.377E-01	-0.472
150	AlOH+2	2.0	7.910E-08	-7.102	4.454E-08	-7.351	5.631E-01	-0.249
151	AlOH2+	1.0	4.579E-07	-6.339	3.967E-07	-6.402	8.663E-01	-0.062
152	AlOH3	0.0	8.987E-08	-7.046	9.036E-08	-7.044	1.005E+00	0.002
153	AlOH4-	-1.0	1.697E-06	-5.770	1.470E-06	-5.833	8.663E-01	-0.062

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-9.7533	-8.3892	-1.3641
Aragonit	-9.7533	-8.2285	-1.5248
Dolomite	-19.2688	-16.5444	-2.7244
Siderite	-12.1005	-10.7466	-1.3539
Gypsum	-5.3921	-4.6068	-0.7853
Anhydrit	-5.3919	-4.3519	-1.0401
Gibbs(c)	12.2976	9.4284	2.8692
Al(OH)3a	12.2976	12.3323	-0.0348
Hematite	13.3403	-2.2244	15.5647
Goethite	6.6701	-1.0000	7.6701
Fe(OH)3a	6.6700	4.8910	1.7790
Pyrite	-110.9724	-19.1324	-91.8400
FeS ppt	-62.6112	-3.9150	-58.6962
Mackinit	-62.6112	-4.6480	-57.9632
PCO2	-3.7326	-1.1627	-2.5699
O2 gas	-47.8743	-2.8534	-45.0209
H2 gas	-26.0483	-3.0483	-23.0000
N2 gas	-4.2376	-3.1815	-1.0561
H2S gas	-64.0608	-0.7327	-63.3280
CH4 gas	-68.2497	-2.6650	-65.5848
NH3 gas	-29.2635	2.2424	-31.5059
Melanter	-7.7399	-2.5153	-5.2246
Alunite	6.5278	1.5056	5.0221
K-Jarosi	-10.3550	-7.4013	-2.9537

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        DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1S112 Formation from Rainwater
0050002000 0 0         0.00000
ELEMENTS
C           15        0.61017E+02
             0        0.00000E+00
SOLUTION 1
 Rainwater
  8 15 2     5.70      4.50      3.20      1.00
      14  3.000D-01  16  2.840D+00  17  1.440D+00   6  6.900D-01   7  2.200D-01
       6  3.280D+00   5  1.000D-01  15  2.000D-02
MINERALS
Calcite    2      4.0      -8.5      -2.3         1             -1.364
 15   1.00
  4   1.00
 -1.7191E+02 -7.7993E-02  2.8393E+03  7.1595E+01  0.0000E+00
Dolomite   3      8.0      -17.      -9.4         0             -2.724
  4   1.00       5   1.00      15   2.00
Pyrite     4       0.      -18.       11.         0            -91.840
  1  -2.00       2  -2.00       8   1.00      42   2.00
PCO2       1      4.0      -1.5      -4.8         1             -2.570
 35   1.00
  1.0839E+02  1.9851E-02 -6.9195E+03 -4.0452E+01  6.6936E+05
Fe(OH)3a   3      3.0       4.9        0.         0              1.779
115   1.00       3   3.00       1  -3.00
          0        0.        0.        0.         0              0.000
1SOLUTION NUMBER 1
Rainwater
```

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Mg	4.113229D-06	-5.3858
Na	1.426731D-04	-3.8457
K	5.626357D-06	-5.2498
Cl	8.461977D-06	-5.0725
TOT ALK	3.277797D-07	-6.4844
S	2.956461D-05	-4.5292
N	2.322416D-05	-4.6341

----DESCRIPTION OF SOLUTION----

```
               PH =   5.7000
               PE =   4.5000
     ACTIVITY H2O =   1.0000
   IONIC STRENGTH =   0.0001
      TEMPERATURE =   3.2000
ECTRICAL BALANCE =   8.8607D-05
             THOR =   2.5066D-04
 TOTAL ALKALINITY =   3.2778D-07
       ITERATIONS =  16
     TOTAL CARBON =   1.8319D-05
```

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	2.022E-06	-5.694	1.995E-06	-5.700	9.867E-01	-0.006
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	1.000E+00	0.000	1.000E+00	0.000	1.000E+00	0.000
5	Mg+2	2.0	4.099E-06	-5.387	3.883E-06	-5.411	9.474E-01	-0.023
6	Na+	1.0	1.427E-04	-3.846	1.407E-04	-3.852	9.865E-01	-0.006
7	K+	1.0	5.626E-06	-5.250	5.549E-06	-5.256	9.865E-01	-0.006

14 Cl-	-1.0	8.462E-06	-5.073	8.347E-06	-5.078	9.865E-01	-0.006
15 CO3-2	-2.0	3.228E-11	-10.491	3.058E-11	-10.515	9.473E-01	-0.024
16 SO4-2	-2.0	2.953E-05	-4.530	2.797E-05	-4.553	9.472E-01	-0.024
17 NO3-	-1.0	4.722E-59	-58.326	4.658E-59	-58.332	9.864E-01	-0.006
31 OH-	-1.0	7.934E-10	-9.100	7.827E-10	-9.106	9.865E-01	-0.006
33 H2 AQ	0.0	3.562E-24	-23.448	3.562E-24	-23.448	1.000E+00	0.000
34 HCO3-	-1.0	2.352E-06	-5.628	2.321E-06	-5.634	9.866E-01	-0.006
35 H2CO3	0.0	1.597E-05	-4.797	1.597E-05	-4.797	1.000E+00	0.000
49 N2 AQ	0.0	1.161E-05	-4.935	1.161E-05	-4.935	1.000E+00	0.000

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
PCO2	-4.7968	-1.1627	-3.6341
O2 gas	-53.0741	-2.8534	-50.2207
H2 gas	-23.4483	-3.0483	-20.4000
N2 gas	-4.9351	-3.1815	-1.7536
H2S gas	-53.1253	-0.7327	-52.3926
CH4 gas	-58.9141	-2.6650	-56.2491
NH3 gas	-25.7122	2.2424	-27.9546

1STEP NUMBER 1

0-------------

TOTAL MOLALITIES OF ELEMENTS

----- ---------- -- --------

ELEMENT	MOLALITY	LOG MOLALITY
Mg	4.113229D-06	-5.3858
Na	1.426731D-04	-3.8457
K	5.626357D-06	-5.2498
Cl	8.461977D-06	-5.0725
C	1.831903D-05	-4.7371
S	2.956461D-05	-4.5292
N	2.322416D-05	-4.6341

----PHASE BOUNDARIES----

PHASE	DELTA PHASE*	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-1.782894D-03	-9.7533	-8.3892	-1.3641
Dolomite	4.597517D-03	-19.2688	-16.5444	-2.7244
Pyrite	3.552846D-03	-110.9734	-19.1334	-91.8400
CO2	-6.609819D-03	-3.7326	-1.1627	-2.5699
Fe(OH)3a	-3.540741D-03	6.6700	4.8910	1.7790

* NEGATIVE DELTA PHASE INDICATES PRECIPITATION
AND POSITIVE DELTA PHASE INDICATES DISSOLUTION.

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-9.7533	-8.3892	-1.3641
Aragonit	-9.7533	-8.2285	-1.5248
Dolomite	-19.2688	-16.5444	-2.7244
Siderite	-12.1000	-10.7466	-1.3534
Gypsum	-5.3962	-4.6068	-0.7894
Anhydrit	-5.3960	-4.3519	-1.0441
Hematite	13.3403	-2.2244	15.5647
Goethite	6.6701	-1.0000	7.6701
Fe(OH)3a	6.6700	4.8910	1.7790
Pyrite	-110.9734	-19.1324	-91.8410
FeS ppt	-62.6110	-3.9150	-58.6960
Mackinit	-62.6110	-4.6480	-57.9630
PCO2	-3.7326	-1.1627	-2.5699
O2 gas	-47.8762	-2.8534	-45.0228
H2 gas	-26.0474	-3.0483	-22.9991
N2 gas	-4.9328	-3.1815	-1.7513
H2S gas	-64.0610	-0.7327	-63.3283
CH4 gas	-68.2460	-2.6650	-65.5810
NH3 gas	-29.6097	2.2424	-31.8521
Melanter	-7.7434	-2.5153	-5.2281
K-Jarosi	-11.2974	-7.4013	-3.8962

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	2.814624D-03	-2.5506
Mg	4.601631D-03	-2.3371
Na	1.426731D-04	-3.8457
K	5.626357D-06	-5.2498
Fe	1.210495D-05	-4.9170
Cl	8.461977D-06	-5.0725
C	8.206417D-04	-3.0858
S	7.135256D-03	-2.1466
N	2.322416D-05	-4.6341

----DESCRIPTION OF SOLUTION----

PH =	6.9995
PE =	4.5000
ACTIVITY H2O =	0.9998
IONIC STRENGTH =	0.0234
TEMPERATURE =	3.2000
ELECTRICAL BALANCE =	8.8607D-05
THOR =	4.6118D-02
TOTAL ALKALINITY =	6.3727D-04
ITERATIONS =	19

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	1.129E-07	-6.947	1.001E-07	-7.000	8.868E-01	-0.052
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	9.998E-01	0.000	9.998E-01	0.000	1.000E+00	0.000
4	Ca+2	2.0	2.168E-03	-2.664	1.253E-03	-2.902	5.780E-01	-0.238
5	Mg+2	2.0	3.702E-03	-2.432	2.168E-03	-2.664	5.855E-01	-0.232
6	Na+	1.0	1.407E-04	-3.852	1.222E-04	-3.913	8.685E-01	-0.061
7	K+	1.0	5.534E-06	-5.257	4.776E-06	-5.321	8.630E-01	-0.064
8	Fe+2	2.0	9.640E-06	-5.016	5.642E-06	-5.249	5.853E-01	-0.233
14	Cl-	-1.0	8.462E-06	-5.073	7.303E-06	-5.136	8.630E-01	-0.064
15	CO3-2	-2.0	2.436E-07	-6.613	1.408E-07	-6.851	5.780E-01	-0.238
16	SO4-2	-2.0	5.607E-03	-2.251	3.206E-03	-2.494	5.717E-01	-0.243
17	NO3-	-1.0	3.404E-51	-50.468	2.926E-51	-50.534	8.596E-01	-0.066
31	OH-	-1.0	1.809E-08	-7.743	1.560E-08	-7.807	8.624E-01	-0.064
33	H2 AQ	0.0	8.919E-27	-26.050	8.967E-27	-26.047	1.005E+00	0.002
34	HCO3-	-1.0	6.148E-04	-3.211	5.361E-04	-3.271	8.719E-01	-0.060
35	H2CO3	0.0	1.841E-04	-3.735	1.851E-04	-3.733	1.005E+00	0.002
49	N2 AQ	0.0	1.161E-05	-4.935	1.167E-05	-4.933	1.005E+00	0.002
78	CaSO4	0.0	6.401E-04	-3.194	6.436E-04	-3.191	1.005E+00	0.002
87	MgHCO3+	1.0	1.503E-05	-4.823	1.303E-05	-4.885	8.669E-01	-0.062
88	MgSO4	0.0	8.840E-04	-3.054	8.888E-04	-3.051	1.005E+00	0.002
96	NaSO4-	-1.0	1.951E-06	-5.710	1.691E-06	-5.772	8.669E-01	-0.062
100	KSO4-	-1.0	9.266E-08	-7.033	8.032E-08	-7.095	8.669E-01	-0.062
107	FeHCO3+	1.0	1.957E-07	-6.708	1.696E-07	-6.771	8.669E-01	-0.062
108	FeSO4	0.0	2.081E-06	-5.682	2.092E-06	-5.679	1.005E+00	0.002
115	Fe+3	3.0	1.384E-14	-13.859	4.696E-15	-14.328	3.393E-01	-0.469

```
         DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1Downstream Water Speciation
0000000000 0 0         0.00000
ELEMENTS
C           15        0.61017E+02
             0        0.00000E+00
SOLUTION 1 Downstream Water, 4-8-95

11 15 2     8.41       4.50       6.50       1.00
14  5.470D+00  16  2.770D+02  17  9.130D+00   6  3.800D+00   7  1.090D+00
 4  5.280D+01   5  4.920D+01   8  2.500D-01  10  5.000D-02  13  5.800D+00
15  4.780D+01
1SOLUTION NUMBER 1
Downstream Water, 4-8-95
```

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	1.317962D-03	-2.8801
Mg	2.024608D-03	-2.6937
Na	1.653655D-04	-3.7816
K	2.788843D-05	-4.5546
Fe	4.478542D-06	-5.3489
Al	1.853960D-06	-5.7319
Si	9.657473D-05	-4.0151
Cl	1.543586D-04	-3.8115
TOT ALK	7.837415D-04	-3.1058
S	2.884871D-03	-2.5399
N	1.473131D-04	-3.8318

----DESCRIPTION OF SOLUTION----

```
               PH =   8.4100
               PE =   4.5000
     ACTIVITY H2O =   0.9999
  IONIC STRENGTH =   0.0111
      TEMPERATURE =   6.5000
ELECTRICAL BALANCE =  1.8061D-04
             THOR =   2.0361D-02
 TOTAL ALKALINITY =   7.8374D-04
       ITERATIONS =  12
     TOTAL CARBON =   7.5959D-04
```

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	4.266E-09	-8.370	3.890E-09	-8.410	9.121E-01	-0.040
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	9.999E-01	0.000	9.999E-01	0.000	1.000E+00	0.000
4	Ca+2	2.0	1.112E-03	-2.954	7.401E-04	-3.131	6.656E-01	-0.177
5	Mg+2	2.0	1.746E-03	-2.758	1.170E-03	-2.932	6.701E-01	-0.174
6	Na+	1.0	1.642E-04	-3.785	1.479E-04	-3.830	9.012E-01	-0.045
7	K+	1.0	2.764E-05	-4.558	2.483E-05	-4.605	8.984E-01	-0.047
8	Fe+2	2.0	1.851E-08	-7.733	1.241E-08	-7.906	6.706E-01	-0.174
10	Al+3	3.0	4.689E-15	-14.329	2.048E-15	-14.689	4.368E-01	-0.360
13	H4SiO4	0.0	9.465E-05	-4.024	9.489E-05	-4.023	1.003E+00	0.001
14	Cl-	-1.0	1.544E-04	-3.811	1.387E-04	-3.858	8.984E-01	-0.047
15	CO3-2	-2.0	7.360E-06	-5.133	4.901E-06	-5.310	6.659E-01	-0.177

16 SO4-2	-2.0	2.423E-03	-2.616	1.604E-03	-2.795	6.621E-01	-0.179
17 NO3-	-1.0	6.817E-41	-40.166	6.112E-41	-40.214	8.965E-01	-0.047
31 OH-	-1.0	6.097E-07	-6.215	5.475E-07	-6.262	8.980E-01	-0.047
33 H2 AQ	0.0	1.301E-29	-28.886	1.304E-29	-28.885	1.003E+00	0.001
34 HCO3-	-1.0	7.213E-04	-3.142	6.516E-04	-3.186	9.033E-01	-0.044
35 H2CO3	0.0	7.987E-06	-5.098	8.007E-06	-5.097	1.003E+00	0.001
49 N2 AQ	0.0	7.366E-05	-4.133	7.385E-05	-4.132	1.003E+00	0.001
78 CaSO4	0.0	1.965E-04	-3.707	1.970E-04	-3.705	1.003E+00	0.001
87 MgHCO3+	1.0	9.483E-06	-5.023	8.536E-06	-5.069	9.001E-01	-0.046
88 MgSO4	0.0	2.640E-04	-3.578	2.647E-04	-3.577	1.003E+00	0.001
115 Fe+3	3.0	2.912E-17	-16.536	1.272E-17	-16.896	4.368E-01	-0.360
118 FeOH2+	1.0	2.957E-07	-6.529	2.661E-07	-6.575	9.001E-01	-0.046
119 FeOH3	0.0	3.720E-06	-5.429	3.730E-06	-5.428	1.003E+00	0.001
120 FeOH4-	-1.0	4.395E-07	-6.357	3.957E-07	-6.403	9.001E-01	-0.046
153 AlOH4-	-1.0	1.849E-06	-5.733	1.665E-06	-5.779	9.001E-01	-0.046
164 H3SiO4-	-1.0	1.927E-06	-5.715	1.735E-06	-5.761	9.001E-01	-0.046

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-8.4404	-8.3987	-0.0417
Aragonit	-8.4404	-8.2408	-0.1996
Dolomite	-16.6820	-16.6324	-0.0495
Siderite	-13.2159	-10.7697	-2.4462
Gypsum	-5.9255	-4.5985	-1.3271
Anhydrit	-5.9254	-4.3417	-1.5838
SiO2 (a)	-4.0227	-2.8740	-1.1487
Chalcedy	-4.0227	-3.7803	-0.2423
Quartz	-4.0227	-4.2709	0.2482
Gibbs(c)	10.5412	9.2156	1.3256
Al(OH)3a	10.5412	12.0850	-1.5438
Kaolinit	13.0371	9.1468	3.8903
Albite	-21.6765	-19.2577	-2.4187
Anorth	-22.7331	-20.2755	-2.4576
Kspar	-22.4515	-22.0675	-0.3840
Kmica	23.3608	15.5822	7.7785
Chlorite	78.4554	75.7262	2.7292
Ca-Mont	-45.5638	-47.8576	2.2938
Talc	25.5735	23.6467	1.9268
Illite	-40.9580	-42.9187	1.9608
Chrysotl	33.6188	34.6402	-1.0214
Sepiol c	15.7080	16.2789	-0.5709
Sepiol d	15.7080	18.6600	-2.9520
Hematite	16.6687	-2.5123	19.1809
Goethite	8.3343	-1.0000	9.3343
Fe(OH)3a	8.3343	4.8910	3.4433
Pyrite	-137.9227	-19.0270	-118.8958
FeS ppt	-77.4144	-3.9150	-73.4994
Mackinit	-77.4144	-4.6480	-72.7664
PCO2	-5.0965	-1.2159	-3.8806
O2 gas	-40.9763	-2.8706	-38.1057
H2 gas	-28.8847	-3.0647	-25.8200
N2 gas	-4.1317	-3.1941	-0.9375
H2S gas	-79.0773	-0.7754	-78.3019
CH4 gas	-81.3787	-2.6964	-78.6822
NH3 gas	-33.6133	2.1662	-35.7794
Melanter	-10.7013	-2.4629	-8.2384
Alunite	-3.8007	1.0367	-4.8374
K-Jarosi	-10.4215	-7.6932	-2.7283

```
          DATA READ FROM DISK
ELEMENTS
SPECIES
LOOK MIN
LOOK MIN
1Upstream-S115 Mix
0010002000 1 0        0.00000
ELEMENTS
       C          15        0.61017E+02
       C          15        0.61017E+02
                   0        0.00000E+00
SOLUTION 1 Upstream Water, 4-8-95
11 15 2     8.12      4.50      7.00      1.00
   14  1.120D+00  16  4.560D+00  17  1.990D+00   6  8.500D-01   7  2.600D-01
    4  8.370D+00   5  3.330D+00   8  1.800D-01  10  2.400D-01  13  6.700D+00
   15  3.790D+01
SOLUTION 2 S-115 Water, 4-8-94
11 15 2     7.20      4.50      3.70      1.00
   14  4.310D+00  16  5.950D+02  17  7.120D+00   6  5.100D+00   7  1.800D+00
    4  1.020D+02   5  9.360D+01   8  5.000D-02  10  1.140D-01  13  6.000D+00
   15  3.730D+01
MINERALS
Calcite    2      4.0      -8.5      -2.3         1             -0.042
  15   1.00       4   1.00
 -1.7191E+02 -7.7993E-02  2.8393E+03  7.1595E+01  0.0000E+00
Dolomite   3      8.0      -17.      -9.4         0             -0.050
   4   1.00       5   1.00      15   2.00
Gypsum     3      6.0      -4.6      -0.11        1             -1.327
   4   1.00      16   1.00       3   2.00
  6.8240E+01  0.0000E+00 -3.2215E+03 -2.5063E+01  0.0000E+00
PCO2       1      4.0      -1.5      -4.8         1             -3.881
  35   1.00
1.0839E+02  1.9851E-02 -6.9195E+03 -4.0452E+01  6.6936E+05
Ca-Mont    5       0.      -45.       58.        0               2.294
   3  -12.0       4  0.165     153   2.33       13   3.67       1   2.00
Fe(OH)3a   3      3.0       4.9       0.         0               3.443
 115   1.00       3  3.00       1  -3.00
0       0.        0.        0.        0                          0.000
STEPS
 0.150
1SOLUTION NUMBER 1 Upstream Water, 4-8-95
```

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	2.088460D-04	-3.6802
Mg	1.369784D-04	-3.8633
Na	3.697534D-05	-4.4321
K	6.649712D-06	-5.1772
Fe	3.223303D-06	-5.4917
Al	8.895566D-06	-5.0508
Si	1.115173D-04	-3.9527
Cl	3.159319D-05	-4.5004
TOT ALK	6.211780D-04	-3.2068
S	4.747265D-05	-4.3236
N	3.209634D-05	-4.4935

----DESCRIPTION OF SOLUTION---

```
             PH =   8.1200
             PE =   4.5000
   ACTIVITY H2O =   1.0000
IONIC STRENGTH  =   0.0011
    TEMPERATURE =   7.0000
```

ELECTRICAL BALANCE = 1.7540D-05
THOR = 2.6590D-03
TOTAL ALKALINITY = 6.2118D-04
ITERATIONS = 14
TOTAL CARBON = 5.9113D-04

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	7.854E-09	-8.105	7.586E-09	-8.120	9.659E-01	-0.015
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	1.000E+00	0.000	1.000E+00	0.000	1.000E+00	0.000
4	Ca+2	2.0	2.063E-04	-3.686	1.786E-04	-3.748	8.658E-01	-0.063
5	Mg+2	2.0	1.353E-04	-3.869	1.173E-04	-3.931	8.665E-01	-0.062
6	Na+	1.0	3.696E-05	-4.432	3.564E-05	-4.448	9.643E-01	-0.016
7	K+	1.0	6.648E-06	-5.177	6.409E-06	-5.193	9.640E-01	-0.016
8	Fe+2	2.0	6.697E-08	-7.174	5.804E-08	-7.236	8.667E-01	-0.062
10	Al+3	3.0	1.806E-13	-12.743	1.321E-13	-12.879	7.317E-01	-0.136
13	H4SiO4	0.0	1.104E-04	-3.957	1.104E-04	-3.957	1.000E+00	0.000
14	Cl-	-1.0	3.159E-05	-4.500	3.046E-05	-4.516	9.640E-01	-0.016
15	CO3-2	-2.0	2.502E-06	-5.602	2.167E-06	-5.664	8.659E-01	-0.063
16	SO4-2	-2.0	4.563E-05	-4.341	3.948E-05	-4.404	8.653E-01	-0.063
17	NO3-	-1.0	8.884E-43	-42.051	8.562E-43	-42.067	9.638E-01	-0.016
31	OH-	-1.0	3.051E-07	-6.516	2.941E-07	-6.532	9.640E-01	-0.016
33	H2 AQ	0.0	4.929E-29	-28.307	4.930E-29	-28.307	1.000E+00	0.000
34	HCO3-	-1.0	5.732E-04	-3.242	5.529E-04	-3.257	9.647E-01	-0.016
35	H2CO3	0.0	1.308E-05	-4.883	1.308E-05	-4.883	1.000E+00	0.000
49	N2 AQ	0.0	1.605E-05	-4.795	1.605E-05	-4.794	1.000E+00	0.000
78	CaSO4	0.0	1.176E-06	-5.930	1.176E-06	-5.929	1.000E+00	0.000
88	MgSO4	0.0	6.624E-07	-6.179	6.626E-07	-6.179	1.000E+00	0.000
115	Fe+3	3.0	8.385E-17	-16.077	6.135E-17	-16.212	7.317E-01	-0.136
118	FeOH2+	1.0	3.701E-07	-6.432	3.568E-07	-6.448	9.642E-01	-0.016
119	FeOH3	0.0	2.628E-06	-5.580	2.629E-06	-5.580	1.000E+00	0.000
120	FeOH4-	-1.0	1.518E-07	-6.819	1.464E-07	-6.835	9.642E-01	-0.016
153	AlOH4-	-1.0	8.846E-06	-5.053	8.529E-06	-5.069	9.642E-01	-0.016

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-9.4124	-8.4003	-1.0121
Aragonit	-9.4124	-8.2428	-1.1696
Dolomite	-19.0075	-16.6456	-2.3619
Siderite	-12.9005	-10.7732	-2.1273
Gypsum	-8.1518	-4.5973	-3.5544
Anhydrit	-8.1518	-4.3405	-3.8112
SiO2 (a)	-3.9568	-2.8693	-1.0875
Chalcedy	-3.9568	-3.7737	-0.1831
Quartz	-3.9568	-4.2625	0.3057
Gibbs(c)	11.4810	9.1838	2.2971
Al(OH)3a	11.4810	12.0481	-0.5671
Kaolinit	15.0483	9.0975	5.9508
Albite	-21.3876	-19.2216	-2.1660
Anorth	-21.7999	-20.2594	-1.5406
Kspar	-22.1328	-22.0245	-0.1082
Kmica	25.4992	15.4994	9.9998
Chlorite	72.6371	75.5149	-2.8778
Ca-Mont	-43.1909	-47.7762	4.5853
Talc	21.1000	23.5820	-2.4820
Illite	-39.3504	-42.8424	3.4920
Chrysotl	29.0137	34.5702	-5.5565
Sepiol c	12.7477	16.2639	-3.5162
Sepiol d	12.7477	18.6600	-5.9123
Hematite	16.2956	-2.5553	18.8509
Goethite	8.1478	-1.0000	9.1478

Fe(OH)3a	8.1478	4.8910	3.2568
Pyrite	-135.9986	-19.0112	-116.9874
FeS ppt	-76.1174	-3.9150	-72.2024
Mackinit	-76.1174	-4.6480	-71.4694
PCO2	-4.8833	-1.2237	-3.6595
O2 gas	-41.9482	-2.8732	-39.0751
H2 gas	-28.3072	-3.0672	-25.2400
N2 gas	-4.7945	-3.1960	-1.5984
H2S gas	-77.8776	-0.7818	-77.0958
CH4 gas	-78.9185	-2.7011	-76.2173
NH3 gas	-33.1005	2.1548	-35.2553
Melanter	-11.6399	-2.4552	-9.1847
Alunite	-3.9175	0.9666	-4.8842
K-Jarosi	-13.9170	-7.7368	-6.1802

1SOLUTION NUMBER 2 S-115 Water, 4-8-94

TOTAL MOLALITIES OF ELEMENTS
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ELEMENT	MOLALITY	LOG MOLALITY
Ca	2.547081D-03	-2.5940
Mg	3.853235D-03	-2.4142
Na	2.220268D-04	-3.6536
K	4.607272D-05	-4.3366
Fe	8.960670D-07	-6.0477
Al	4.228722D-06	-5.3738
Si	9.994489D-05	-4.0002
Cl	1.216731D-04	-3.9148
TOT ALK	6.118256D-04	-3.2134
S	6.199226D-03	-2.2077
N	1.149276D-04	-3.9396

----DESCRIPTION OF SOLUTION----

PH = 7.2000
PE = 4.5000
ACTIVITY H2O = 0.9998
IONIC STRENGTH = 0.0206
TEMPERATURE = 3.7000
ELECTRICAL BALANCE = -4.8781D-05
THOR = 4.0008D-02
TOTAL ALKALINITY = 6.1183D-04
ITERATIONS = 14
TOTAL CARBON = 7.0277D-04

DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	7.079E-08	-7.150	6.310E-08	-7.200	8.913E-01	-0.050
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	9.998E-01	0.000	9.998E-01	0.000	1.000E+00	0.000
4	Ca+2	2.0	1.992E-03	-2.701	1.182E-03	-2.928	5.932E-01	-0.227
5	Mg+2	2.0	3.135E-03	-2.504	1.881E-03	-2.726	6.001E-01	-0.222
6	Na+	1.0	2.192E-04	-3.659	1.917E-04	-3.717	8.744E-01	-0.058
7	K+	1.0	4.538E-05	-4.343	3.946E-05	-4.404	8.696E-01	-0.061
8	Fe+2	2.0	6.982E-07	-6.156	4.190E-07	-6.378	6.001E-01	-0.222
10	Al+3	3.0	1.684E-09	-8.774	5.979E-10	-9.223	3.550E-01	-0.450
13	H4SiO4	0.0	9.983E-05	-4.001	1.003E-04	-3.999	1.005E+00	0.002
14	Cl-	-1.0	1.217E-04	-3.915	1.058E-04	-3.976	8.696E-01	-0.061
15	CO3-2	-2.0	3.612E-07	-6.442	2.143E-07	-6.669	5.933E-01	-0.227
16	SO4-2	-2.0	4.940E-03	-2.306	2.902E-03	-2.537	5.875E-01	-0.231
17	NO3-	-1.0	2.001E-49	-48.699	1.734E-49	-48.761	8.664E-01	-0.062
31	OH-	-1.0	2.987E-08	-7.525	2.596E-08	-7.586	8.689E-01	-0.061

33	H2 AQ	0.0	3.525E-27	-26.453	3.542E-27	-26.451	1.005E+00	0.002
34	HCO3-	-1.0	5.763E-04	-3.239	5.058E-04	-3.296	8.776E-01	-0.057
35	H2CO3	0.0	1.080E-04	-3.966	1.085E-04	-3.964	1.005E+00	0.002
49	N2 AQ	0.0	5.746E-05	-4.241	5.774E-05	-4.239	1.005E+00	0.002
78	CaSO4	0.0	5.497E-04	-3.260	5.523E-04	-3.258	1.005E+00	0.002
87	MgHCO3+	1.0	1.222E-05	-4.913	1.066E-05	-4.972	8.729E-01	-0.059
88	MgSO4	0.0	7.056E-04	-3.151	7.089E-04	-3.149	1.005E+00	0.002
96	NaSO4-	-1.0	2.762E-06	-5.559	2.411E-06	-5.618	8.729E-01	-0.059
100	KSO4-	-1.0	6.935E-07	-6.159	6.054E-07	-6.218	8.729E-01	-0.059
107	FeHCO3+	1.0	1.384E-08	-7.859	1.209E-08	-7.918	8.729E-01	-0.059
108	FeSO4	0.0	1.415E-07	-6.849	1.422E-07	-6.847	1.005E+00	0.002
115	Fe+3	3.0	1.014E-15	-14.994	3.600E-16	-15.444	3.550E-01	-0.450
118	FeOH2+	1.0	2.403E-08	-7.619	2.098E-08	-7.678	8.729E-01	-0.059
119	FeOH3	0.0	1.568E-08	-7.805	1.576E-08	-7.803	1.005E+00	0.002
151	AlOH2+	1.0	3.770E-07	-6.424	3.291E-07	-6.483	8.729E-01	-0.059
152	AlOH3	0.0	1.242E-07	-6.906	1.248E-07	-6.904	1.005E+00	0.002
153	AlOH4-	-1.0	3.686E-06	-5.433	3.218E-06	-5.492	8.729E-01	-0.059

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-9.5965	-8.3906	-1.2059
Aragonit	-9.5965	-8.2303	-1.3662
Dolomite	-18.9910	-16.5579	-2.4331
Siderite	-13.0467	-10.7501	-2.2966
Gypsum	-5.4650	-4.6054	-0.8595
Anhydrit	-5.4648	-4.3500	-1.1148
SiO2 (a)	-3.9985	-2.9004	-1.0981
Chalcedy	-3.9985	-3.8177	-0.1808
Quartz	-3.9985	-4.3182	0.3197
Gibbs(c)	12.3764	9.3958	2.9806
Al(OH)3a	12.3764	12.2945	0.0819
Kaolinit	16.7559	9.4258	7.3301
Albite	-21.2051	-19.4624	-1.7427
Anorth	-21.9091	-20.3671	-1.5420
Kspar	-21.8916	-22.3111	0.4195
Kmica	27.9301	16.0515	11.8786
Chlorite	71.1302	76.9236	-5.7934
Ca-Mont	-42.3545	-48.3190	5.9645
Talc	19.0291	24.0130	-4.9840
Illite	-38.5907	-43.3509	4.7603
Chrysotl	27.0259	35.0368	-8.0108
Sepiol c	11.3530	16.3634	-5.0105
Sepiol d	11.3530	18.6600	-7.3070
Hematite	12.3123	-2.2685	14.5808
Goethite	6.1561	-1.0000	7.1561
Fe(OH)3a	6.1560	4.8910	1.2650
Pyrite	-115.5683	-19.1163	-96.4520
FeS ppt	-65.4730	-3.9150	-61.5580
Mackinit	-65.4730	-4.6480	-60.8250
PCO2	-3.9644	-1.1709	-2.7934
O2 gas	-46.8817	-2.8560	-44.0257
H2 gas	-26.4508	-3.0508	-23.4000
N2 gas	-4.2385	-3.1834	-1.0551
H2S gas	-66.2024	-0.7393	-65.4631
CH4 gas	-70.1554	-2.6698	-67.4856
NH3 gas	-29.8904	2.2308	-32.1211
Melanter	-8.9157	-2.5072	-6.4085
Alunite	6.0511	1.4339	4.6172
K-Jarosi	-12.6100	-7.4459	-5.1640

1STEP NUMBER 1 0-------------

0 0.150 = FRACTION OF SOLUTION 1. 0.850 = FRACTION OF SOLUTION 2.

TOTAL MOLALITIES OF ELEMENTS

ELEMENT	MOLALITY	LOG MOLALITY
Ca	2.196346D-03	-2.6583
Mg	3.295797D-03	-2.4820
Na	1.942691D-04	-3.7116
K	4.015927D-05	-4.3962
Fe	1.245152D-06	-5.9048
Al	4.928748D-06	-5.3073
Si	1.016808D-04	-3.9928
Cl	1.081611D-04	-3.9659
C	6.860230D-04	-3.1637
S	5.276463D-03	-2.2777
N	1.025029D-04	-3.9893

----PHASE BOUNDARIES----

PHASE	DELTA PHASE*	LOG IAP	LOG KT	LOG IAP/KT
Calcite	2.472982D-03	-8.4336	-8.3919	-0.0417
Dolomite	-1.174226D-03	-16.6206	-16.5711	-0.0495
Gypsum	-2.250189D-03	-5.9312	-4.6041	-1.3271
PCO2	2.051632D-05	-5.0596	-1.1790	-3.8806
Ca-Mont	-1.514253D-06	-45.9159	-48.2097	2.2938
Fe(OH)3a	1.850713D-06	8.3343	4.8910	3.4433

* NEGATIVE DELTA PHASE INDICATES PRECIPITATION
AND POSITIVE DELTA PHASE INDICATES DISSOLUTION.

---- LOOK MIN IAP ----

PHASE	LOG IAP	LOG KT	LOG IAP/KT
Calcite	-8.4336	-8.3919	-0.0417
Aragonit	-8.4336	-8.2321	-0.2016
Dolomite	-16.6206	-16.5711	-0.0495
Siderite	-13.2027	-10.7536	-2.4491
Gypsum	-5.9312	-4.6041	-1.3271
Anhydrit	-5.9311	-4.3483	-1.5828
SiO2 (a)	-4.0243	-2.8957	-1.1286
Chalcedy	-4.0243	-3.8110	-0.2134
Quartz	-4.0243	-4.3098	0.2854
Gibbs(c)	10.6692	9.3637	1.3055
Al(OH)3a	10.6692	12.2571	-1.5880
Kaolinit	13.2897	9.3760	3.9137
Albite	-21.7343	-19.4259	-2.3084
Anorth	-23.0092	-20.3507	-2.6585
Kspar	-22.4210	-22.2677	-0.1533
Kmica	23.9258	15.9679	7.9579
Chlorite	79.0865	76.7102	2.3763
Ca-Mont	-45.9159	-48.2367	2.3208
Talc	25.7949	23.9477	1.8472
Illite	-41.1793	-43.2739	2.0946
Chrysotl	33.8436	34.9661	-1.1226
Sepiol c	15.8550	16.3484	-0.4934
Sepiol d	15.8550	18.6600	-2.8050
Hematite	16.6688	-2.3119	18.9807
Goethite	8.3344	-1.0000	9.3344
Fe(OH)3a	8.3343	4.8910	3.4433
Pyrite	-137.5705	-19.1003	-118.4701
FeS ppt	-77.2493	-3.9150	-73.3343
Mackinit	-77.2493	-4.6480	-72.6013
PCO2	-5.0596	-1.1790	-3.8806
O2 gas	-41.7387	-2.8586	-38.8801
H2 gas	-28.9298	-3.0533	-25.8765
N2 gas	-4.2891	-3.1853	-1.1038
H2S gas	-78.9123	-0.7457	-78.1666
CH4 gas	-81.2299	-2.6745	-78.5554
NH3 gas	-33.6566	2.2192	-35.8758
Melanter	-10.7006	-2.4993	-8.2013

Alunite	-3.2985	1.3631	-4.6616
K-Jarosi	-10.3032	-7.4900	-2.8131

TOTAL MOLALITIES OF ELEMENTS

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ELEMENT	MOLALITY	LOG MOLALITY
Ca	1.244663D-03	-2.9049
Mg	2.121570D-03	-2.6733
Na	1.942691D-04	-3.7116
K	4.015927D-05	-4.3962
Al	1.400538D-06	-5.8537
Si	9.612344D-05	-4.0172
Cl	1.081611D-04	-3.9659
C	8.310690D-04	-3.0804
S	3.026274D-03	-2.5191
N	1.025029D-04	-3.9893

----DESCRIPTION OF SOLUTION---

```
               PH =  8.4383
               PE =  4.5000
     ACTIVITY H2O =  0.9999
  IONIC STRENGTH =  0.0015
      TEMPERATURE =  4.1950
ELECTRICAL BALANCE = -3.8833D-05
             THOR =  2.1491D-02
  TOTAL ALKALINITY =  8.5234D-04
       ITERATIONS = 30
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DISTRIBUTION OF SPECIES

I	SPECIES	Z	MOLALITY	LOG MOLAL	ACTIVITY	LOG ACT	GAMMA	LOG GAM
1	H+	1.0	4.000E-09	-8.398	3.645E-09	-8.438	9.113E-01	-0.040
2	E-	-1.0	3.162E-05	-4.500	3.162E-05	-4.500	1.000E+00	0.000
3	H2O	0.0	9.999E-01	0.000	9.999E-01	0.000	1.000E+00	0.000
4	Ca+2	2.0	1.046E-03	-2.980	6.934E-04	-3.159	6.628E-01	-0.179
5	Mg+2	2.0	1.833E-03	-2.737	1.224E-03	-2.912	6.675E-01	-0.176
6	Na+	1.0	1.928E-04	-3.715	1.736E-04	-3.761	9.002E-01	-0.046
7	K+	1.0	3.980E-05	-4.400	3.571E-05	-4.447	8.973E-01	-0.047
8	Fe+2	2.0	1.767E-08	-7.753	1.180E-08	-7.928	6.679E-01	-0.175
10	Al+3	3.0	5.218E-15	-14.282	2.262E-15	-14.645	4.335E-01	-0.363
13	H4SiO4	0.0	9.428E-05	-4.026	9.452E-05	-4.024	1.003E+00	0.001
14	Cl-	-1.0	1.082E-04	-3.966	9.705E-05	-4.013	8.973E-01	-0.047
15	CO3-2	-2.0	8.012E-06	-5.096	5.313E-06	-5.275	6.632E-01	-0.178
16	SO4-2	-2.0	2.564E-03	-2.591	1.690E-03	-2.772	6.592E-01	-0.181
17	NO3-	-1.0	8.154E-42	-41.089	7.302E-42	-41.137	8.954E-01	-0.048
31	OH-	-1.0	5.251E-07	-6.280	4.710E-07	-6.327	8.970E-01	-0.047
33	H2 AQ	0.0	1.172E-29	-28.931	1.175E-29	-28.930	1.003E+00	0.001
34	HCO3-	-1.0	7.898E-04	-3.102	7.127E-04	-3.147	9.024E-01	-0.045
35	H2CO3	0.0	8.694E-06	-5.061	8.717E-06	-5.060	1.003E+00	0.001
49	N2 AQ	0.0	5.125E-05	-4.290	5.139E-05	-4.289	1.003E+00	0.001
78	CaSO4	0.0	1.892E-04	-3.723	1.897E-04	-3.722	1.003E+00	0.001
87	MgHCO3+	1.0	1.087E-05	-4.964	9.770E-06	-5.010	8.992E-01	-0.046
88	MgSO4	0.0	2.717E-04	-3.566	2.725E-04	-3.565	1.003E+00	0.001
115	Fe+3	3.0	2.414E-17	-16.617	1.046E-17	-16.980	4.335E-01	-0.363
118	FeOH2+	1.0	2.148E-07	-6.668	1.931E-07	-6.714	8.992E-01	-0.046
119	FeOH3	0.0	2.567E-06	-5.591	2.574E-06	-5.589	1.003E+00	0.001
120	FeOH4-	-1.0	2.915E-07	-6.535	2.621E-07	-6.582	8.992E-01	-0.046
153	AlOH4-	-1.0	1.397E-06	-5.855	1.256E-06	-5.901	8.992E-01	-0.046
164	H3SiO4-	-1.0	1.848E-06	-5.733	1.662E-06	-5.779	8.992E-01	-0.046

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**            **  INPUT UNKNOWN
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APPENDIX VIII

QUALITY ASSURANCE ANALYSES

Constituent/ Parameter	DRI 7/31/95 Upstream	UNLV 7/31/95 Upstream	DRI 7/31/95 Dnstrm.	UNLV 7/31/95 Dnstrm.
Cl	0.43	0.37	3.14	2.9
SO4	3.82	3.5	223	235
NO3	0.04	<0.1	8.15	8.2
Na	2.05	1.9	3.48	3.3
K	0.65	0.6	1.09	0.9
Ca	7.86	8.2	46.1	47.5
Mg	3.04	3.2	38.4	36.9
As	0.009	<0.1	0.01	<0.1
Fe	0.09	0.1	0.45	0.6
Mn	<0.01	<0.1	0.07	0.1
Zn	<0.005	<0.1	<0.005	<0.1
Ba	0.214	0.2	0.123	0.1
Al	<0.1	<0.1	0.3	0.4

All values are reported in mg/L unless otherwise noted.

Contituent/ Parameter	DRI 11/10/94 Upstream	IMC 11/10/94 Upstream	DRI 11/10/94 Dnstrm.	IMC 11/10/94 Dnstrm.
EC (µS/cm)	88	87.2	666	83.7
pH (standard units)	7.11	6.93	7.86	7.71
HCO3	35	29.8	81.5	64.9
Cl	0.8	<1.5	7.4	6.52
SO4	10.7	10.7	281	269
Na	2.17	3.05	4.23	4.99
K	0.6	<1	1.16	<1
Ca	9.46	8.76	69.3	66.9
Mg	3.45	3.4	41.3	40.3
NO3 (as N)	0.02	<0.06	0.33	0.32
TDS	46	44.9	466	464
TSS	1.3	<5	1.3	<5
As	0.005	0.009	0.01	0.011
Fe	0.06	0.074	0.34	0.359
Mn	<0.01	<0.005	0.12	0.105
Zn	0.01	<0.005	<0.005	<0.005
Ba	0.221	0.219	0.096	0.088
Se	<0.002	<0.005	<0.002	<0.005
Al	0.13	0.334	0.08	0.27
B	0.13	0.476	0.15	0.372
Be	<0.001	---	<0.001	<0.005
Hg	<0.0002	<0.0002	<0.0002	<0.0002
Ag	<0.005	<0.01	<0.005	<0.01
Pb	<0.05	<0.005	<0.05	<0.005
Cu	<0.005	<0.005	<0.005	<0.005
Cr	<0.01	<0.01	<0.01	<0.01
Cd	<0.005	<0.005	<0.005	<0.005

All values reported in mg/L unless otherwise noted.

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