Division of Geological & Geophysical Surveys

PUBLIC-DATA FILE 92-19

STREAMFLOW, SEDIMENT LOAD, AND WATER QUALITY STUDY OF HOSEANNA CREEK BASIN NEAR HEALY, ALASKA: 1991 PROGRESS REPORT

by

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September 1992

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INTRODUCTION

This report discusses sediment, streamflow, and water quality data collected during the 1991 summer field season by Alaska Division of Water (formerly the Hydrology Section of the Alaska Division of Geological and Geophysical Surveys) investigators in Hoseanna Creek basin.

Hoseanna Creek flows west into the Nenana River approximately three miles north of Healy, Alaska. The total basin area is approximately 48 mi^2. Hoseanna Creek appears on USGS topographic maps as Lignite Creek, but is referred to as Hoseanna Creek by Usibelli Coal Mine and DGGS (see Ray and Maurer, 1989).

The lithologies of the basin (see Wahrhaftig, 1987; Wilbur and Clark, 1987; Wahrhaftig, et al., 1969) produce mass wasting, which contributes to high sediment loads in some of the streams in the basin. The purpose of this study is to estimate the discharge and quantify the sediment yield of selected basins above mining influence.

Previous studies in the basin have concentrated on Hoseanna Creek, with shorter duration studies on smaller tributaries. This report discusses the data collected at Hoseanna and Clinker creeks during the summer of 1991. Table 1 shows the basins studied during each summer since studies began by DGGS and DOW in the Hoseanna basin.

Table 1. Basin characteristics of sampling sites with reference to the report which contains the data from the sites.

Site	Area (mi^2)	Percent of total basin area	Period of Record	Principle Lithology
Sanderson	5.1	11.6	1986-88	Schist
Clinker	1.7	3.9	1991	Schist
North Hoseanna	3.1	7.2	1986-88	Coal Group
Hoseanna @ Brd 6	20.8	47.5	1988-90	Mixed
Popovitch	4.1	9.3	1986-88	Nenana Gravel, Coal Group
Louise	1.6	3.6	1988-89	Nenana Gravel, Coal Group
Frances	1.7	3.9	1986-88	Nenana Gravel, Coal Group
Hoseanna @ Brd 3	43.8	100.0	1986-91	Mixed
Runaway	0.9	—	1989-90	Coal Group, Schist
Two Bull	0.9	—	1988-90	Nenana Gravel, Coal Group

*Table 1 (cont.). **Basin characteristics of sampling sites with reference to the report which contains the data from the sites.***

Site	Report number	
Sanderson	1-4	* Report
Clinker	6	
North Hoseanna	1-4	1 - Mack (1987)
Hoseanna @ Brd 6	3-5	2 - Mack (1988)
Popovitch	1-4	3 - Ray and Maurer (1989)
Louise	3,4	4 - Ray (1990)
Frances	1-4	5 - Ray et al. (1991)
Hoseanna @ Brd 3	1-6	6 - This report
Runaway	4,5	
Two Bull	3-5	

METHODS

PRECIPITATION

The precipitation data for the basin was gathered in three locations during 1991. DOW operates a Wyoming gage with a data recording device at Gold Run Pass (see Mack ,1988 for location and construction specifications). Readings are taken every 30 minutes, with changes as small as twelve one-hundredths of an inch recorded. DOW also operates a tipping-bucket rain gage located at Bridge 1. However due to problems with the data recorder, much of the data from the summer were lost. The other reporting station is operated by Usibelli Coal Mine personnel and is located at Poker Flat mine. The resolution of both tipping-bucket gages is 0.01 inches. Neither tipping-bucket gage is wind protected.

DISCHARGE

Stream velocities used in the calculation of discharge were measured with a Price type AA meter for higher flows and a Price pygmy meter for lower flows. A bridge crane was used to measure the flows at the bridges during high-water events. Velocities were measured at six-tenths depth, with sufficient number of sections such that no one section contained over ten percent of the total flow. If the depth was greater than 2.5 feet, measurements were made at two-tenths and eight-tenths depth. The average of the two readings was interpreted as the mean velocity. Discharge was calculated using the standard midpoint method (US Dept. of Interior, 1981). Flow at Clinker Creek was gaged with a nine-inch Parshall flume, with the stage converted to flow estimates using the standard equation for Parshall flumes (US Dept. of Interior, 1981). The discharge at Bridge 3 was estimated from the flow at Bridge 1 (measured by USGS). A relationship for the two bridges was developed using the data collected from previous years.

A continuous stage record was recorded at Clinker Creek using an Omnidata DP320 stream stage recorder with a pressure transducer. The small, battery operated device can measure water levels from 0 to 10 feet in intervals of one-hundredth of a foot. The data are stored on EPROM microchips, which are then read by a computer at the lab.

High flow events which were not directly measured were estimated using the indirect slope-area method (Dalrymple and Benson, 1984).

SEDIMENT RATING EQUATIONS

Sediment rating equations were calculated at each site to estimate sediment concentrations from discharge data. Leopold and Maddock (1953) found that equations of the form:

$$TSS = aQ^b$$

where TSS = total suspended solids (mg/l)
Q = discharge (cfs)
a,b = numerical constants

adequately approximate the relationship. Using the TSS data from the grab and automated samples, these equations were developed as linear log-log plots (log TSS = a + b log Q). Using the actual and estimated sediment concentrations and the continuous discharge data, we calculated the daily sediment load. Whenever possible, the actual values (automated or grab) were used in the calculation. The daily loads were then added to estimate the season load. The daily loads for the 1991 season from Bridge 3 were calculated from the daily composite samples (except when TSS values were available from the level-actuated isco).

WATER QUALITY

To ensure consistency of data between the different field seasons, the same water quality sampling and analytical methods were used during the 1987-91 field seasons (see also Mack, 1988). The following methods for surface water, ground water, and laboratory analysis are from Ray and Maurer (1989):

Surface Water

Surface water for chemical analyses was obtained and composited from Hoseanna Creek with a hand-held depth-integrating suspended-sediment sampler and a churn splitter, according to the methods of the U.S. Department of the Interior (1977). Samples collected from the splitter at each site were: filtered, for determining dissolved major anions; unfiltered, for determining suspended solids; and filtered and acidified, for determining dissolved trace metals and major cations. Water for major ion and dissolved trace-metal analyses was immediately pumped through 0.45 micron membrane filters. All acidified samples were collected in pre-acid-washed bottles, and acidified with Ultrex-grade nitric acid, to a concentration of 1.5 ml acid per liter sample.

Water temperature, dissolved oxygen, and specific conductance of surface water samples were measured in situ with a digital 4041 Hydrolab. A Beckman digital pH meter was used to measure pH on a composited sample. Alkalinity was measured electrometrically on a composited sample with an Beckman pH meter and a Hach digital titrator, according to the methods of the U.S. Environmental Protection Agency (1983). Settleable solids were determined in the field with Imhoff Cones according to the methods of the American Public Health Association, and others (1985).

Ground Water

Water levels in all wells were measured prior to pumping with a Johnson Watermark electric water-depth indicator. "Well Wizard" equipment was used to purge and sample all wells. The submersible bladder pump and tubing are composed of non-metallic materials. Water temperature, pH, and specific conductance were measured at regular intervals with a digital 4041 Hydrolab during well purging. After at least three well casing volume was removed from the well, sampling commenced when specific conductance fluctuated less than 10 percent. Water samples were obtained according to the methods of Scalf and others (1981). Water was collected in a churn splitter at the well head. Water temperature, pH, specific conductance and alkalinity were determined in the field using the same instrumentation and methods described for surface water samples. Samples for chemical constituent analysis were also treated and preserved in the same manner as surface water samples. Two additional samples were collected at each site: filtered, for determining nutrients, and unfiltered and acidified, for determining total iron. The sample for determining nutrients was kept on ice and placed in a freezer within one hour of collection.

Laboratory Analysis

Water quality analyses for surface water and ground water were conducted in the DGGS hydrology laboratory located in the Mineral Industry Research Laboratory (MIRL) on the University of Alaska Fairbanks (UAF) campus. Laboratory procedures used to analyze surface water are described in Mack (1988). Analytical methods and detection limits for surface water and ground water constituents are shown in Appendix E. The laboratory is a participant in EPA analytical quality assurance studies, and has participated in the USGS Standard Reference Water Sample Quality Assurance program since 1980. For all analyses, calibrations were performed using in-house analytical standards and blanks, and were monitored and verified by running previously analyzed USGS Standard Reference Water Samples along with the water samples collected for this study.

RESULTS

PRECIPITATION

Precipitation during the summer of 1991 was light, with every month below the long-term averages (Table 2). July was the only month which was close to the average with three inches falling at both Gold Run Pass and Poker Flat. The 7.68 inches which fell at Gold Run Pass was only 60 percent of the average precipitation for 1987-91 (13.11 inches). Similar results were found at Poker Flat. The daily precipitation from each gage is found in Appendix A.

Table 2. Monthly precipitation for Gold Run Pass (GRP), Poker Flat (PF) and Bridge 1 (B1). All values in inches.

Site	MAY	JUN	JUL	AUG	SEP	Total
GRP 1986	—	—	—	—	—	—
PF 1986	1.62	2.43	4.30	3.37	1.79	13.51
GRP 1987	0.12	1.08	2.52	3.24	4.32	11.28
PF 1987	0.23	2.17	3.74	2.10	1.16	9.40
GRP 1988	2.16	5.88	4.92	2.52	1.56	17.04
PF 1988	2.15	4.25	4.20	1.87	1.43	13.90
GRP 1989	0.96	6.20	1.32	4.92	0.84	14.24
PF 1989	0.49	3.90	1.25	3.11	1.31	10.06
GRP 1990	0.96	0.96	4.44	4.92	4.08	15.36
PF 1990	0.90	0.74	3.72	4.59	3.14	13.09
B1 1990	—	—	—	3.96	2.85	—
GRP 1991	0.36	1.44	3.00	2.16	0.72	7.68
PF 1991	0.53	0.89	3.05	1.39	1.13	6.99
B1 1991	—	—	2.06	—	1.05	—
Avg GRP (87-91)	0.91	3.11	3.24	3.55	2.30	13.11
Avg PF (87-91)	0.86	2.39	3.19	2.61	1.63	10.68
Avg PF (78-91)	0.89	2.67	3.09	2.92	1.93	11.50

DISCHARGE

Discharge was measured at Clinker Creek and at Hoseanna Creek at Bridge 1 (USGS station). Estimates of flow for Hoseanna Creek at Bridge 3 were based on the data collected at Bridge 1. The flume on Runaway Creek was removed on May 16 and installed on Clinker Creek. The daily average flows from these sites are found in Appendix B and summarized in Table 3.

The average daily flow (June-September) for Hoseanna Creek at Bridge 1 was 45.6 cfs. The gage has been operated by the US Geological Survey since May 1985. The average June through September flow for Hoseanna Creek at Bridge 1 for the period of 1985-91 is 57.6 cfs.

The near record snowpack resulted in high flows in May and early June for both sites. This is seen in the hydrographs for both sites (Figures 1 and 2). The general slope of the hydrographs shows the higher flows in the spring, slowing decreasing through the summer.

Table 3. Flow data for 1987-1991 field seasons. All values in cfs.

	Peak Flow					Season Average				
Site	87	88	89	90	91	87	88	89	90	91
Hoseanna Brd 3	449	740	1200	1000	700	35.9	42.6	52.6	70.0	41.0
Clinker Creek	----	----	----	----	12.3	----	----	----	----	2.39

SEDIMENT LOAD

The quality of the regression curves were the same for both sites, with each having an r^2 value of 0.65. Table 4 shows the r^2 value, number of samples used, and the coefficients for the sediment rating curves.

Table 4. Coefficients, r^2 value, and number of samples used (n) for the sediment rating equations. The equations are of the form: $TSS = aQ^b$.

Site	a	b	r^2	n
Hoseanna Cr at Bridge 3	0.32	1.91	0.65	146
Clinker Creek	14.6	2.16	0.65	112

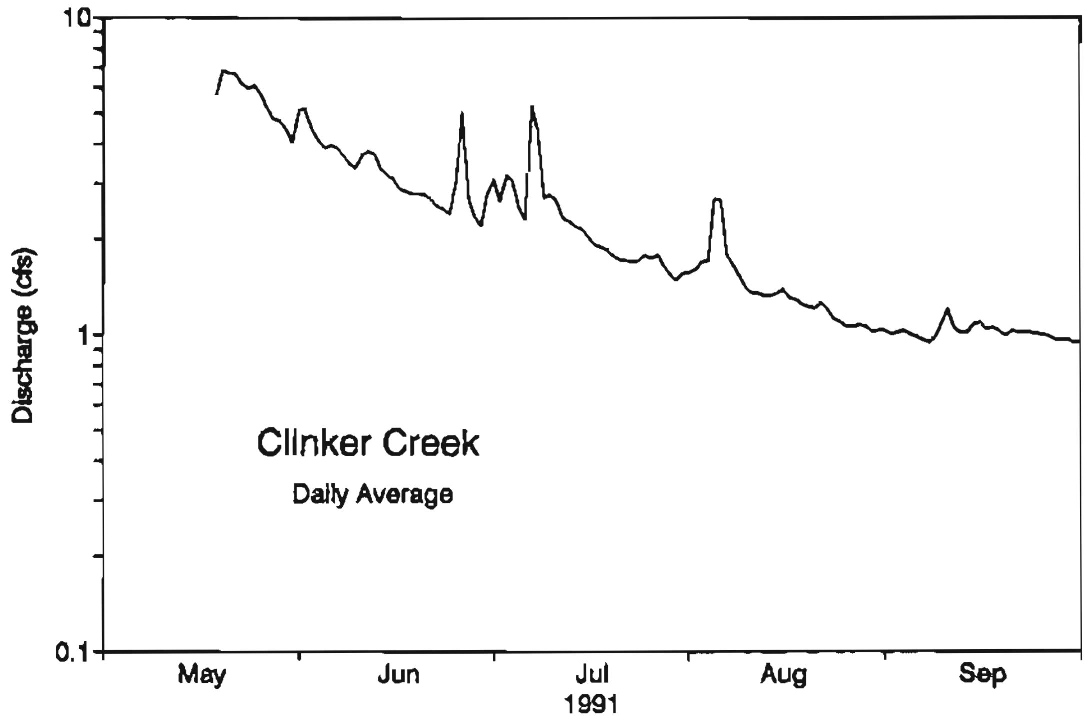

Figure 1. Hydrograph of Clinker Creek (1991).

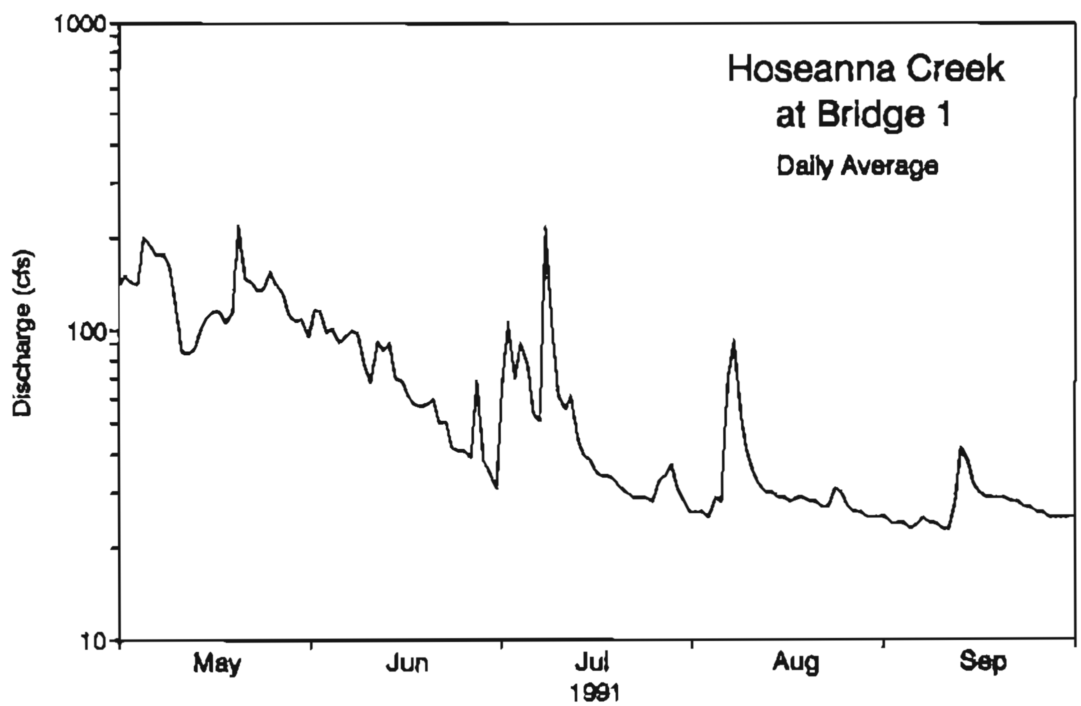

Figure 2. Hydrograph of Hoseanna Creek at Bridge 1 (1991).

Hoseanna Creek at Bridge 3

Figure 3 shows the plot of TSS versus discharge for this site. The r^2 value is 0.65. This is lowest r^2 value calculated since the study began. The previous low was 0.71 in 1987. This site had both composite and level-activated samples. There is little spread at the high flows (represented by one storm with level-activated samples). However there is considerable spread in the data at moderate flows.

Clinker Creek

Figure 4 shows the plot of TSS versus discharge for this site. The r^2 value is 0.65. The poor r^2 value results from fitting a straight line to data which has curvature. Table 5 summarizes the results of the sediment regression equations for all available data for each site since the study began. Figure 5 plots these data.

Table 5. Coefficients, r^2 value, and number of samples used (n) for the sediment rating equations for the 1986-1991 seasons. The equations are of the form: $TSS = aQ^b$.

Site	a	b	r^2	n
Hoseanna @ Brd 3 (1987)	1.81	1.59	0.71	113
1988	2.82	1.56	0.74	127
1989	6.16	1.26	0.85	259
1990	2.12	1.35	0.75	190
1991	0.32	1.91	0.65	146
1986-1991	**3.53**	**1.37**	**0.71**	**858**
Clinker Creek (1991)	14.6	2.16	0.65	112
1991	**14.6**	**2.16**	**0.65**	**112**

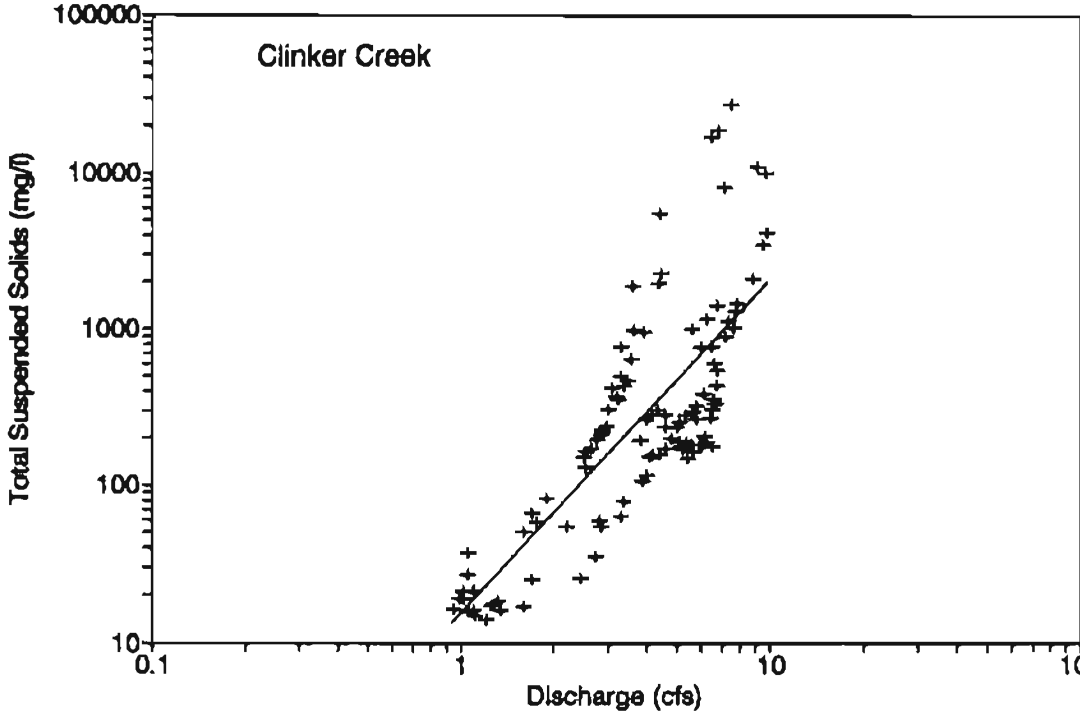

Figure 3. TSS versus discharge for Clinker Creek(1991 data). r^2 value equals 0.65.

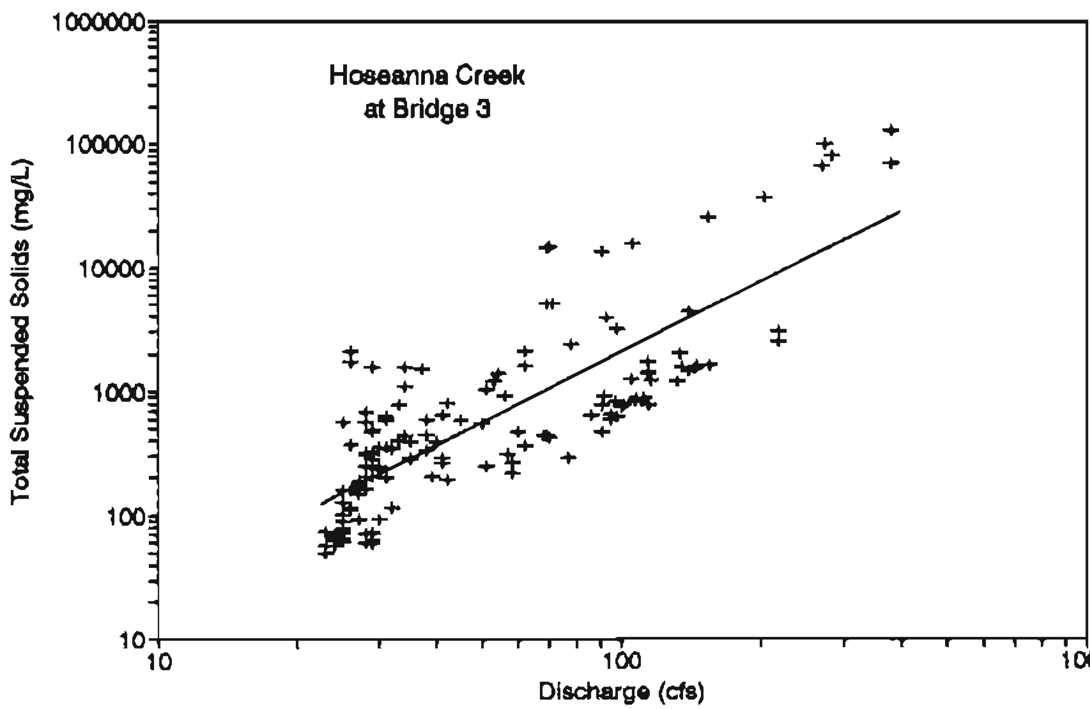

Figure 4. TSS versus discharge for Hoseanna Creek at Bridge 3 (1991 data). r^2 value equals 0.65.

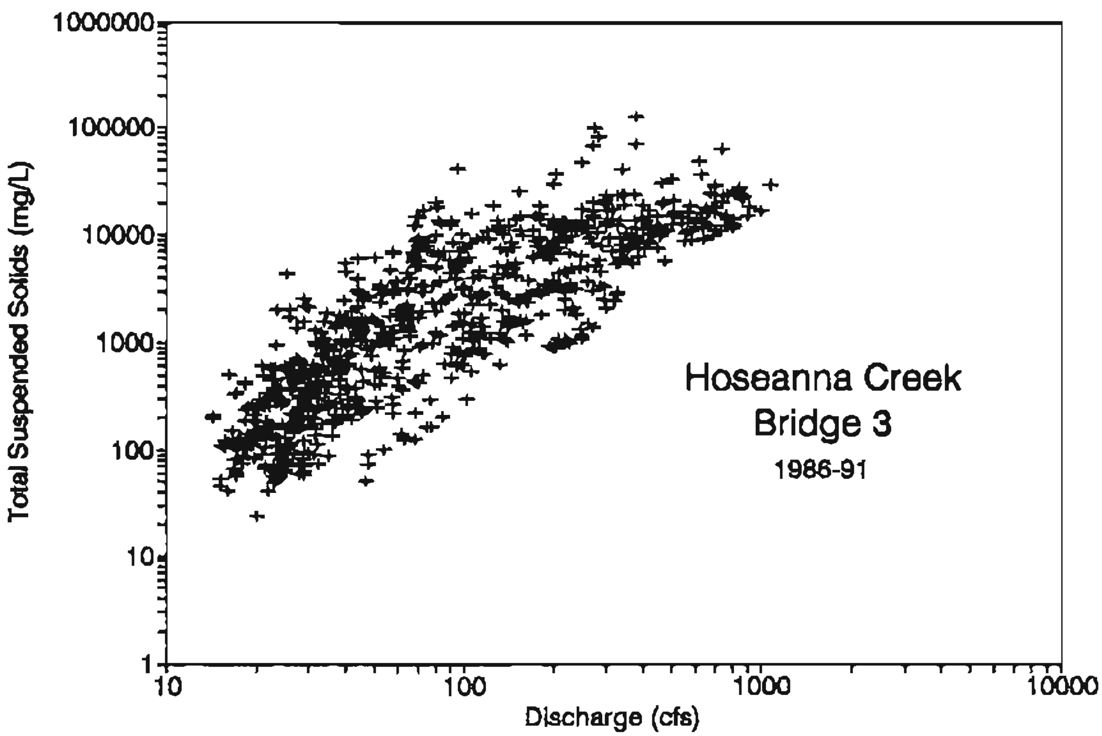

Figure 5. TSS versus discharge for Hoseanna Creek at Bridge 3 (1986-1991). r^2 value = 0.71, n = 858.

WATER QUALITY

Surface Water

Surface water-quality samples have been collected at two sites on Hoseanna Creek since 1987 (Bridges 1 and 3). During the 1991 field season, samples were taken from each site in late September. Samples were collected during low, baseflow conditions. Field-determined parameters compared well between the two sites, with only slight differences in temperature, pH, and conductivity. The results of the analyses of these samples are found in Appendix F. The major ion data is summarized in Table 6. The results of the 1991 analyses are similar to those of previous years. The percentage of both potassium and calcium ions has remained very steady through the study period at two percent and 37 percent, respectively. However the calcium percentage did drop slightly this year. Magnesium and sodium continue to fluctuate, with magnesium dropping and sodium rising this year. Bicarbonate continues to be the dominant anion, with a slight rise this year. Sulfate percentages has remained steady at about 30 percent. Chloride percentages have shown the greatest fluctuations, but were generally 20 percent. However this year the average was closer to 10 percent. Nitrate generally remains less than one percent for both sites.

Figure 6 is a Piper diagram showing all the samples collected for Bridge 1 and Bridge 3. The Piper diagram was plotted using HC-Gram (McIntosh, 1987). The cation portion of the diagram shows that calcium percentages have remained constant (linear trend of symbols), while the anion portion of the diagram shows that the sulfate percentages have remained nearly constant. Table 7 shows the mean values of selected water quality constituents from the Hoseanna Creek sites (1987-1991).

Table 6. Average percentages of the major ion composition (in meq/l) at Hoseanna Creek for 1987-1991.

	Bridge 3					Bridge 1				
	1987	1988	1989	1990	1991	1987	1988	1989	1990	1991
Calcium	37	37	37	37	36	38	36	37	38	34
Magnesium	44	51	35	44	40	43	49	29	41	37
Sodium	16	11	26	17	22	16	14	32	19	27
Potassium	3	1	2	2	2	3	1	2	2	2
Bicarbonate	56	47	50	50	59	56	46	50	50	58
Sulfate	34	31	32	36	32	29	29	31	34	31
Chloride	10	22	18	14	9	12	25	19	16	11
Nitrate	<1	<1	<1	<1	<1	3	<1	<1	<1	<1

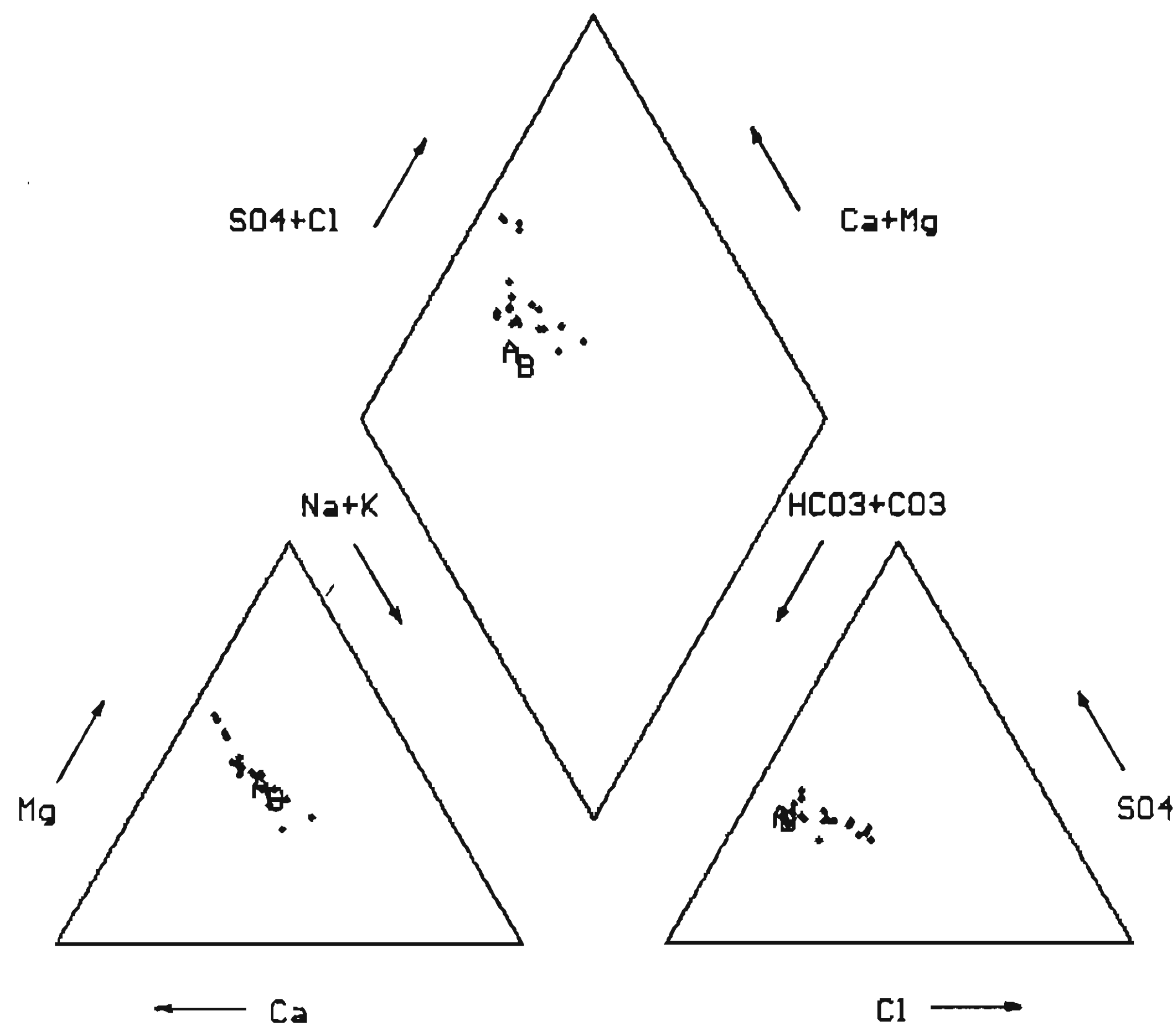

Figure 6. Piper diagram for the surface water sites. The + (plus) indicates samples collected at Bridge 1 and Bridge 3 prior to September 1991. The "A" is the Bridge 3 site on September 25, 1991, the "B" is the Bridge 1 site on September 25, 1991.

Table 7. Mean values of selected water quality constituents from Hoseanna Creek sites (1987-1991). All values in mg/l unless otherwise noted.

	Bridge 3	Bridge 1
Field Determination		
pH	7.29	7.32
Dissolved oxygen	12.9	11.4
Specific Conductance (umhos/cm)	512	547
Cations		
Calcium	35.7	36.8
Magnesium	26.2	25.4
Sodium	20.4	24.8
Potassium	3.8	4.2
Anions		
Alkalinity	124	127
Sulfate	75.5	72.4
Chloride	28.9	34.9
Nitrate	0.61	2.63
Lab Determinations		
Color (pcu)	35	35
Total Suspended Sediment	580	670
Turbidity (NTU)	150	170
Total Dissolved Solids	266	278

Ground Water

The location of the three ground water monitoring wells sampled during 1991 are given in Table 8. Detailed descriptions of the GAMW wells and installations are given by Golder Associates (1987). GAMW-4 and GAMW-5 are located in the Poker Flat spoils near Hoseanna Creek. GAMW-3 is parallel to the flow gradient of the spoils, however it is in unmined terrain (Golder Associates, 1987).

Table 9 gives the initial depth-to-water, volume and pumping rates for the ground water monitoring wells. Samples for analyses are not collected until at least three well casings have been purged and the conductivity has stabilized.

Table 8. Coordinates for ground water monitoring wells at Usibelli Coal Mine.

Well Name	Longitude	Latitude
GAMW-3	148° - 54' - 42.5"	63° - 54' - 26.6"
GAMW-4	148° - 55' - 33.9"	63° - 54' - 26.9"
GAMW-5	148° - 56' - 57.2"	63° - 54' - 18.9"

Table 9. Initial water level readings and purging protocol for ground water monitoring wells at Usibelli Coal Mine.

Well Name	Date	Initial[1] Depth to Water (ft)	Calc Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)	Comments
GAMW-3	9-15-87	26.86	—	—	---	
	5-23-88	25.97	1.5	1.4	—	2
	5-24-88	27.69	1.2	8.0	—	3
	7-18-88	27.59	1.3	4.1	5.0	
	9-07-88	28.04	1.2	8.0	6.4	
	9-20-89	27.82	1.2	5.5	5.7	
	9-12-90	26.68	1.4	4.2	5.0	
	10-08-91	28.08	1.2	3.4	2.8	9
GAMW-4	9-15-87	7.68	—	—	—	
	5-24-88	7.96	3.6	6.8	—	4
	5-25-88	8.28	3.6	17.0	12.7	
	7-18-88	8.74	3.5	14.7	9.8	
	9-07-88	8.62	3.6	12.0	13.1	
	9-20-89	9.26	3.4	10.5	13.7	
	9-12-90	7.11	3.7	12.5	9.4	
	9-24-91	9.29	3.4	12.0	13.8	
GAMW-5	9-15-87	72.22	—	—	—	
	5-25-88	71.84	3.9	7.0	2.3	
	7-18-88	82.70	2.3	5.3	1.3	
	7-19-88	-----	—	—	1.1	5
	9-07-88	82.87	2.2	—	—	6
	9-21-89	81.95	2.4	22.0	1.0	7
	9-12-90	80.13	2.6	19.9	0.8	8
	9-25-91	82.74	2.3	16.5	0.8	10

Comments:

1. All measurements are from top of PVC casing.
2. Irregular pumping rate due to low water yield and pump failure.
3. Irregular pumping rate due to low water yield.
4. Irregular pumping rate due to ice in well.
5. Pumped well from 2330 hrs, 7-18-88 to 1040 hrs, 7-19-88 due to very low water yield.
6. Pumped well from 1755 hrs, 9-7-88 to 1053 hrs, 9-8-88 due to very low water yield.
7. Pumped well from 1022 hrs, 9-21-89 to 0845 hrs, 9-22-89 due to very low water yield.
8. Pumped well from 1610 hrs, 9-12-90 to 1730 hrs, 9-13-90 due to very low water yield.
9. Pump in well not working. Used peristaltic pump to purge well.
10. Pumped well from 1550 hrs, 9-24-91 to 1140 hrs, 9-25-91 due to very low water yield.

The results of the ground water sample analyses are found in Appendix F. The results from the analyses varied considerably among the sites, with little variance between dates. However wells GAMW-3 and

5 did differ from previous samplings. The conductivity in GAMW-5 dropped to 1230 μmhos/cm from the previous average of 5320 μmhos/cm. The conductivity in GAMW-3 dropped to 653 μmhos/cm from the previous average of 1435 μmhos/cm. The reduction of the conductivity in both sites correlates to the reduction of sodium and chloride in both wells. The reduction of chloride was significant in GAMW-5, with the concentration falling from the previous average of 1360 mg/L to 197 mg/L. pH for all the wells were well below 7. The water temperatures were generally less than 4°C.

Table 10 gives the major ion average percentages (based on meq/l) for the ground water samples. As indicated by the variation in the specific conductance, the composition also varies widely among the sites. The waters were classified following the 1988 sampling as sodium bicarbonate-chloride (GAMW-3), calcium-potassium bicarbonate (GAMW-4), and sodium chloride (GAMW-5). After the 1989 and 1990 sampling, GAMW-3 and GAMW-5 remained in their respective classifications. However GAMW-4 was changed from calcium-potassium bicarbonate to sodium bicarbonate. After the 1991 sampling, the waters are now classified as sodium bicarbonate for GAMW-3 (formerly sodium bicarbonate-chloride) and GAMW-4. GAMW-5 is now classified as calcium-sodium bicarbonate (formerly sodium chloride). Figure 7 is a Piper diagram showing the distribution of ground water samples collected.

Table 10. Average percentages of the major ion composition (in meq/l) of ground water monitoring wells at Usibelli Coal Mine (1988-1991).

	GAMW-3	GAMW-4	GAMW-5
Calcium	19	26	23
Magnesium	14	13	17
Sodium	62	42	59
Potassium	5	19	1
Bicarbonate	50	86	24
Chloride	37	3	73
Sulfate	12	10	3
Fluoride	<1	1	<1

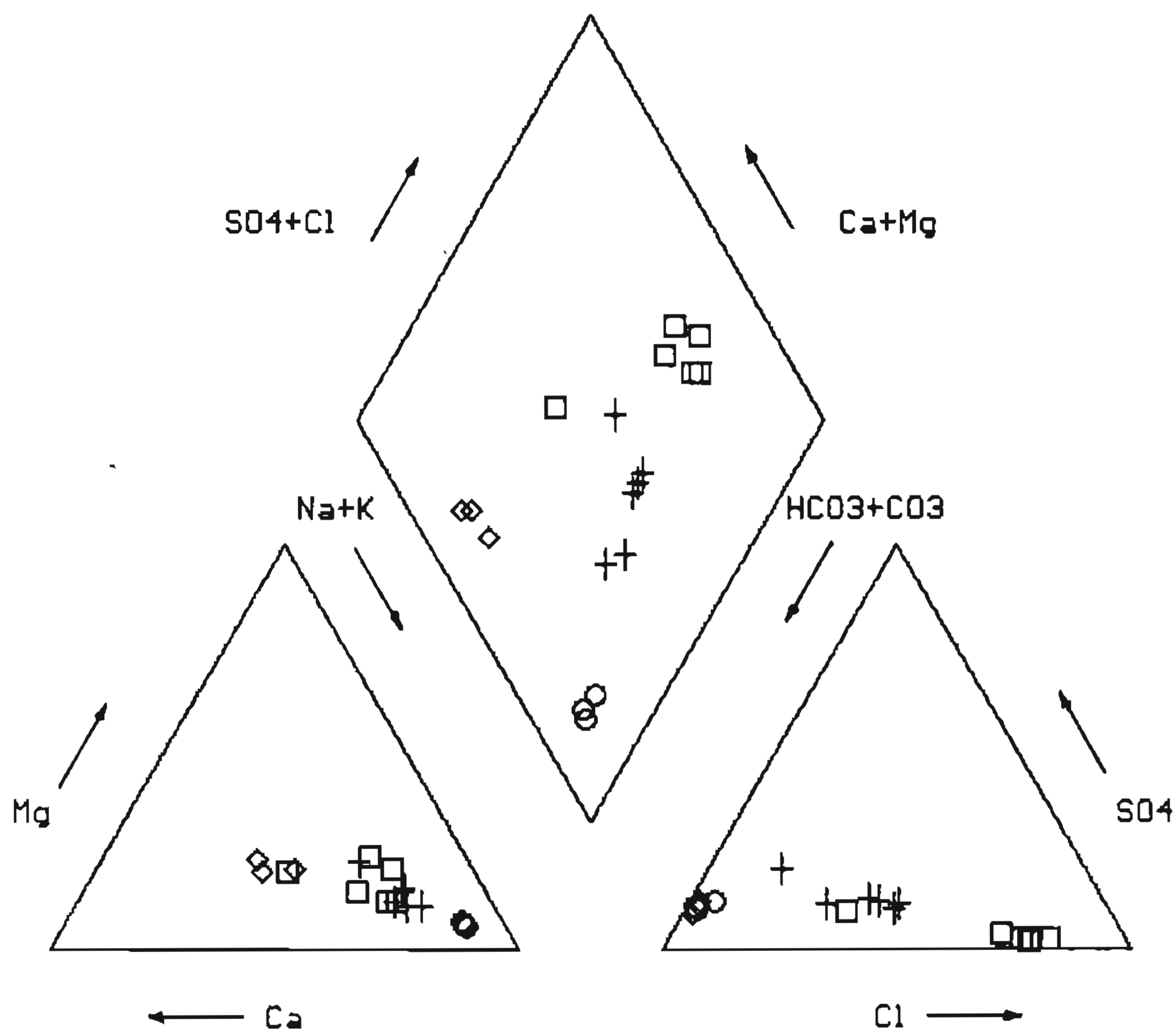

Figure 7. Piper diagram for the ground water sites. The sites are represented as follows: GAMW-3 (+), GAMW-4 1988 (diamond), GAMW-5 (square), and GAMW-4 1989-91 (circle).

DISCUSSION

The precipitation at Gold Run Pass was greater than Poker Flat again in 1991, as it has been in every year of the study. The 1987-91 record shows that the Gold Run Pass gage averages two and one-half inches more than the gage at Poker Flat (about 23 percent). Certainly some of this discrepancy is real, resulting from heavier showers further in the basin due to orographic effects. However, some may be due to the inability of the Poker Flat gage to accurately measure the rainfall because of wind. The Gold Run Pass gage has a "Wyoming" wind shield around it to protect the gage orifice from the wind. The Poker Flat gage does not have such a device. The previous Poker Flat gage site was better protected from the wind than the present site. If this is true, than the present site may not be recording the actual rainfall due to the wind blowing across the opening of the gage (Ray, 1990). The same condition now exists for the gage at Bridge 1.

The data continues to show that the events which produce the large flow events (resulting in high sediment loads) are the large cyclonic storms from the Gulf of Alaska or Bering Sea (Ray and Maurer, 1989). These moisture-laden storms are accompanied by low-level west-southwesterly winds and are capable of dropping more than two inches of rain in 24 hours to 48 hours (Ray, 1990).

The precipitation which fell during June through September 1991 was the least amount recorded at the precipitation gages since their installation. The 6.46 inches which fell at Poker Flat was the lowest since records began in 1978 and far below the 8.73 inches recorded in 1985. The 7.32 inches recorded at Gold Run Pass was the lowest since 11.16 inches in 1987.

Table 11 shows the average flow (cfs), total runoff (inches), total precipitation (inches), and the runoff to precipitation ratio for Bridge 3 for June through September.

Table 11. Average flow (cfs), total runoff (inches), total precipitation at Gold Run Pass (inches), and runoff to precipitation ratio for Hoseanna Creek at Bridge 3 for June through September.

Site	Average Flow	Runoff	Precipitation	Ratio
1987	37.1	3.84	11.16	.344
1988	40.7	4.22	14.88	.284
1989	53.6	5.55	13.28	.418

Table 11 (cont.). Average flow (cfs), total runoff (inches), total precipitation at Gold Run Pass (inches), and runoff to precipitation ratio for Hoseanna Creek at Bridge 3 for June through September.

Site	Average Flow	Runoff	Precipitation	Ratio
1990	70.0	7.25	14.40	.504
1991	41.0	4.25	7.32	.581

The average runoff-to-precipitation ratio for the three years is approximately 0.41. The variance among the values is due to variation in temperature, wind, and the frequency of the rainfall events (Ray, 1990). Although 1991 season had the highest runoff ratio, it also had the lowest precipitation recorded since the study began. Much of the runoff occurred early in the month of June. The high runoff was due to the near record snowpack. The ratio does not account for this "precipitation" in the calculation, so the actual water available for runoff is under estimated. This results in a higher ratio. Most of the runoff occurred when the factors which increase evapotranspiration was low (temperature, plant growth). With lower evapotranspiration, more water is available for ground water recharge.

Table 12 shows the load for each site sampled from 1987-1991. The loads are for the period of discharge record.

Table 12. Sediment load estimates (tons) for the period of discharge record.

Site	1987	1988	1989	1990	1991
Hoseanna @ Brd 3	40000	59200	100300	64000	43700
Clinker Creek	—	—	—	—	268

Ray (1990) discussed the importance of the magnitude and number of the storm events in determining the season sediment load at Bridge 3. Data collected in 1991 continues to support the theory. The 1991 season had the second lowest sediment load (only one peak over 500 cfs). The 1991 season load only surpassed the 1987 season load (no peaks above 500 cfs) by less than ten percent. Table 13 show the correlation of storm events and season sediment load.

Table 13. Number of flow events over 500 and 1000 cfs and the corresponding season sediment load (tons).

Peak Storm Flow	1987	1988	1989	1990	1991
# greater than 500 cfs	0	2	3	2	1
# greater than 1000 cfs	0	0	1	1	0
Season Sediment Load (tons)	40000	59200	103000	64000	47300

As discussed by Ray and Maurer (1989), Ray (1990) and Ray (1991) most of sediment transported during a season occurs over a relatively short period of time. Table 14 shows the percentage of sediment transported in discrete, short periods of time. On average, over 50 percent of the season's sediment load for Hoseanna Creek at Bridge 3 is transported in three days. Clinker Creek required over five days to transport 50 percent of its load. Since most of Clinker Creek is underlain by schist, it is less likely to large sediment loads during individual storms.

Table 14. The percentage of seasonal sediment load in short durations.

	DAYS				
Site	1	2	3	5	10
Hoseanna @ Brd 3 (1988)	44	55	65	78	87
1989	42	56	63	78	91
1990	29	40	50	62	73
1991	20	33	45	58	70
Clinker (1991)	16	26	34	47	67
AVERAGE	**30**	**42**	**51**	**65**	**78**

WATER QUALITY

Surface Water

The surface water-quality sampling of Hoseanna Creek has been conducted since 1987. Samples were generally taken during non-storm periods, which represent average to low-flow conditions. The samples collected in 1991 met this criteria. The purpose of the surface water quality study is to measure the general water-quality conditions above and below the Poker Flat mine and determine the effect of Poker Flat mine on the water quality of Hoseanna Creek. The most likely influence of the Poker Flat mine is from ground water input from the spoils. If samples were taken during storm runoff, any effects of the mine would probably be diluted by the large volume of surface runoff. To measure the maximum influence from the mine, samples should be taken at low-flow conditions when surface runoff is low and the ground water contribution is high.

Figure 8 shows the cation portion of a Piper diagram of all surface and ground water samples collected since to beginning of the study. Both water types show a linear trend. The ground water trend will be discussed in the next section. The surface water trend shows the natural variations of the water chemistry over the last five years at different hydrologic setting. Many factors influence the chemical composition of the stream. But the underlying factor here is the ratio of surface runoff to ground water input. Samples which plot on the left side of the chart are either surface runoff dominated or short residence time ground water. As the ground water contribution or residence time increases, the composition moves toward the right (toward the ground water composition). It is expected as the ground water contribution becomes dominant, the composition of the surface water would become similar to the ground water.

Ground Water

As discussed in the previous section, the cation portion of the Piper diagram (Figure 8) shows a linear trend for the ground water samples. The trend is a function of residence time and cation exchange. From left to right, the first cluster is GAMW-4 (1988 samples). These samples had an unusual chemical composition and appear to be a mixture of surface and ground waters (Ray and Maurer, 1989). The next two clusters are GAMW-5 and GAMW-3. These wells are located low in the basin where long residence time and significant ion exchange has occurred. Although the two wells have similar composition, well GAMW-5 has a much higher concentration due to resaturation of material not previously in contact with the ground water (Ray and Maurer, 1989). The last cluster is GAMW-4. It is also low in the basin and has similar characteristics of GAMW-3 and GAMW-5.

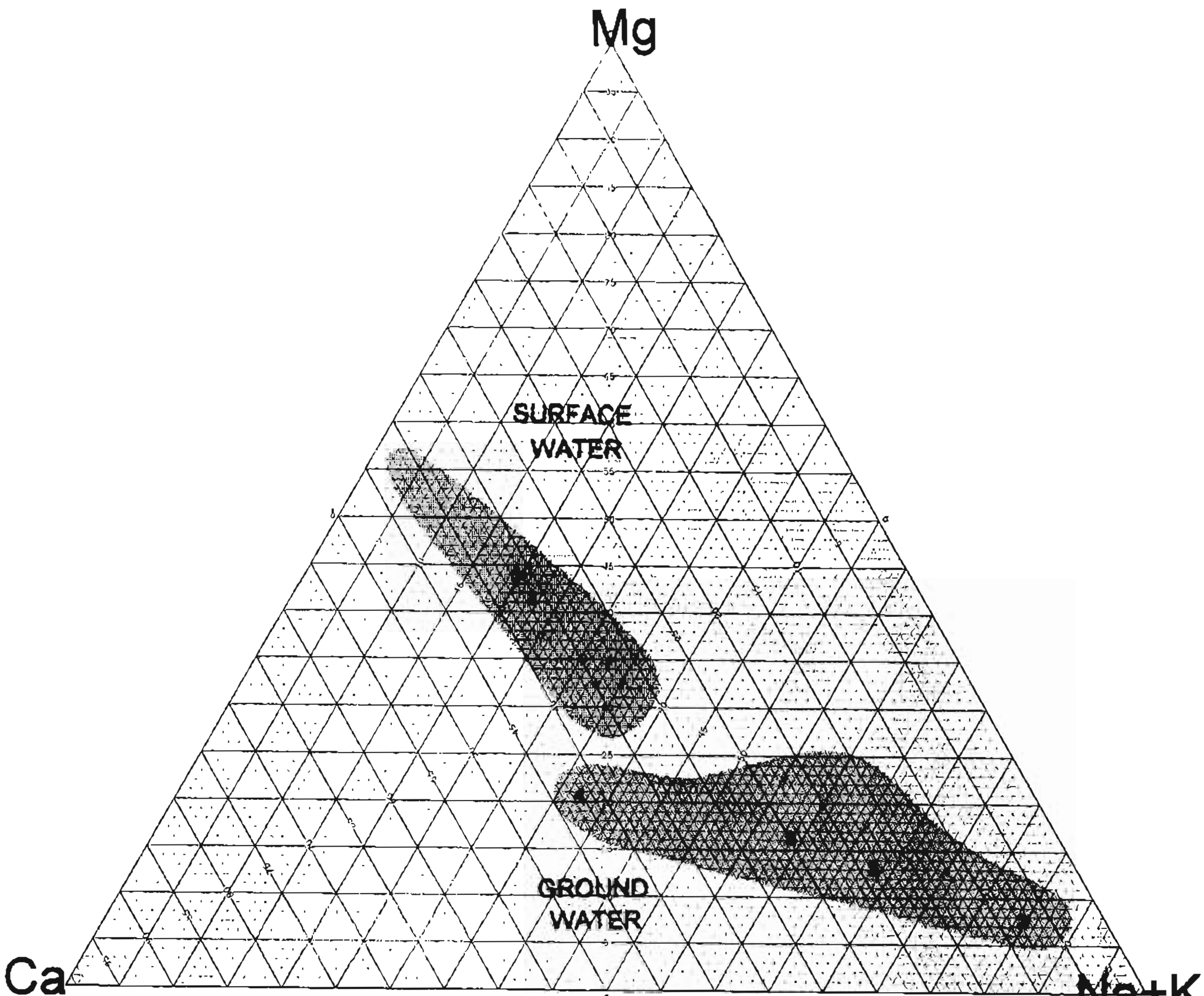

Figure 8. Triangular diagram (cations) for the surface and ground water sites. The shaded areas show the range of the surface and ground water samples. The numbers in the shaded areas are the average from that site. The numbers indicate the following sites: Bridge 1 (1), Bridge 3 (3), GAMW-4 1988 (4), GAMW-3 (3), GAMW-4 1989-91 (2), and GAMW-5 (5)..

10. The best time to sample the surface water is during the late-fall or even late-winter when the surface runoff is at a minimum.

11. The water type classification for the five ground water monitoring wells is significantly different.

12. Little change in the water chemistry has occurred in GAMW-3 and GAMW-5. What changes have taken place may be due to fertilization the of the spoils.

13. The water chemistry of GAMW-4 in 1988 may have been influenced by surface water runoff down the well casing.

14. Major surface-water cations show a linear trend on a Piper diagram. Future samples should plot on this line which represents the natural variations in the stream.

15. Major ground-water cations show a linear trend which represents the residence time and ion exchange.

CONCLUSIONS

Most of the conclusions listed below are from Ray (1990) and Ray (1991). Some of the conclusion topics may not have been discussed in this report.

1. Large cyclonic storms are responsible for most of the sediment transport, while the isolated convective storms result in minor sediment production.

2. A large portion of the seasonal sediment load occurs during the first major flood event of the season (may coincide with break-up).

3. The runoff prior to break-up carries a significant sediment load which is important factor in the annual sediment load.

4. Most of the seasonal sediment load is transported over a relative few days during high-flow events.

5. Rating equations have a limited accuracy, in that they are power functions.

6. Good sediment rating equations (high r^2 values) are difficult to obtain for small creeks due to mass wasting events.

7. Some streams are better suited for the establishment of good rating equations (also noted by Wilbur, 1989).

8. Hysteresis results in additional variance in the calculation of the sediment rating equations.

9. The available sediment for transport decreases through the summer, resulting in additional variance in the calculation of the sediment rating equations.

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APPENDIX A

Gold Run Pass

Daily Precipitation - 1991 (inches)

Date	May	Jun	Jul	Aug	Sep
1	—	0.24	0.96	0.12	—
2	—	—	—	—	—
3	—	0.12	0.12	—	—
4	—	—	0.24	0.12	—
5	—	—	0.12	0.24	—
6	—	0.12	—	0.48	0.12
7	—	—	—	0.48	—
8	—	—	0.72	0.12	—
9	—	—	—	—	—
10	—	—	—	—	—
11	—	0.12	0.24	—	0.12
12	—	—	—	—	0.36
13	—	—	—	—	0.12
14	—	—	—	—	—
15	—	—	—	—	—
16	—	—	—	—	—
17	—	—	—	0.12	—
18	—	—	—	—	—
19	0.12	—	—	0.12	—
20	0.24	—	—	—	—
21	—	—	—	—	—
22	—	—	—	0.12	—
23	—	—	—	0.12	—
24	—	—	—	—	—
25	—	—	—	0.12	—
26	—	0.48	0.36	—	—
27	—	0.36	0.12	—	—
28	—	—	0.12	—	—
29	—	—	—	—	—
30	—	—	—	—	—
31	—		—	—	
Total	0.36	1.44	3.00	2.16	0.72

Season Total = 7.68 inches

APPENDIX A (cont)

Poker Flat

Daily Precipitation - 1991 (inches)

Date	May	Jun	Jul	Aug	Sep
1	—	0.10	—	—	—
2	—	—	—	—	—
3	—	—	0.07	—	—
4	—	—	0.11	0.35	—
5	—	—	0.08	0.13	—
6	0.01	0.22	—	0.32	0.18
7	—	0.11	0.16	0.27	—
8	—	—	0.71	0.03	—
9	0.01	—	—	0.03	—
10	—	0.11	—	—	—
11	—	—	0.08	—	0.16
12	—	0.07	0.21	—	0.60
13	—	—	—	—	0.13
14	—	—	—	—	—
15	—	0.05	—	0.03	—
16	—	—	—	—	0.04
17	—	—	0.07	0.05	—
18	—	—	0.27	—	—
19	0.10	—	0.09	—	—
20	0.41	—	—	0.05	0.02
21	—	—	—	—	—
22	—	—	0.02	0.06	—
23	—	—	—	0.04	—
24	—	—	0.07	—	—
25	—	—	—	0.03	—
26	—	0.22	0.26	—	—
27	—	—	0.56	—	—
28	—	—	0.28	—	—
29	—	—	—	—	—
30	—	—	0.01	—	—
31	—		—	—	
Total	0.53	0.89	3.05	1.39	1.13

Season Total = 6.99 inches

APPENDIX A (cont)

Bridge 1

Daily Precipitation - 1991 (inches)

Date	May	Jun	Jul	Aug	Sep
1	—	—	—	m	—
2	—	—	0.04	m	—
3	—	—	0.10	m	—
4	—	—	0.10	m	—
5	—	—	0.02	m	—
6	—	—	—	m	0.11
7	—	—	0.01	m	—
8	—	—	0.69	m	0.01
9	—	—	—	m	—
10	—	—	—	m	0.01
11	—	—	0.13	m	0.39
12	—	—	0.07	m	0.50
13	—	—	—	m	—
14	—	—	0.16	m	—
15	—	—	0.05	m	—
16	—	—	—	m	0.03
17	—	—	0.26	m	—
18	—	—	0.05	m	—
19	—	—	0.09	0.07	—
20	—	—	0.02	—	—
21	—	—	0.01	—	—
22	—	—	—	0.04	—
23	—	—	—	0.02	—
24	—	—	0.06	—	—
25	—	Install Gage	—	—	—
26	—	1.01	0.26	—	—
27	—	0.01	0.29	—	—
28	—	—	0.16	—	—
29	—	—	0.03	—	—
30	—	—	—	—	—
31	—		m	—	
Total			2.60		1.05

Season Total =

m - missing data

APPENDIX B

Clinker Creek

Daily Average Discharge - 1991 (cfs)

Date	May	Jun	Jul	Aug	Sep
1		5.12	2.78	1.57	1.04
2		5.13	3.11	1.58	1.04
3		4.46	2.63	1.62	1.01
4		4.15	3.21	1.70	1.02
5		3.87	3.08	1.72	1.03
6		3.98	2.50	2.69	1.00
7		3.90	2.30	2.68	0.99
8		3.72	5.29	1.79	0.97
9		3.46	4.42	1.65	0.95
10		3.38	2.72	1.54	0.99
11		3.68	2.77	1.42	1.09
12		3.80	2.66	1.35	1.21
13		3.71	2.34	1.35	1.05
14		3.33	2.27	1.33	1.02
15		3.17	2.20	1.33	1.02
16		3.10	2.13	1.35	1.08
17		2.88	2.05	1.39	1.09
18		2.83	1.94	1.30	1.05
19	5.70	2.79	1.91	1.29	1.06
20	6.82	2.80	1.86	1.25	1.03
21	6.65	2.77	1.77	1.23	1.00
22	6.63	2.67	1.73	1.22	1.04
23	6.18	2.56	1.71	1.26	1.03
24	5.96	2.49	1.70	1.20	1.02
25	6.13	2.41	1.71	1.13	1.02
26	5.67	3.12	1.79	1.09	1.01
27	5.17	5.08	1.74	1.07	1.00
28	4.76	2.69	1.79	1.06	1.00
29	4.75	2.36	1.66	1.07	0.97
30	4.46	2.20	1.56	1.06	0.97
31	4.04		1.49	1.02	
Average	5.61	3.39	2.35	1.43	1.03

Season average = 2.39 cfs

APPENDIX B (cont)

Hoseanna Creek at Bridge 1 (data from USGS)

Daily Average Discharge - 1991 (cfs)

Date	May	Jun	Jul	Aug	Sep
1	140	116	69	26	24
2	150	115	106	26	24
3	143	98	70	25	24
4	141	101	91	29	23
5	201	91	78	28	24
6	189	95	54	71	25
7	175	100	51	93	24
8	177	97	219	53	24
9	164	77	98	41	23
10	116	68	62	35	23
11	85	92	56	32	28
12	84	86	62	30	42
13	87	91	45	30	38
14	102	70	40	29	32
15	110	69	38	29	30
16	115	62	35	28	29
17	114	58	34	29	29
18	105	57	34	29	29
19	114	58	33	28	29
20	219	60	31	28	28
21	146	50	30	27	28
22	144	51	29	27	27
23	134	42	29	31	27
24	135	41	29	30	26
25	155	41	28	27	26
26	140	39	33	26	25
27	132	69	34	26	25
28	112	38	37	25	25
29	107	35	31	25	25
30	108	31	28	25	25
31	95		26	25	
Average	134	69.9	52.9	32.7	27.0

Season average = 63.4 cfs

APPENDIX C

Clinker Creek

Daily Sediment Load - 1991 (tons)

Date	May	Jun	Jul	Aug	Sep
1		3.20	0.50	0.16	0.04
2		3.60	6.91	0.17	0.04
3		3.00	1.00	0.18	0.04
4		3.18	1.50	0.21	0.04
5		3.00	1.00	0.22	0.04
6		2.00	0.50	15.0	0.04
7		1.11	0.40	5.35	0.04
8		1.00	7.60	0.25	0.04
9		2.00	3.51	0.19	0.03
10		1.00	0.90	0.15	0.04
11		2.01	0.50	0.12	0.05
12		1.70	0.26	0.10	0.07
13		1.00	0.58	0.10	0.05
14		0.64	0.52	0.10	0.04
15		0.60	0.48	0.10	0.04
16		0.50	0.43	0.10	0.05
17		0.50	0.38	0.11	0.05
18		0.43	0.32	0.09	0.05
19	15.1	0.50	0.30	0.09	0.05
20	22.0	0.50	0.28	0.08	0.04
21	18.0	0.46	0.24	0.08	0.04
22	15.0	0.40	0.22	0.07	0.04
23	10.0	0.30	0.21	0.08	0.04
24	5.07	0.20	0.21	0.07	0.04
25	4.00	0.17	0.22	0.06	0.04
26	3.50	42.0	0.25	0.05	0.04
27	3.00	28.0	0.23	0.05	0.04
28	2.92	0.45	0.25	0.05	0.04
29	3.00	0.50	0.20	0.05	0.04
30	3.56	1.00	0.16	0.05	0.04
31	2.85		0.14	0.04	
Total	108	105	30.2	23.5	1.29

Season Total = 268 tons

APPENDIX C (cont)

Hoseanna Creek at Bridge 3

Daily Sediment Load - 1991 (tons)

Date	May	Jun	Jul	Aug	Sep
1		385	9290	146	4.52
2		241	6530	121	4.11
3		168	2810	38.1	4.28
4		218	3360	123	4.59
5		116	501	51.9	4.59
6		153	207	994	5.36
7		204	143	981	3.69
8		217	5470	173	4.49
9		60.2	841	71.0	3.52
10		80.7	271	37.2	3.08
11		229	141	29.7	24.2
12		148	350	28.9	91.0
13		191	70.5	18.8	61.4
14		79.3	42.5	24.2	9.90
15		81.4	34.3	22.1	7.65
16	444	60.3	27.1	23.3	5.58
17	437	34.3	40.2	36.9	5.04
18	354	47.7	100	38.5	4.61
19	535	41.6	35.3	15.7	5.73
20	1780	76.2	29.7	18.8	5.40
21	634	73.9	20.1	10.8	4.53
22	606	34.3	18.5	12.9	6.85
23	727	22.0	16.0	48.7	6.76
24	572	32.0	25.3	28.5	7.83
25	690	29.2	12.3	13.5	8.01
26	548	21.5	69.4	8.08	10.7
27	431	964	144	11.2	5.20
28	270	46.3	151	8.65	4.88
29	243	26.7	52.7	6.87	4.43
30	260	16.9	42.5	6.10	4.18
31	169	25.8	5.26		
Total	8700	4100	31000	3150	326

Season total = 47,300 tons

APPENDIX D

Sediment samples collected

Type: g - grab sample
i - automated Isco sample
c - composited Isco sample

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Clinker Creek	22-Apr-91	1005	130	88.4	1.25	g
Clinker Creek	19-May-91	1700	500	1000	5.61	g
Clinker Creek	20-May-91	1559	400	1120	7.30	g
Clinker Creek	24-May-91	1415	450	324	5.80	g
Clinker Creek	28-May-91	1507	80	236	4.60	g
Clinker Creek	30-May-91	1430	100	305	4.32	g
Clinker Creek	31-May-91	1320	90	266	3.98	g
Clinker Creek	01-Jun-91	1815	290	763	6.02	i
Clinker Creek	01-Jun-91	1900	400	1160	6.24	i
Clinker Creek	01-Jun-91	1945	300	774	6.46	i
Clinker Creek	01-Jun-91	2030	230	606	6.61	i
Clinker Creek	01-Jun-91	2115	190	1410	6.76	i
Clinker Creek	01-Jun-91	2200	170	437	6.71	i
Clinker Creek	01-Jun-91	2245	150	333	6.66	i
Clinker Creek	01-Jun-91	2330	130	357	6.60	i
Clinker Creek	02-Jun-91	15	110	306	6.56	i
Clinker Creek	02-Jun-91	100	100	175	6.53	i
Clinker Creek	02-Jun-91	145	110	269	6.40	i
Clinker Creek	02-Jun-91	230	90	189	6.28	i
Clinker Creek	02-Jun-91	315	85	208	6.17	i
Clinker Creek	02-Jun-91	400	80	184	6.06	i
Clinker Creek	02-Jun-91	445	75	183	5.90	i
Clinker Creek	02-Jun-91	530	55	268	5.78	i
Clinker Creek	02-Jun-91	615	55	163	5.65	i
Clinker Creek	02-Jun-91	700	50	182	5.55	i
Clinker Creek	02-Jun-91	745	50	149	5.42	i
Clinker Creek	02-Jun-91	830	55	190	5.36	i
Clinker Creek	02-Jun-91	915	50	171	5.25	i
Clinker Creek	02-Jun-91	1000	50	178	5.16	i
Clinker Creek	02-Jun-91	1045	55	255	5.12	i
Clinker Creek	02-Jun-91	1130	50	190	5.10	i
Clinker Creek	04-Jun-91	934	37	284	4.16	g
Clinker Creek	07-Jun-91	1056	38	106	3.88	g
Clinker Creek	11-Jun-91	847	70	196	3.80	g
Clinker Creek	14-Jun-91	830	40	80.4	3.35	g
Clinker Creek	14-Jun-91	1440	60	64.0	3.30	g
Clinker Creek	18-Jun-91	856	39	55.3	2.86	g
Clinker Creek	21-Jun-91	146	40	60.6	2.80	g
Clinker Creek	25-Jun-91	955	40	25.6	2.45	g
Clinker Creek	26-Jun-91	2115	2200	8080	7.10	i
Clinker Creek	26-Jun-91	2200	10200	27200	7.50	i

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Clinker Creek	26-Jun-91	2245	4000	18600	6.80	i
Clinker Creek	26-Jun-91	2330	1400	16900	6.47	i
Clinker Creek	27-Jun-91	15	2300	10900	9.09	i
Clinker Creek	27-Jun-91	100	1200	9930	9.70	i
Clinker Creek	27-Jun-91	145	1300	4190	9.75	i
Clinker Creek	27-Jun-91	230	1200	3460	9.48	i
Clinker Creek	27-Jun-91	315	550	2100	8.79	i
Clinker Creek	27-Jun-91	400	360	1450	7.82	i
Clinker Creek	27-Jun-91	445	350	1290	7.75	i
Clinker Creek	27-Jun-91	530	220	1020	7.63	i
Clinker Creek	27-Jun-91	615	180	889	7.15	i
Clinker Creek	27-Jun-91	700	150	545	6.77	i
Clinker Creek	27-Jun-91	745	100	387	6.12	i
Clinker Creek	27-Jun-91	830	95	298	5.66	i
Clinker Creek	27-Jun-91	915	80	282	5.31	i
Clinker Creek	27-Jun-91	1000	70	235	5.00	i
Clinker Creek	27-Jun-91	1045	65	200	4.80	i
Clinker Creek	27-Jun-91	1130	60	171	4.60	i
Clinker Creek	27-Jun-91	1215	50	156	4.40	i
Clinker Creek	27-Jun-91	1300	50	157	4.20	i
Clinker Creek	27-Jun-91	1345	55	152	4.10	i
Clinker Creek	27-Jun-91	1430	45	116	4.00	i
Clinker Creek	28-Jun-91	830	31	59.8	2.80	g
Clinker Creek	02-Jul-91	835	170	776	3.30	g
Clinker Creek	04-Jul-91	833	170	986	3.61	g
Clinker Creek	09-Jul-91	947	75	283	4.60	g
Clinker Creek	12-Jul-91	1340	33	35.5	2.73	g
Clinker Creek	16-Jul-91	853	45	55.2	2.20	g
Clinker Creek	19-Jul-91	852	28	82.4	1.90	g
Clinker Creek	23-Jul-91	837	30	25.3	1.70	g
Clinker Creek	26-Jul-91	909	40	58.3	1.75	g
Clinker Creek	30-Jul-91	830	39	50.8	1.60	g
Clinker Creek	02-Aug-91	1051	29	16.9	1.60	g
Clinker Creek	06-Aug-91	910	27	1880	3.60	g
Clinker Creek	07-Aug-91	130	2300	5580	4.41	i
Clinker Creek	07-Aug-91	215	1200	2270	4.45	i
Clinker Creek	07-Aug-91	300	1100	1980	4.36	i
Clinker Creek	07-Aug-91	345	500	958	3.90	i
Clinker Creek	07-Aug-91	430	600	646	3.56	i
Clinker Creek	07-Aug-91	515	240	471	3.46	i
Clinker Creek	07-Aug-91	600	220	435	3.40	i
Clinker Creek	07-Aug-91	645	270	504	3.29	i
Clinker Creek	07-Aug-91	730	180	358	3.24	i
Clinker Creek	07-Aug-91	815	180	371	3.19	i
Clinker Creek	07-Aug-91	900	190	423	3.09	i
Clinker Creek	07-Aug-91	945	150	309	3.01	i
Clinker Creek	07-Aug-91	1030	110	241	2.95	i
Clinker Creek	07-Aug-91	1115	100	226	2.89	i
Clinker Creek	07-Aug-91	1200	95	223	2.88	i

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Clinker Creek	07-Aug-91	1245	95	213	2.86	i
Clinker Creek	07-Aug-91	1330	85	196	2.75	i
Clinker Creek	07-Aug-91	1415	85	171	2.65	i
Clinker Creek	07-Aug-91	1500	80	166	2.56	i
Clinker Creek	07-Aug-91	1545	70	130	2.54	i
Clinker Creek	07-Aug-91	1630	70	151	2.52	i
Clinker Creek	09-Aug-91	840	31	66.5	1.70	g
Clinker Creek	13-Aug-91	855	26	16.0	1.35	g
Clinker Creek	16-Aug-91	1515	25	18.3	1.31	g
Clinker Creek	20-Aug-91	842	26	17.5	1.28	g
Clinker Creek	22-Aug-91	1315	28	13.9	1.20	g
Clinker Creek	23-Aug-91	832	25	17.2	1.25	g
Clinker Creek	27-Aug-91	829	25	21.4	1.10	g
Clinker Creek	30-Aug-91	1005	26	16.0	1.10	g
Clinker Creek	02-Sep-91	855	26	15.8	1.06	g
Clinker Creek	06-Sep-91	1250	26	19.0	1.02	g
Clinker Creek	10-Sep-91	845	29	16.3	0.95	g
Clinker Creek	13-Sep-91	1010	34	27.2	1.05	g
Clinker Creek	17-Sep-91	835	25	14.8	1.11	g
Clinker Creek	20-Sep-91	925	60	37.0	1.05	g
Clinker Creek	24-Sep-91	825	27	21.4	1.02	g
Clinker Creek	25-Sep-91	1235	30	20.9	1.02	g
Clinker Creek	27-Sep-91	845	32	19.2	0.99	g
Clinker Creek	01-Oct-91	1110	31	20.9	0.99	g
Clinker Creek	04-Oct-91	815	29	15.4	0.95	g
Clinker Creek	08-Oct-91	1445	90	84.0	0.89	g
Hoseanna Cr at Brd 3	16-May-91		850	1430	115	c
Hoseanna Cr at Brd 3	17-May-91		750	1420	114	c
Hoseanna Cr at Brd 3	18-May-91		800	1250	105	c
Hoseanna Cr at Brd 3	19-May-91		1100	1740	114	c
Hoseanna Cr at Brd 3	20-May-91		1800	3020	219	c
Hoseanna Cr at Brd 3	21-May-91		1000	1610	146	c
Hoseanna Cr at Brd 3	22-May-91		900	1560	144	c
Hoseanna Cr at Brd 3	23-May-91		1100	2010	134	c
Hoseanna Cr at Brd 3	24-May-91		900	1570	135	c
Hoseanna Cr at Brd 3	25-May-91		1100	1650	155	c
Hoseanna Cr at Brd 3	26-May-91		950	1450	140	c
Hoseanna Cr at Brd 3	27-May-91		750	1210	132	c
Hoseanna Cr at Brd 3	28-May-91		550	893	112	c
Hoseanna Cr at Brd 3	29-May-91		550	843	107	c
Hoseanna Cr at Brd 3	30-May-91		320	894	108	c
Hoseanna Cr at Brd 3	31-May-91		230	659	95	c
Hoseanna Cr at Brd 3	01-Jun-91		450	1230	116	c
Hoseanna Cr at Brd 3	02-Jun-91		330	778	115	c
Hoseanna Cr at Brd 3	03-Jun-91		240	634	98	c
Hoseanna Cr at Brd 3	04-Jun-91		290	799	101	c
Hoseanna Cr at Brd 3	05-Jun-91		160	473	91	c
Hoseanna Cr at Brd 3	06-Jun-91		230	598	95	c

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Brd 3	07-Jun-91		280	758	100	c
Hoseanna Cr at Brd 3	08-Jun-91		290	831	97	c
Hoseanna Cr at Brd 3	09-Jun-91		170	290	77	c
Hoseanna Cr at Brd 3	10-Jun-91		130	440	68	c
Hoseanna Cr at Brd 3	11-Jun-91		330	921	92	c
Hoseanna Cr at Brd 3	12-Jun-91		250	639	86	c
Hoseanna Cr at Brd 3	13-Jun-91		250	777	91	c
Hoseanna Cr at Brd 3	14-Jun-91		150	420	70	c
Hoseanna Cr at Brd 3	15-Jun-91		150	437	69	c
Hoseanna Cr at Brd 3	16-Jun-91		140	361	62	c
Hoseanna Cr at Brd 3	17-Jun-91		120	219	58	c
Hoseanna Cr at Brd 3	18-Jun-91		120	310	57	c
Hoseanna Cr at Brd 3	19-Jun-91		100	266	58	c
Hoseanna Cr at Brd 3	20-Jun-91		170	471	60	c
Hoseanna Cr at Brd 3	21-Jun-91		130	548	50	c
Hoseanna Cr at Brd 3	22-Jun-91		120	250	51	c
Hoseanna Cr at Brd 3	23-Jun-91		85	194	42	c
Hoseanna Cr at Brd 3	24-Jun-91		100	289	41	c
Hoseanna Cr at Brd 3	25-Jun-91		90	264	41	c
Hoseanna Cr at Brd 3	26-Jun-91		75	204	39	c
Hoseanna Cr at Brd 3	27-Jun-91		1600	5180	69	c
Hoseanna Cr at Brd 3	28-Jun-91		200	452	38	c
Hoseanna Cr at Brd 3	29-Jun-91		130	283	35	c
Hoseanna Cr at Brd 3	30-Jun-91		85	202	31	c
Hoseanna Cr at Brd 3	01-Jul-91		4300	14800	69	c
Hoseanna Cr at Brd 3	01-Jul-91	2130	14000	101000	275	i
Hoseanna Cr at Brd 3	01-Jul-91	2230	28700	129000	380	i
Hoseanna Cr at Brd 3	02-Jul-91	2330	16900	82300	284	i
Hoseanna Cr at Brd 3	02-Jul-91	30	11300	70300	381	i
Hoseanna Cr at Brd 3	02-Jul-91	130	16000	67100	271	i
Hoseanna Cr at Brd 3	02-Jul-91	230	8100	37300	204	i
Hoseanna Cr at Brd 3	02-Jul-91	330	5200	26000	154	i
Hoseanna Cr at Brd 3	02-Jul-91	430	1800	4390	140	i
Hoseanna Cr at Brd 3	02-Jul-91		4000	15900	106	c
Hoseanna Cr at Brd 3	03-Jul-91		4500	14900	70	c
Hoseanna Cr at Brd 3	04-Jul-91		3100	13700	91	c
Hoseanna Cr at Brd 3	05-Jul-91		400	2380	78	c
Hoseanna Cr at Brd 3	06-Jul-91		260	1420	54	c
Hoseanna Cr at Brd 3	07-Jul-91		550	1040	51	c
Hoseanna Cr at Brd 3	08-Jul-91		650	2490	219	c
Hoseanna Cr at Brd 3	09-Jul-91		1000	3180	98	c
Hoseanna Cr at Brd 3	10-Jul-91		500	1620	62	c
Hoseanna Cr at Brd 3	11-Jul-91		400	933	56	c
Hoseanna Cr at Brd 3	12-Jul-91		850	2090	62	c
Hoseanna Cr at Brd 3	13-Jul-91		270	581	45	c
Hoseanna Cr at Brd 3	14-Jul-91		190	394	40	c
Hoseanna Cr at Brd 3	15-Jul-91		170	335	38	c
Hoseanna Cr at Brd 3	16-Jul-91		140	287	35	c
Hoseanna Cr at Brd 3	17-Jul-91		140	438	34	c

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Brd 3	18-Jul-91		400	1090	34	c
Hoseanna Cr at Brd 3	19-Jul-91		180	397	33	c
Hoseanna Cr at Brd 3	20-Jul-91		160	355	31	c
Hoseanna Cr at Brd 3	21-Jul-91		110	248	30	c
Hoseanna Cr at Brd 3	22-Jul-91		90	237	29	c
Hoseanna Cr at Brd 3	23-Jul-91		85	205	29	c
Hoseanna Cr at Brd 3	24-Jul-91		85	323	29	c
Hoseanna Cr at Brd 3	25-Jul-91		85	162	28	c
Hoseanna Cr at Brd 3	26-Jul-91		260	779	33	c
Hoseanna Cr at Brd 3	27-Jul-91		650	1570	34	c
Hoseanna Cr at Brd 3	28-Jul-91		380	1510	37	c
Hoseanna Cr at Brd 3	29-Jul-91		200	630	31	c
Hoseanna Cr at Brd 3	30-Jul-91		230	563	28	c
Hoseanna Cr at Brd 3	31-Jul-91		130	368	26	c
Hoseanna Cr at Brd 3	01-Aug-91		1200	2080	26	c
Hoseanna Cr at Brd 3	02-Aug-91		1200	1730	26	c
Hoseanna Cr at Brd 3	03-Aug-91		160	565	25	c
Hoseanna Cr at Brd 3	04-Aug-91		450	1570	29	c
Hoseanna Cr at Brd 3	05-Aug-91		220	687	28	c
Hoseanna Cr at Brd 3	06-Aug-91		1400	5190	71	c
Hoseanna Cr at Brd 3	07-Aug-91		1200	3910	93	c
Hoseanna Cr at Brd 3	08-Aug-91		370	1210	53	c
Hoseanna Cr at Brd 3	09-Aug-91		230	642	41	c
Hoseanna Cr at Brd 3	10-Aug-91		170	394	35	c
Hoseanna Cr at Brd 3	11-Aug-91		160	344	32	c
Hoseanna Cr at Brd 3	12-Aug-91		150	357	30	c
Hoseanna Cr at Brd 3	13-Aug-91		110	233	30	c
Hoseanna Cr at Brd 3	14-Aug-91		140	310	29	c
Hoseanna Cr at Brd 3	15-Aug-91		120	283	29	c
Hoseanna Cr at Brd 3	16-Aug-91		170	308	28	c
Hoseanna Cr at Brd 3	17-Aug-91		180	472	29	c
Hoseanna Cr at Brd 3	18-Aug-91		150	492	29	c
Hoseanna Cr at Brd 3	19-Aug-91		100	207	28	c
Hoseanna Cr at Brd 3	20-Aug-91		110	249	28	c
Hoseanna Cr at Brd 3	21-Aug-91		70	148	27	c
Hoseanna Cr at Brd 3	22-Aug-91		80	177	27	c
Hoseanna Cr at Brd 3	23-Aug-91		170	582	31	c
Hoseanna Cr at Brd 3	24-Aug-91		100	352	30	c
Hoseanna Cr at Brd 3	25-Aug-91		75	185	27	c
Hoseanna Cr at Brd 3	26-Aug-91		55	115	26	c
Hoseanna Cr at Brd 3	27-Aug-91		70	160	26	c
Hoseanna Cr at Brd 3	28-Aug-91		55	128	25	c
Hoseanna Cr at Brd 3	29-Aug-91		40	102	25	c
Hoseanna Cr at Brd 3	30-Aug-91		40	90.4	25	c
Hoseanna Cr at Brd 3	31-Aug-91		38	78.0	25	c
Hoseanna Cr at Brd 3	01-Sep-91		38	69.9	24	c
Hoseanna Cr at Brd 3	02-Sep-91		33	63.4	24	c
Hoseanna Cr at Brd 3	03-Sep-91		37	66.1	24	c
Hoseanna Cr at Brd 3	04-Sep-91		34	74.0	23	c

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr at Brd 3	05-Sep-91		32	70.9	24	c
Hoseanna Cr at Brd 3	06-Sep-91		30	79.4	25	c
Hoseanna Cr at Brd 3	07-Sep-91		28	57.0	24	c
Hoseanna Cr at Brd 3	08-Sep-91		31	69.3	24	c
Hoseanna Cr at Brd 3	09-Sep-91		29	56.7	23	c
Hoseanna Cr at Brd 3	10-Sep-91		26	49.6	23	c
Hoseanna Cr at Brd 3	11-Sep-91		100	321	28	c
Hoseanna Cr at Brd 3	12-Sep-91		210	803	42	c
Hoseanna Cr at Brd 3	13-Sep-91		160	599	38	c
Hoseanna Cr at Brd 3	14-Sep-91		50	115	32	c
Hoseanna Cr at Brd 3	15-Sep-91		40	94.5	30	c
Hoseanna Cr at Brd 3	16-Sep-91		39	71.3	29	c
Hoseanna Cr at Brd 3	17-Sep-91		35	64.4	29	c
Hoseanna Cr at Brd 3	18-Sep-91		35	59.0	29	c
Hoseanna Cr at Brd 3	19-Sep-91		38	73.3	29	c
Hoseanna Cr at Brd 3	20-Sep-91		35	71.6	28	c
Hoseanna Cr at Brd 3	21-Sep-91		45	60.0	28	c
Hoseanna Cr at Brd 3	22-Sep-91		45	94.0	27	c
Hoseanna Cr at Brd 3	23-Sep-91		55	92.9	27	c
Hoseanna Cr at Brd 3	24-Sep-91		60	112	26	c
Hoseanna Cr at Brd 3	25-Sep-91		55	114	26	c
Hoseanna Cr at Brd 3	26-Sep-91		75	159	25	c
Hoseanna Cr at Brd 3	27-Sep-91		40	77.1	25	c
Hoseanna Cr at Brd 3	28-Sep-91		35	72.4	25	c
Hoseanna Cr at Brd 3	29-Sep-91		37	65.7	25	c
Hoseanna Cr at Brd 3	30-Sep-91		36	62.0	25	c
Hoseanna Cr at Brd 3	01-Oct-91		60	50.5		c
Hoseanna Cr at Brd 3	02-Oct-91		30	44.2		c
Hoseanna Cr at Brd 3	03-Oct-91		34	52.2		c
Hoseanna Cr at Brd 3	04-Oct-91		37	63.2		c
Hoseanna Cr at Brd 3	05-Oct-91		31	49.6		c
Hoseanna Cr at Brd 3	06-Oct-91		34	52.3		c
Hoseanna Cr at Brd 3	07-Oct-91		50	116		c
Hoseanna Cr at Brd 3	08-Oct-91		31	50.0		c
Hoseanna Cr ab Clinker Cr	19-May-91	1705	800	1730		g
Hoseanna Cr ab Clinker Cr	20-May-91	1604	900	1830		g
Hoseanna Cr ab Clinker Cr	30-May-91	1425	380	844		g
Hoseanna Cr ab Clinker Cr	31-May-91	1316	190	447		g
Hoseanna Cr ab Clinker Cr	04-Jun-91	930	170	527		g
Hoseanna Cr ab Clinker Cr	07-Jun-91	1054	120	349		g
Hoseanna Cr ab Clinker Cr	11-Jun-91	843	280	758		g
Hoseanna Cr ab Clinker Cr	14-Jun-91	825	95	612		g
Hoseanna Cr ab Clinker Cr	14-Jun-91	1525	55	419		g
Hoseanna Cr ab Clinker Cr	18-Jun-91	902	100	341		g
Hoseanna Cr ab Clinker Cr	21-Jun-91	1350	95	327		g
Hoseanna Cr ab Clinker Cr	25-Jun-91	1001	65	274		g
Hoseanna Cr ab Clinker Cr	28-Jun-91	835	130	742		g
Hoseanna Cr ab Clinker Cr	02-Jul-91	845	1300	4470		g

Location	Date	Time	Turbidity (NTU)	TSS (mg/L)	Q (cfs)	Type
Hoseanna Cr ab Clinker Cr	04-Jul-91	840	1800	8600		g
Hoseanna Cr ab Clinker Cr	09-Jul-91	940	900	2880		g
Hoseanna Cr ab Clinker Cr	12-Jul-91	1330	500	1390		g
Hoseanna Cr ab Clinker Cr	16-Jul-91	900	400	352		g
Hoseanna Cr ab Clinker Cr	19-Jul-91	856	190	526		g
Hoseanna Cr ab Clinker Cr	23-Jul-91	849	80	70.6		g
Hoseanna Cr ab Clinker Cr	26-Jul-91	905	190	981		g
Hoseanna Cr ab Clinker Cr	30-Jul-91	827	34	150		g
Hoseanna Cr ab Clinker Cr	02-Aug-91	1046	100	268		g
Hoseanna Cr ab Clinker Cr	06-Aug-91	905	3400	10600		g
Hoseanna Cr ab Clinker Cr	09-Aug-91	839	170	414		g
Hoseanna Cr ab Clinker Cr	13-Aug-91	854	60	156		g
Hoseanna Cr ab Clinker Cr	16-Aug-91	1510	140	172		g
Hoseanna Cr ab Clinker Cr	20-Aug-91	840	35	75.0		g
Hoseanna Cr ab Clinker Cr	22-Aug-91	1330	33	75.9		g
Hoseanna Cr ab Clinker Cr	23-Aug-91	839	280	743		g
Hoseanna Cr ab Clinker Cr	27-Aug-91	833	26	55.2		g
Hoseanna Cr ab Clinker Cr	30-Aug-91	1008	22	46.3		g
Hoseanna Cr ab Clinker Cr	02-Sep-91	905	28	52.1		g
Hoseanna Cr ab Clinker Cr	06-Sep-91	1255	50	96.1		g
Hoseanna Cr ab Clinker Cr	10-Sep-91	840	22	43.2		g
Hoseanna Cr ab Clinker Cr	13-Sep-91	1015	45	145		g
Hoseanna Cr ab Clinker Cr	17-Sep-91	840	18	36.8		g
Hoseanna Cr ab Clinker Cr	20-Sep-91	930	24	44.5		g
Hoseanna Cr ab Clinker Cr	24-Sep-91	830	20	42.4		g
Hoseanna Cr ab Clinker Cr	25-Sep-91	1235	18	24.2		g
Hoseanna Cr ab Clinker Cr	27-Sep-91	850	19	24.1		g
Hoseanna Cr ab Clinker Cr	01-Oct-91	1115	21	29.5		g
Hoseanna Cr ab Clinker Cr	04-Oct-91	820	19	27.3		g
Hoseanna Cr ab Clinker Cr	08-Oct-91	1450	45	98.4		g
Hoseanna Cr ab Sanderson Cr	22-Apr-91	1030	950	2160		g

APPENDIX E

GROUNDWATER

Constituents	Instrument	Method	Detection limit (ppm)
Major ions			
Alkalinity	Electrometric titration (in field)	310.1	0.6
F	DIONEX ion chromatography	300.0	0.01
Cl	DIONEX ion chromatography	300.0	0.01
NO_3	DIONEX ion chromatography	300.0	0.02
PO_4	DIONEX ion chromatography	300.0	0.1
SO_4	DIONEX ion chromatography	300.0	0.01
Na	Flame atomic absorption spectrophotometry	273.1	0.1
K	Flame atomic absorption spectrophotometry	258.1	0.01
Ca	Direct current plasma emission spectrophotometry		AES 0029
0.01			
Mg	Direct current plasma emission spectrophotometry		AES 0029
0.01			
Trace metals			
As	AA, hydride	206.3	0.004
Al	DCP	AES 0029	0.002
Ba	DCP	AES 0029	0.001
Be	DCP	AES 0029	1.0
Cd	DCP	AES 0029	0.001
Cu	DCP	AES 0029	0.01
Cr	DCP	AES 0029	0.001
Fe dissolved	0.45um filter, DCP	AES 0029	0.03
Fe total	unfiltered, HCl digestion, DCP	AES 0029	0.03
Mn	DCP	AES 0029	0.005
Ni	DCP	AES 0029	0.05
Pb	DCP	AES 0029	0.03
Zn	DCP	AES 0029	0.02
Other determinations			
Total dissolved solids	calculated from analytical data		
pH	pH meter (field)	150.1	
Specific conductance	conductivity meter (field)	120.1	
Acidity	Electrometric titration (field)	305.1	

APPENDIX E (cont)

SURFACE WATER

Constituents	Instument	Method	Detection limit (ppm)
Major ions			
Alkalinity	Electrometric titration (in field)	310.1	0.6
F	DIONEX ion chromatography	300.0	0.01
Cl	DIONEX ion chromatography	300.0	0.01
NO_3	DIONEX ion chromatography	300.0	0.02
SO_4	DIONEX ion chromatography	300.0	0.01
Na	Flame atomic absorption spectrophotometry	273.1	0.1
K	Flame AA	258.1	0.01
Ca	DCP	AES 0029	0.001
Mg	DCP	AES 0029	0.001
Trace metals			
As	AA, hydride	206.3	0.004
Ba	DCP	AES 0029	0.001
Cd	DCP	AES 0029	0.001
Cu	DCP	AES 0029	0.01
Cr	DCP	AES 0029	0.001
Fe	DCP	AES 0029	0.03
Mn	DCP	AES 0029	0.005
Pb	DCP	AES 0029	0.03
Zn	DCP	AES 0029	0.02
Other determinations			
Total dissolved solids	calculated for analytical data		
pH	pH meter (field)	150.1	
Specific conductance	conductivity meter (field)	120.1	
Acidity	Electrometric titration (field)	305.1	
Temperature	Meter (field)	170.1	
Dissolved oxygen	Meter (field)	360.1	
Color	spectrophotometer (lab)	110.3	1 PCU
Settleable solids	Imhoff cone (field)	160.5	0.1 ml/l
Total suspended solids	Filtration (lab)	160.2	1 mg/l
Turbidity	Turner turbidimeter	180.1	0.1 NTU

APPENDIX F

Surface Water

SITE	DATE	TIME	Tw	pH	Acidity	DO	% SAT	Color	TSS	TURB	SS	Q
HOSEANNA B1	08 JUN 87	1708	13.3	6.70	3.50	10.5	100	20	1850	700	1.4	36.4
	03 AUG 87	1630	16.5	6.79	4.60	9.5	100	25	198	100	0.1	31.7
	14 SEP 87	1540	4.1	7.56	7.90	14.4	100	30	625	180	0.5	35.5
	23 MAY 88	1840	9.2	7.24	4.25	10.6	96	80	2360	440	1.3	46.2
	19 JUL 88	1500	20.1	7.32	2.19	8.3	95	30	253	38	0.1	23.0
	08 SEP 88	1230	5.9	7.84	2.50	12.9	100	30	78.6	36	Tr	26.4
	21 SEP 89	1110	4.0	7.65	2.72	14.0	100	45	234	55	Tr	22.9
	13 SEP 90	1100	6.2	7.39		12.5	100	30	427	230	0.7	115
	02 NOV 90	1530	0.6	7.12				30	17.2	15	Tr	24.2
	14 MAR 91	1400	0.4	6.87				20	21.0	22	Tr	14.1
	25 SEP 91	0910	3.0	8.09	3.15	9.8	73	30	131	60	Tr	26.2
HOSEANNA B3	08 JUN 87	1510	13.1	6.68	6.10	10.7	100	15	1970	600	2.0	41.8
	03 AUG 87	1515	15.6	6.85	5.70	10.0	100	40	275	95	Tr	36.9
	14 SEP 87	1400	2.0	7.36	8.10	15.4	100	25	378	120	Tr	26.4
	23 MAY 88	1620	8.6	7.19	5.90	12.4	100	70	1440	340	0.8	42.4
	19 JUL 88	1010	12.2	7.76	2.75	14.1	100	30	292	45	0.8	24.7
	08 SEP 88	1000	3.0	7.92	2.32	14.0	100	20	84.2	30	Tr	24.0
	21 SEP 89	0825	2.8	7.65	4.08	14.5	100	55	113	55	Tr	19.7
	13 SEP 90	0915	5.5	7.10		12.6	100	30	578	210	0.6	114
	02 NOV 90	1235	0.6	7.18				35	66.9	35	Tr	21.4
	14 MAR 91	1610	0.5	6.84				25	16.9	29	Tr	12.0
	25 SEP 91	1000	2.8	7.63	3.84	12.4	91	30	80.9	55	Tr	24.8

All units are mg/l except:

Water Temp (Tw) - ^{o}C
pH - pH units
Color - PCU
Turbidity - NTU
Settleable Solids (SS) - ml/l
Discharge (Q) - cfs
Conductivity - umhos/cm at 25 ^{o}C
Alkalinity - mg/l as $CaCO_3$

Ground Water

SITE	DATE	TIME	Tw	pH	Acidity	DO	% SAT	Color	TSS	TURB	SS	Q
GAMW 3	24 MAY 88	1650	2.4	6.40	66.6							
	18 JUL 88	1450	3.9	6.15	147							
	07 SEP 88	1415	1.5	5.96	278							
	20 SEP 89	1432	1.1	6.15	163							
	12 SEP 90	1447	2.3	6.11	121							
	08 OCT 91	1300	2.5	6.05	154							
GAMW 4	25 MAY 88	1000	1.2	6.70	32.5							
	18 JUL 88	1700	1.9	6.95	56.3							
	07 SEP 88	1650	1.9	6.35	83.3							
	20 SEP 89	1802	1.8	6.10	95.3							
	12 SEP 90	1305	1.9	6.15	55.4							
	24 SEP 91	1415	3.8	6.23	74.1							
GAMW 5	25 MAY 88	1710	4.9	6.30	129							
	19 JUL 88	1200	3.7	6.24	224							
	08 SEP 88	1100	2.3	6.36	302							
	21 SEP 89	1840	3.9	6.02	332							
	22 SEP 89	0925	3.4	6.04	381							
	13 SEP 90	1730	3.0	5.83	284							
	25 SEP 91	1150	3.2	5.80	314							

All units are mg/l except:

Water Temp (Tw) - ^oC
pH - pH units

Color - PCU
Turbidity - NTU
Settleable Solids (SS) - ml/l
Discharge (Q) - cfs

Conductivity - umhos/cm at 25 ^oC
Alkalinity - mg/l as $CaCO_3$

APPENDIX F (cont)

Surface Water

SITE	DATE	Cond	TDS	Ca	Mg	Na	K	ALK	F	Cl	NO3	SO4	PO4
HOSEANNA B1	08 JUN 87	456	207	25.3	17.8	14.6	3.99	103	0.16	14.1	21.6	47.2	<DL
	03 AUG 87	583	236	33.9	22.1	15.1	5.08	120	0.20	20.6	0.26	67.2	<DL
	14 SEP 87	631	254	36.0	25.5	14.7	5.14	140	0.20	19.1	0.20	69.5	<DL
	23 MAY 88	459	250	36.3	32.6	6.78	1.03	106	0.63	47.0	0.21	61.6	<DL
	19 JUL 88	571	322	45.9	38.5	13.4	3.45	129	0.80	62.3	0.27	79.7	<DL
	08 SEP 88	570	285	36.2	24.9	30.9	4.58	130	0.81	32.2	1.41	76.2	<DL
	21 SEP 89	638	325	46.0	21.6	45.9	5.50	139	0.78	38.6	0.85	82.4	<DL
	13 SEP 90	352	214	28.9	20.2	13.7	2.34	105	0.45	15.2	0.66	70.0	<DL
	02 NOV 90	522	299	38.4	24.5	27.3	4.70	134	0.55	39.8	1.82	81.5	<DL
	14 MAR 91	705	380	38.8	25.8	55.1	5.92	150	0.72	75.9	1.46	86.7	<DL
	25 SEP 91	533	284	39.0	25.9	35.8	4.42	142	0.67	19.3	0.16	73.9	<DL
HOSEANNA B3	08 JUN 87	441	184	25.6	18.2	14.6	3.80	94	0.09	12.2	0.23	53.0	<DL
	03 AUG 87	554	230	31.6	22.3	14.7	4.68	116	0.17	15.3	0.09	71.4	<DL
	14 SEP 87	582	248	34.7	26.5	14.7	4.70	133	0.16	14.9	0.05	72.8	<DL
	23 MAY 88	433	242	36.7	33.7	5.63	0.97	100	0.56	38.5	0.26	65.9	<DL
	19 JUL 88	516	318	44.8	38.4	11.8	3.22	125	0.75	60.6	0.26	82.9	<DL
	08 SEP 88	532	275	35.4	25.6	23.2	3.99	139	0.79	24.5	1.16	77.4	<DL
	21 SEP 89	580	316	42.5	24.9	35.3	4.90	141	0.76	36.8	0.82	85.4	<DL
	13 SEP 90	357	209	28.7	20.1	11.2	2.55	100	0.45	13.7	0.62	71.4	<DL
	02 NOV 90	508	286	34.9	25.8	24.1	4.15	130	0.53	32.0	1.69	84.4	<DL
	14 MAR 91	640	349	40.0	27.2	42.0	5.36	146	0.69	55.0	1.42	90.2	<DL
	25 SEP 91	491	274	38.3	26.0	27.4	3.93	145	0.65	14.8	0.16	76.0	<DL

APPENDIX F (cont)

Ground Water

SITE	DATE	Cond	TDS	Ca	Mg	Na	K	ALK	F	Cl	NO3	SO4	PO4
GAMW 3	24 MAY 88	1562	826	64.8	35.9	164	19.3	346	0.80	248	<0.02	85.4	<DL
	18 JUL 88	1538	820	55.6	18.6	195	20.5	354	0.81	245	<0.02	71.7	<DL
	07 SEP 88	1645	795	45.9	22.4	187	27.6	373	0.84	201	<0.02	86.9	<DL
	20 SEP 89	1400	831	49.8	26.7	208	34.4	358	0.17	212	1.46	83.4	<DL
	12 SEP 90	1030	602	32.1	13.2	165	24.1	324	0.91	115	0.18	57.6	<DL
	08 OCT 91	653	479	31.9	11.0	132	16.2	270	0.80	45.7	0.08	79.4	<DL
GAMW 4	25 MAY 88	415	233	35.8	9.06	5.62	45.1	186	1.01	3.85	0.06	21.3	<DL
	18 JUL 88	504	277	42.8	12.9	8.56	47.9	230	1.43	3.84	<0.02	21.8	<DL
	07 SEP 88	445	256	30.6	9.51	6.73	55.8	204	1.18	3.54	<0.02	25.9	<DL
	20 SEP 89	425	246	7.30	3.52	75.3	13.4	199	0.93	3.89	0.42	21.5	<DL
	12 SEP 90	410	207	6.55	2.78	64.8	15.2	151	0.67	6.58	<DL	20.2	<DL
	24 SEP 91	439	273	7.83	3.10	83.3	15.4	225	0.81	2.85	<DL	25.0	<DL
GAMW 5	25 MAY 88	4013	3034	190	133	792	10.5	454	4.39	1570	<0.02	61.7	<DL
	19 JUL 88	7841	3580	283	193	893	15.6	645	6.23	1730	<0.02	72.0	<DL
	08 SEP 88	6905	3440	251	89.6	956	11.2	638	6.10	1680	<0.02	63.1	<DL
	21 SEP 89	3193	1716	182	58.9	360	29.7	532	2.84	680	2.12	81.0	<DL
	22 SEP 89	5945	3184	245	78.6	806	52.1	646	3.37	1540	2.36	68.8	<DL
	13 SEP 90	4030	2112	204	64.0	480	26.3	501	1.97	962	1.78	71.3	<DL
	25 SEP 91	1230	975	174	49.5	198	10.1	452	2.30	197	0.40	72.9	<DL

APPENDIX F (cont)

Surface Water

All units are mg/l

SITE	DATE	Al	As	B	Ba	Be	Cd	Co	Cr
HOSEANNA B1	08 JUN 87	0.057	<0.004	0.14	0.098	<1.0	<0.001	<0.01	<0.002
	03 AUG 87	0.057	<0.004	0.19	0.117	<1.0	<0.001	<0.01	<0.002
	14 SEP 87	0.050	<0.004	0.19	0.116	<1.0	<0.001	<0.01	<0.002
	23 MAY 88	0.058	<0.004	0.13	0.110	<1.0	<0.001	0.009	<0.002
	19 JUL 88	0.061	<0.004	0.15	0.107	<1.0	<0.001	0.010	0.003
	08 SEP 88	0.057	<0.004	0.17	0.099	<1.0	<0.001	0.011	0.002
	20 SEP 89	0.054	<0.004	0.16	0.087	<1.0	<0.001	0.005	<0.002
	13 SEP 90								
	02 NOV 90								
	14 MAR 91								
	25 SEP 91								
HOSEANNA B3	08 JUN 87	0.055	<0.004	0.13	0.089	<1.0	<0.001	<0.01	<0.002
	03 AUG 87	0.066	<0.004	0.17	0.096	<1.0	<0.001	<0.01	<0.002
	14 SEP 87	0.055	<0.004	0.19	0.094	<1.0	<0.001	<0.01	<0.002
	23 MAY 88	0.057	<0.004	0.12	0.091	<1.0	<0.001	0.012	<0.001
	19 JUL 88	0.059	<0.004	0.14	0.076	<1.0	<0.001	0.011	0.002
	08 SEP 88	0.059	<0.004	0.16	0.064	<1.0	<0.001	0.012	0.005
	20 SEP 89	0.059	<0.004	0.15	0.067	<1.0	<0.001	0.007	<0.002
	13 SEP 90								
	02 NOV 90								
	14 MAR 91								
	25 SEP 91								

APPENDIX F (cont)

Ground Water

All units are mg/l

SITE	DATE	Al	As	B	Ba	Be	Cd	Co	Cr
GAMW 3	24 MAY 88	0.287	<0.004	1.71	0.404	<1.0	<0.001	0.027	0.004
	18 JUL 88	0.276	0.004	1.53	0.398	<1.0	<0.001	0.041	0.003
	07 SEP 88	0.290	<0.004	2.82	0.242	<1.0	0.002	0.040	0.003
	20 SEP 89	0.260	<0.004	2.26	0.121	<1.0	<0.001	0.024	<0.001
	12 SEP 90								
	08 OCT 91								
GAMW 4	25 MAY 88	0.175	0.009	0.45	0.420	<1.0	0.017	0.009	<0.001
	18 JUL 88	0.211	<0.004	0.50	0.355	<1.0	<0.001	<0.001	<0.001
	07 SEP 88	0.191	0.016	0.29	0.135	<1.0	0.042	0.002	<0.001
	20 SEP 89	0.154	<0.004	0.38	0.114	<1.0	0.003	<0.001	<0.001
	12 SEP 90								
	08 OCT 91								
GAMW 5	25 MAY 88	0.271	0.010	1.53	1.37	<1.0	<0.001	0.412	0.004
	19 JUL 88	0.252	0.005	1.41	1.13	<1.0	<0.001	0.267	0.005
	08 SEP 88	0.261	0.013	2.90	1.32	<1.0	0.005	0.345	0.001
	21 SEP 89	0.226	0.007	1.29	0.571	<1.0	<0.001	0.254	0.003
	22 SEP 89	0.278	0.006	2.60	0.943	<1.0	<0.001	0.326	0.006
	13 SEP 90								
	08 OCT 91								

APPENDIX F (cont)

Surface Water

SITE	DATE	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
HOSEANNA B1	08 JUN 87	<0.01		0.09		0.20	0.021		<0.03	1.92	<0.02
	03 AUG 87	<0.01		<0.03		0.24	0.022		<0.03	2.31	<0.02
	14 SEP 87	<0.01		<0.03		0.32	0.023		<0.03	2.24	<0.02
	23 MAY 88	<0.01		0.08		0.47	0.019		<0.03	5.52	<0.02
	19 JUL 88	<0.01		0.04		0.41	0.020		<0.03	6.12	<0.02
	08 SEP 88	<0.01		<0.03		0.36	0.022		<0.03	5.43	<0.02
	20 SEP 89	<0.01		<0.03		0.40	0.029		<0.03	6.28	<0.02
	13 SEP 90		12.1	0.19	0.32	0.14					
	02 NOV 90		0.77	0.25	0.30	0.28					
	14 MAR 91		4.01	0.32	0.43	0.40					
	25 SEP 91		2.74	<0.03	0.33	0.19					
HOSEANNA B3	08 JUN 87	<0.01		0.08		0.23	0.018		<0.03	1.91	<0.02
	03 AUG 87	<0.01		0.07		0.26	0.018		<0.03	2.29	0.03
	14 SEP 87	<0.01		<0.03		0.33	0.023		<0.03	1.72	0.04
	23 MAY 88	<0.01		0.07		0.41	0.019		<0.03	5.54	<0.02
	19 JUL 88	<0.01		<0.03		0.39	0.022		<0.03	6.24	<0.02
	08 SEP 88	<0.01		<0.03		0.38	0.020		<0.03	5.43	<0.02
	20 SEP 89	<0.01		<0.03		0.39	0.025		<0.03	6.06	<0.02
	13 SEP 90		14.2	0.22	0.38	0.14					
	02 NOV 90		4.23	0.52	0.37	0.36					
	14 MAR 91		3.98	0.45	0.01	0.01					
	25 SEP 91		2.56	<0.03	0.33	0.18					

NOTE:
(T) = Total
(D) = Dissolved

APPENDIX F (cont)

Ground Water

SITE	DATE	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
GAMW 3	24 MAY 88	0.13	47.2	39.2		1.23	0.026	<DL	0.109	8.98	0.21
	18 JUL 88	0.15	43.4	31.9		1.19	0.041	<DL	0.111	5.34	0.23
	07 SEP 88	<0.01	36.1	18.0		1.26	0.028	<DL	0.108	7.89	0.10
	20 SEP 89	<0.01	29.5	25.1		1.01	0.028	<DL	0.085	8.07	<0.02
	12 SEP 90		27.5	26.0	1.17	1.11					
	08 OCT 91		124	24.8	2.40	0.92					
GAMW 4	25 MAY 88	0.01	12.7	8.45		0.66	0.012	<DL	<0.03	9.34	<0.02
	18 JUL 88	0.02	12.1	7.12		0.78	0.017	<DL	<0.03	11.2	<0.02
	07 SEP 88	0.81	7.75	3.78		0.58	0.013	<DL	<0.03	8.57	<0.02
	20 SEP 89	<0.01	14.8	12.0		0.47	<0.01	<DL	<0.03	7.65	<0.02
	12 SEP 90		12.3	11.4	0.59	0.57					
	24 SEP 91		15.5	12.6	0.66	0.56					
GAMW 5	25 MAY 88	0.13	57.7	45.8		10.9	0.143	<DL	0.175	10.4	0.30
	19 JUL 88	0.02	59.2	46.1		7.32	0.124	<DL	0.168	12.4	0.34
	08 SEP 88	<0.01	42.8	22.7		8.30	0.112	<DL	0.209	10.2	0.20
	21 SEP 89	<0.01	41.2	34.0		3.91	0.121	<DL	0.198	8.95	0.04
	22 SEP 89	<0.01	56.9	50.0		6.39	0.142	<DL	0.213	9.08	0.13
	13 SEP 90		43.0	41.3	4.66	4.55					
	24 SEP 91		34.0	20.4	3.46	2.05					

NOTE:
(T) = Total
(D) = Dissolved