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HYDROLOGIC AND WATER QUALITY STUDY OF HOSEANNA CREEK BASIN NEAR HEALY, ALASKA: 19951996 PROGRESS REPORT

by

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INTRODUCTION

This report summarizes the ground water and surface water data collected in 1995 and 1996, in addition to related data collected since 1987 in the Hoseanna Creek basin. Discussion of surface water is limited to Hoseanna Creek and two minor seeps in the Two Bull Ridge area, while ground water is discussed from the Poker, Runaway Ridge, and Gold Run Pass areas of the basin. These data collection activities are currently carried out by the Alaska Hydrologic Survey (AHS) section of the Division of Mining and Water Management. This section of the Alaska Department of Natural Resources has been maintained since AHS data collection efforts began in the Hoseanna Creek basin, having been previously under the Division of Water and the Division of Geological and Geophysical Surveys.

Hoseanna Creek flows west into the Nenana River approximately three miles north of Healy, Alaska. The total basin area is approximately 48 mi^2. This creek is referenced as Lignite Creek on USGS topographic maps (Healy (D4) quadrangle), although it is referred to as Hoseanna Creek by Usibelli Coal Mine, Inc., the Division of Geological and Geophysical Surveys (Ray and Maurer, 1989), and others. Other reports available regarding the hydrology of the basin include Mack (1987, 1988), Ray (1990, 1992), Ray, Vohden and Roe (199 1), and Ray and Vohden (1992, 1993). Additional information can be found in Scully et al. (198 1), Parks (1983), Wilbur (1987, 1989, 1995), Chacho et al. (1996) and U.S. Geological Survey Water Resource Data--Alaska annual report of data (e.g. USDOI (1995)).

METHODS

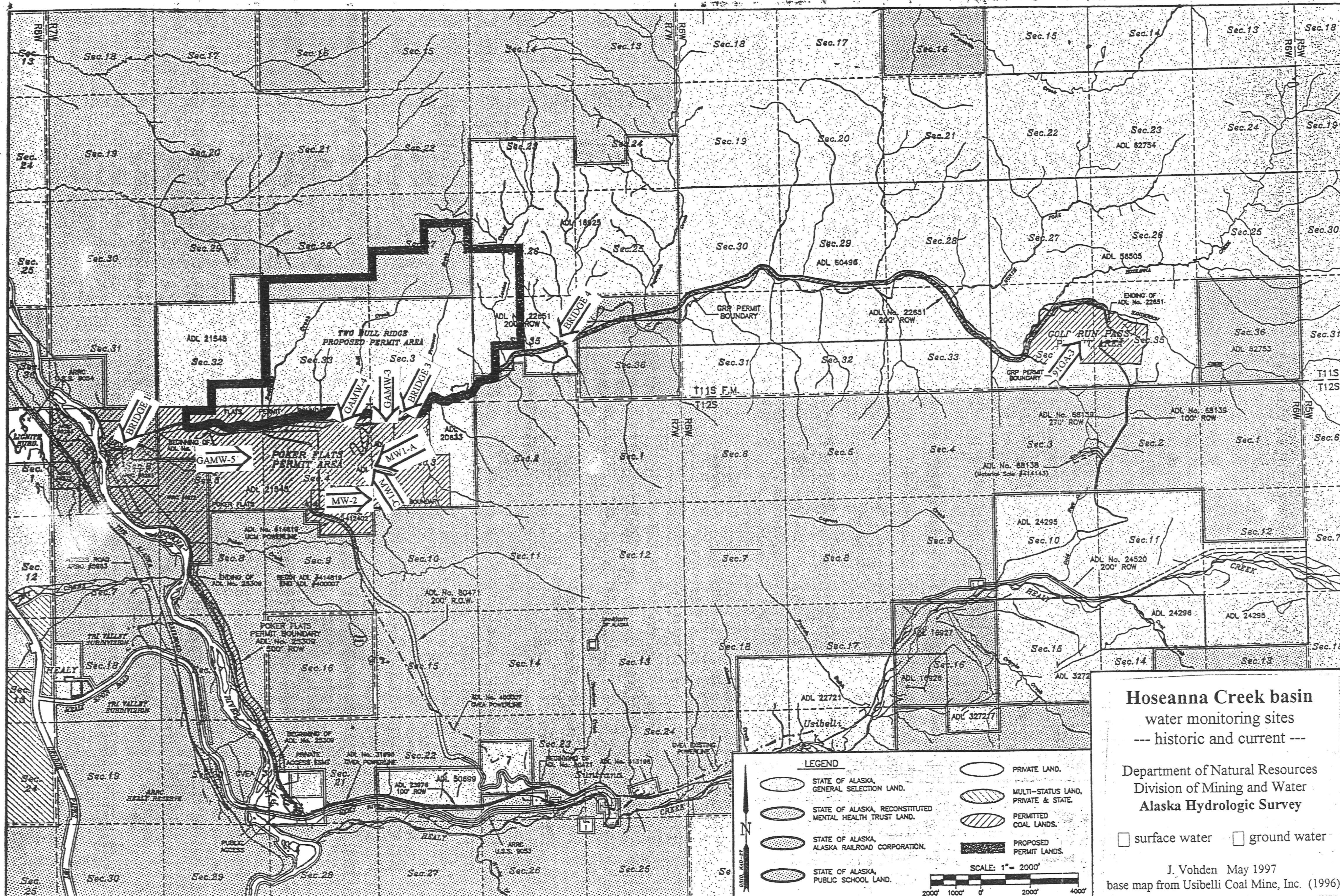
Ground Water

A total of seven wells were investigated in 1995 and 1996. Wells GAMW-3, GAMW-4, and GAMW-5 are located in the Poker and lower Runaway areas and are road accessible. Well 91GA-3 is in the Gold Run Pass/Phase V area and has trail access. Wells MWl-A, MW1-C and MW-2 are in the Runaway Ridge area and also have trail access.

Table 1. Coordinates for ground water monitoring wells in the Hoseanna Creek basin.

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”
91GA-3	148° - 41’ - 30.4”	63” - 55’ - 10.5”
MW1-A	148° - 56’ - 36.9”	63” - 04’ - 49.4”
MWl-C	148° - 54’ - 47.2”	63° - 54’ - 02.4”
MW2	148° - 54’ - 40.6”	63” - 53’ - 53.0”

Monitoring wells are purged using a stainless steel bladder pump (Well Wizard, QED Inc., Ann Arbor, Michigan) to a point where temperature, conductivity and pH stabilize, and when not less than three casing volumes have been pumped. As outlined in the results section, there have been some minor deviations from this methodology. Analytical parameters which are measured in the field include depth to water, temperature, conductivity, pH, and alkalinity. Analytical methods for all parameters are


Hoseanna Creek basin
water monitoring sites
--- historic and current ---
Department of Natural Resources
Division of Mining and Water
Alaska Hydrologic Survey
surface water
ground water
J. Vohden May 1997
base map from Usibelli Coal Mine, Inc. (1996)
LEGEND
STATE OF ALASKA, GENERAL SELECTION LAND.
STATE OF ALASKA, RECONSTITUTED MENTAL HEALTH TRUST LAND.
STATE OF ALASKA, ALASKA RAILROAD CORPORATION.
STATE OF ALASKA, PUBLIC SCHOOL LAND.
PRIVATE LAND.
MULTI-STATUS LAND, PRIVATE & STATE.
PERMITTED COAL LANDS.
PROPOSED PERMIT LANDS.
SCALE: 1" = 2000'
2000' 1000' 0' 2000' 4000'
TWO BULL RIDGE PROPOSED PERMIT AREA
POKER FLATS PERMIT AREA
GOLD RUN PASS PERMIT AREA
BRIDGE 1
BRIDGE 3
BRIDGE 4
GAMW-3
GAMW-4
GAMW-5
MW1-A
MW1-C
MW-2
SIGA-3
T11S F.M.
T12S
R7W
R6W
R5W
HEALY
Usibelli
Suntrana
HEALY CREEK
GRP PERMIT BOUNDARY
ADL 21548
ADL 21545
ADL 18925
ADL No. 22651 200' ROW
ADL 60496
ADL 62754
ADL 58505
ADL 62753
ADL No. 68138 270' ROW
ADL No. 68139 100' ROW
ADL 20833
ADL 24295
ADL 24296
ADL No. 24520 200' ROW
ADL No. 80471 200' R.O.W.
ADL 22721
ADL 18927
ADL 327217
ADL 50699
ADL 23976 100' ROW
POKER FLATS PERMIT BOUNDARY
TRI VALLEY SUBDIVISION
LIGNITE SUBD.
PUBLIC ACCESS
ARRC HEALY RESERVE
UNIVERSITY OF ALASKA

listed in Table 2. After purging, a composite sample is collected in a churn splitter, then divided into appropriate bottles for laboratory analysis. Samples for final field parameters are taken from the churn splitter as well. Four bottles are filled for laboratory analysis: l)filtered, for determining dissolved major anions; 2) filtered and acidified, for determining trace metals and major cations; 3) non-filtered and acidified, for determining total metal concentrations, and 4) non-filtered and non-acidified for determining solids. Filtering is accomplished using 0.45 micron disposable filters; acidification is carried out using ultra-pure nitric acid (J.T. Baker Ultrex) to a pH<2 where specified. Samples are kept cool (<4°C) during shipment to the laboratory.

Table 2. Analytical methods and detection limits.

Parameter	Method	Description[1]	Detection Limit
Acidity	EPA 305.2	Titration	0.1 mg/L
Alkalinity	EPA 310.1	Titration	0.1 mg/L
Calcium	EPA AES 0029	DCP	0.01 mg/L
Chloride	EPA 300.0	IC	10 ug/L
Conductivity	EPA 120.1	Probe	0.5 uSi/cm
Dissolved Oxygen	EPA 360.1	Probe	--
Fluoride	EPA 340.2	ISE	10 ug/L
Hardness	2340 B[2]	Calculation	0.2 mg/L
Hardness	2340C[2]	EDTA Titration	0.1mg/L
Iron	EPA AES 0029	DCP	0.03 mg/L
Magnesium	EPA AES 0029	DCP	0.01 mg/L
Manganese	EPA AES 0029	DCP	0.01 mg/L
Nitrate	EPA 300.0	IC	0.02 mg/L

Table 2 (cont.). Analytical methods and detection limits.

Parameter	Method	Description[1]	Detection Limit
pH	EPA 150.1	Electrometric	--
Phosphate	EPA 300.0	IC	0.1 mg/L
Potassium	EPA 258.1	AA	0.01 mg/L
Residue, Non-Filterable	EPA 160.2	Gravimetric	0.1 mg/L
Settleable Matter	EPA 160.5	Volumetric	0.1 mL/L/hr
Sodium	EPA AES 0029	DCP	0.1 mg/L
Sulfate	EPA 300.0	IC	10 ug/L
Temperature	EPA 170.1	Thermometric	--
Turbidity	EPA 180.1	Nephelometric	0.05 NTU

Notes: 1) DCP=direct current plasma, IC=ion chromatography, AA=atomic absorption spectrometry.

2) American Public Health Association et al, (1992).

Surface Water

Surface water velocities were measured at six-tenths depth, with sufficient number of cross 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 values are calculated using the standard midpoint method (U.S. Dept. Of Interior, 198 1). At Two Bull North and Two Bull South, discharge was measured using the bucket method (Wilbur, 1995) because of low velocities and shallow depths. This method involves the fabrication of a earthen dam and placement of a short length of 4” PVC pipe into which the flow is diverted. Once the stream and pipe reach equilibrium, a calibrated bucket is placed so as to collect the water during a known period of time, from which discharge is calculated. Water quality samples were collected from surface waters using a hand held depth integrated sampler, cornpositing the cross sectional samples into a churn splitter. Analytical procedures carried out in the field include discharge, temperature, dissolved oxygen, pH, conductivity, alkalinity, and settleable solids, Methods for sample treatment and preservation are similar to those collected from ground water.

Water Quality

Prior to the 1996 sampling, analytical procedures not completed in the field were carried out at the Division of Mining and Water Management's Water Quality Laboratory, located on the University of Alaska campus in Fairbanks, Alaska. The laboratory has participated in U.S. Environmental Protection Agency performance evaluation studies and utilizes standard calibration solutions which are NIST certified. Beginning with the 1996 sampling effort, laboratory analyses were completed by Northern Testing Laboratories, Inc., of Fairbanks Alaska. Quality control and quality assurance procedures include those outlined in APHA (1992), USEPA (1983), and USDOI (1977).

RESULTS

Ground Water

There have been some modifications to the ground water wells since this monitoring series began in 1988. Wells GAMW-3, GAMW-4, and GAMW-5 were initially installed by Golder Associates (1987). Due to subsurface movement however, the casings of wells GAMW-3 and GAMW-5 had become pinched over time. This pinching allowed only very narrow tubing to pass through GAMW-3, while GAMW-5 has become completely pinched closed. GAMW-3 has been sampled using the hand-pump method for the years 1992 through 1994. This utilizes a check valve at the bottom of a length of tubing, which is moved up and down to draw water from the well. Well GAMW-5 was not sampled in 1993 and 1994 due to the pinched casing. The two sites were subsequently re-drilled in May 1995 by Tester Drilling (UCM, 1995) in close proximity to the old wells and with specifications designed to replicate the original installations. Unfortunately, sampling during the 1995 series was slowed because the 'new' well GAMW-5 has become pinched beginning at approximately 30 feet below the top of casing. Although the casing was constricted to a diameter of less than one inch, the well was purged successfully as outlined in Table 3, using a 3/4" Teflon bailer. Conductivity had barely stabilized at the time of sampling and the main impetus to sample was the number of full bailers retrieved from the well while trying to keep from stirring up sediments in the bottom of the well casing. This well has exhibited low hydraulic conductivity in the past, as the purging was normally carried out over the course of a full 24 hour period using the bladder pump method. Had purging been continued, sediments would have made the bailer mechanism inoperative hindering any more sampling for a long period of time until they could settle out of solution. Given the circumstances, it was concluded that a satisfactory sample had been collected. Well GAMW-5 was spot-checked on 27 August 1996 for a depth to water measurement, during a visit to the area. This was carried out because of the uncertain nature of the well, and to facilitate planning for the sampling event scheduled for the following month. The depth to water at that time (13:37 on 27 Aug 1997) was 82.45' from top of casing (TOC). Unfortunately, during the three week span until the scheduled sampling time, the well had become completely pinched closed, rendering it unavailable for obtaining a water sample. However, well GAMW-3 was successfully purged and sampled during 1996 using a Teflon bailer.

Surface and subsurface movement was evident in the vicinity of well 91GA-3 (Golder Associates, 1991) during the September 1995 visit. The depth to water was measurable, but nothing larger than the 3/8" depth probe would fit down the well casing. Further investigation proved that this well has become pinched beginning at approximately 10 feet below the top of casing, putting it out of commission with no samples collected in 1995. Wells MWl-A, MW1-C and MW-2 were initially installed by Shannon & Wilson, Inc. (1990) in 1989 and appear in relatively good condition. No sample was collected from MW-2 in 1995, but depth to water was measured at this site (see Table 3) as per the sampling protocol. Water quality has been relatively stable in these wells since monitoring began in the late 1980's. The results of the 1996 sampling as well as historic

Table 3. Initial water level readings and purging protocol for ground water monitoring wells in Hoseanna Creek basin.

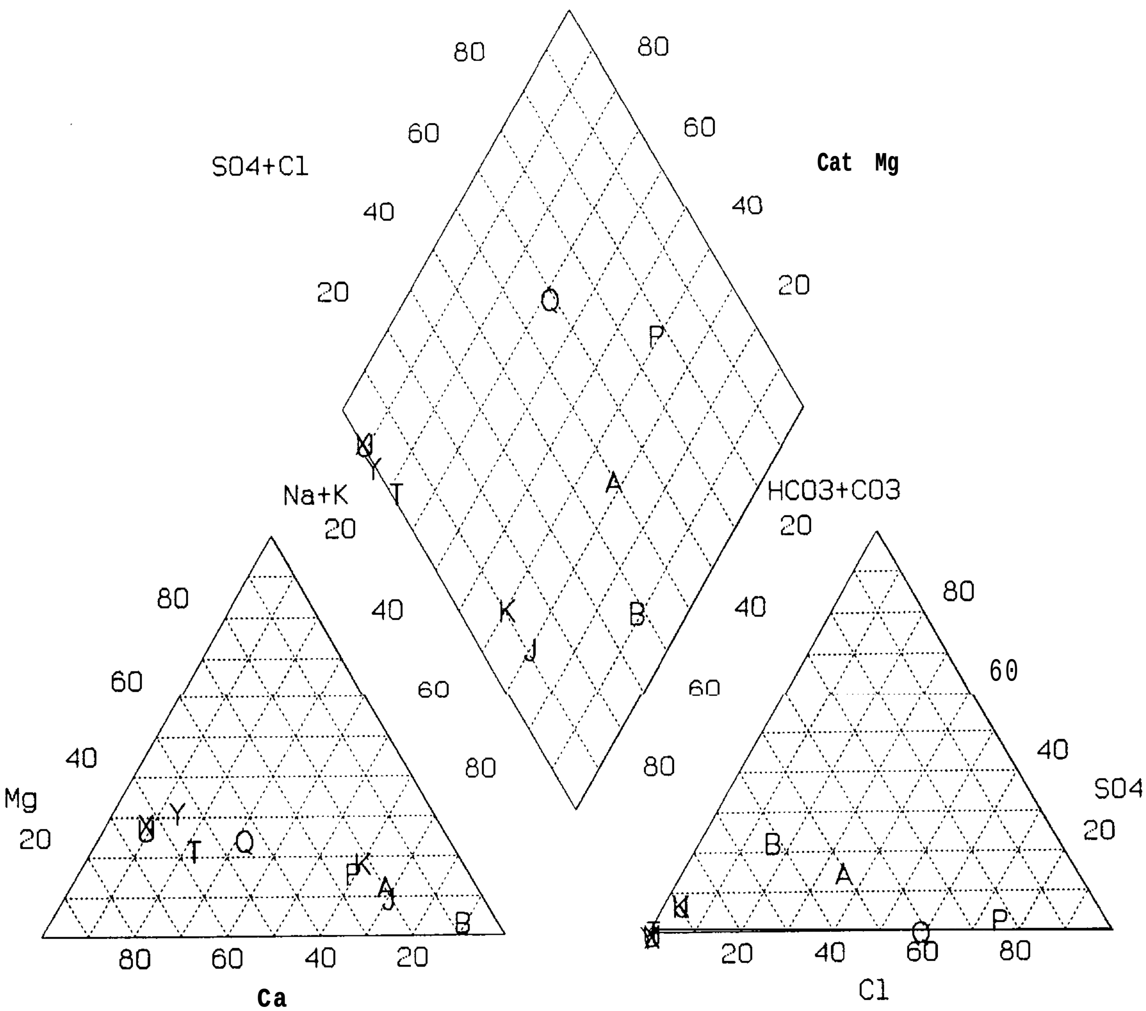
Well ID	Date	Initial Depth to Water[1] (ft)	Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)
GAMW-3	9-15-87	26.86	---	---	---
	5-23-88	25.97	1.5	1.4	---
	5-24-88	27.69	1.2	8.0	---
	7-18-88	27.59	1.3	4.1	5.0
	9-07-88	28.04	1.2	8.0	6.4
	9-20-89	27.82	1.2	5.5	5.7
	9-12-90	26.68	1.4	4.2	5.0
	10-08-91	28.08	1.2	3.4	2.8 [2]
	9-23-92	27.31	1.3	0.4	0.8 [3]
	9-13-93	26.98	1.1	7.0	14 [3]
	9-23-94	27.49	1.3	5.0	6.2 [3]
	9-21-95	26.27	1.4	8.5	11 [4]
	9-12-96	25.56	1.3	11.4	18 [4]
GAMW-4	9-15-87	7.68	---	---	---
	5-24-88	7.96	3.6	6.8	---
	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 [2]
	9-23-92	8.10	3.6	---	---
	9-12-93	9.28	3.4	10.0	11 [2]
	9-23-94	8.65	3.5	13.0	11 [2]
	9-21-95	8.96	3.4	12.0	8.4 [2]
	9-12-96	7.98	3.6	15.0	9.2 [2]
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
	9-07-88	82.87	2.2	---	---
	9-21-89	81.95	2.4	22.0	1.0
	9-12-90	80.13	2.6	19.9	0.8
	9-25-91	82.74	2.3	16.5	0.8
	9-23-92	80.30	2.6	--	--
	9-19-95	82.26	2.1	3.7	1.9 [4]
	8-27-96	82.45	---	---	---
	9-12-96	---	---	---	---

Table 3 (cont.). Initial water level readings andpurgingprotocol for ground water monitorina wells in Hoseanna Creek basin.

Well ID	Date	Initial[1] Depth to Water (ft)	Calc Casing Volume (gal)	Volume Pumped (gal)	Pumping Rate (gal/hr)
MW-1A	11-07-89	44.80	54.8	180	79
	6-21-90	45.45	54.4	165	56
	9-10-90	44.50	54.9	170	58
	9-20-95	44.71	55.0	170	59
MW-1C	6-21-90	61.76	20.4	80	95
	9-l l-90	61.49	20.5	65	75
	9-20-95	61.11	20.7	--	--
MW-2	6-22-90	109.2	4.1	16	12
	9-l l-90	104.8	4.8	24	24
	9-21-95	103.9	4.6	13	22 [4]
91GA-3	9-26-91	115.3	6.5	11	--
	9-19-95	68.11	14.1	--	--

[1] All measurements are from top of PVC casing.
[2] Purged and sampled using peristaltic pump.
[3] Purged and sampled using hand-pump method.
[4] Purged and sampled using Teflon bailer.

data can be found in Appendix B. Well GAMW-5 yielded some aberrant values in 1995, but given that the well was only recently installed, had not been developed, and was purged only moderately before sampling, the values are not unexpected in comparison to the historical data. Although annual trends are not visible in Figure 2, geochemical signatures of the individual wells are consistent with past results. The chemical trends are outlined for well GAMW-4 in Figure 3. This well was chosen because it has been sampled regularly and the well itself has been physically stable since this monitoring series began. Chloride is shown as a solid line only to separate it from the other



A = GAMW-3 -- average of 1988-1995 data
B = GAMW-3 -- September 1996 data

J = GAMW-4 -- average of 1988-1995 data
K = GAMW-4 -- September 1996 data

0 = GAMW-5 -- average of 1988-1995 data
P = GAMW-5 -- September 1996 data

T = MW1-A -- average of 1988-1995 data
U = MW1 -A -- September 1996 data

X = MW2 -- average of 1988-1995 data
Y = MW2 -- September 1996 data

*Figure 2. Piper diagram comparing ground water well data in **Hoseanna** Creek basin.*

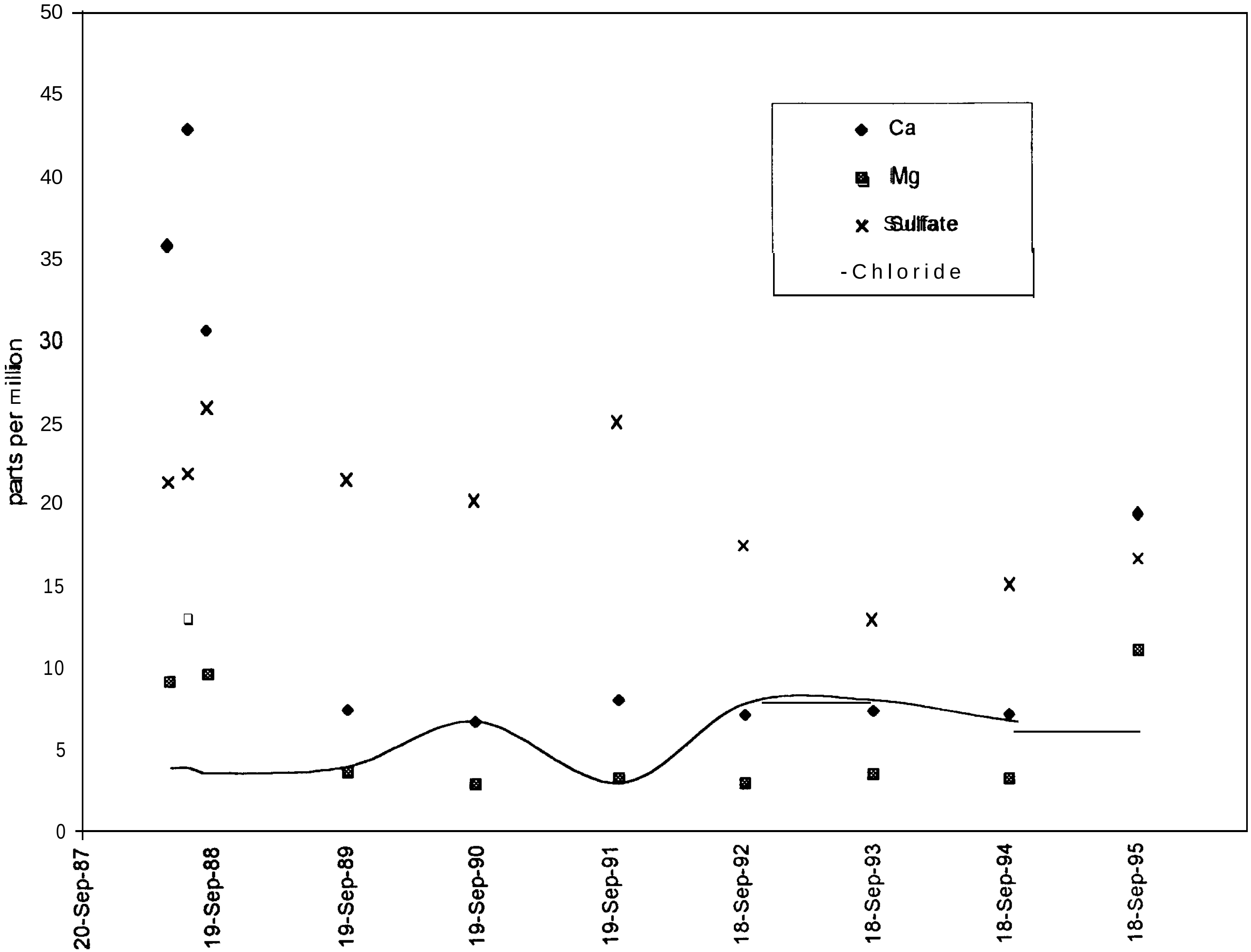


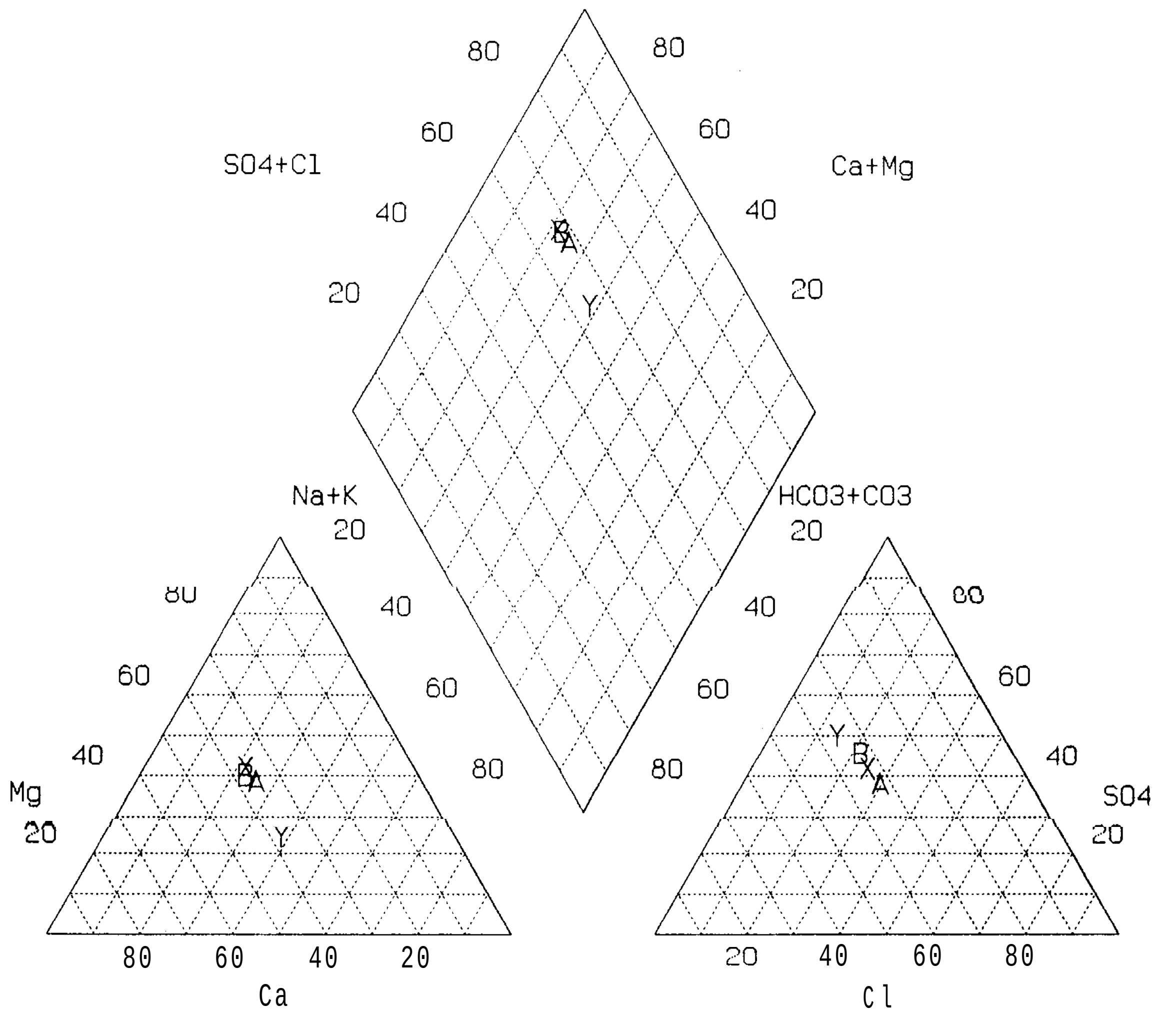
Figure 3. Long term trends of some major constituents in well GAMW-4.

Figure 3. Long term trends of some major constituents in well GAMW-4.

constituents visually. Obviously no statistically valid increasing or decreasing trend is clear in these data. Variation could be attributed to any number of circumstances as will be discussed below in the surface water geochemistry discussion.

Surface Water

Hoseanna Creek is the main receiving water for many small creeks in the basin, As such, the water quality reflects the composite chemistry of numerous smaller sub-basins. The results of sampling in 1995 and 1996, as well as historic data, can be found in Appendix A. As stated in Ray (1993) minor variations in long term trends are difficult to follow with a single annual sampling schedule. Results can be dominated by the water regime for that particular season, month, week, or day when sampling is carried out. Precipitation in one or more sub-basins can affect the surface water quality in Hoseanna Creek significantly, depending on the geology and geochemistry of the particular sub-basin receiving precipitation. This implies that a greater standard deviation would be expected over the long term for any given parameter. Although as seen in Figure 4, results of the 1996 sampling do not differ considerably with the historic average values for these parameters. The relationship of major ions to each other has remained fairly consistent as outlined in Table 4. However, a slight trend is noticed in some major ions sampled at Bridge 1 as seen in Figure 5. Chloride is shown as a solid line only to separate it from the other constituents visually. This conservative tracer appears to vary in concentration, affirming the theory of the effects of sub-basin chemistries. The sulfate ion has shown an increasing concentration over time, although the concentration at



A = Hoseanna Creek Bridge 1 -- average of 1987--1995 data
B = Hoseanna Creek Bridge 3 -- average of 1987--1995 data

X = Hoseanna Creek Bridge 1 -- September 1996
Y = Hoseanna Creek Bridge 3 -- September 1996

Figure 4. Piper diagram comparing surface water sites on Hoseanna Creek.

Table 4. Average percentages of the major ion composition (in meq/l) from Hoseanna Creek monitoring sites for 1987-1996.

	Bridge 3									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Calcium	37	37	37	37	36	33	33	31	36	30
Magnesium	44	51	35	44	40	38	42	38	26	45
Sodium	16	11	26	17	22	26	23	29	35	22
Potassium	3	1	2	2	2	3	2	2	3	3
Bicarbonate	56	47	50	50	59	48	46	36	39	43
Sulfate	34	31	32	36	32	31	35	31	48	40
Chloride	10	22	18	14	9	21	19	34	13	17
Nitrate	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

	Bridge 1									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Calcium	38	36	37	38	34	30	33	31	36	29
Magnesium	43	49	29	41	37	33	42	38	41	42
Sodium	16	14	32	19	27	34	23	29	20	26
Potassium	3	1	2	2	2	3	2	2	2	2
Bicarbonate	56	46	50	50	58	43	46	36	36	42
Sulfate	29	29	31	34	31	27	35	31	44	36
Chloride	12	25	19	16	11	30	19	34	20	22
Nitrate	3	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table 5. Mean values of selected water quality constituents from Hoseanna Creek monitoring sites (I 987-l 996). All values in mg/l unless otherwise noted.

	Bridge 3	Bridge 1
Field Determination		
pH	7.30	7.37
Dissolved oxygen	12.8	11.8
Specific Conductance (umhos/cm)	533	571
Lab Determinations		
Color (pcu)	41	39
Total Suspended Sediment	377	552
Turbidity (NTU)	115	142
Total Dissolved Solids	299	310
Cations		
Calcium	36.9	38.5
Magnesium	27.0	27.3
Sodium	25.0	29.8
Potassium	4.36	4.62
Anions		
Alkalinity	132	135
Sulfate	87.9	84.6
Chloride	34.6	43.1
Nitrate	0.46	1.85

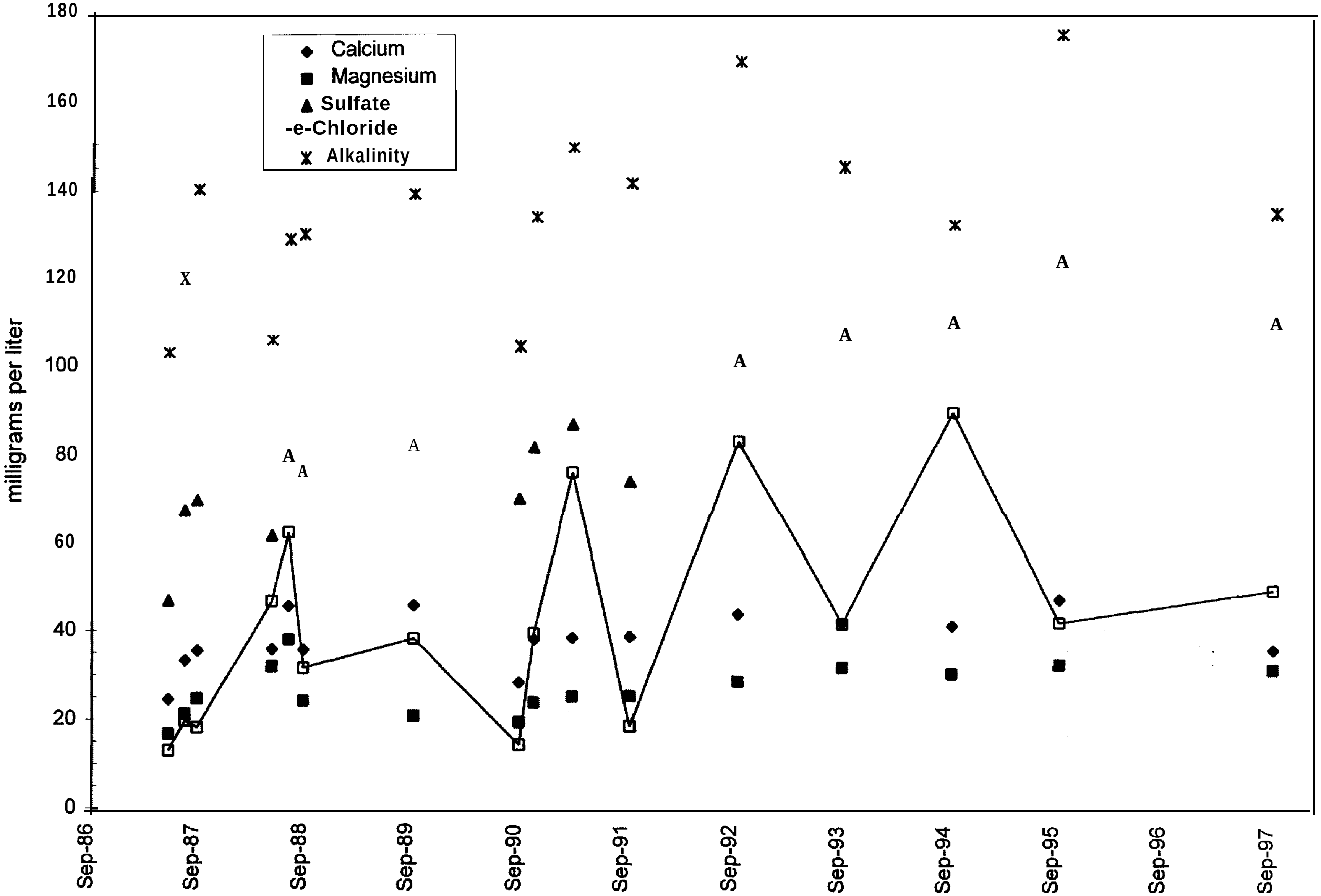


*Figure 5. Long term trends of some major constituents at Bridge 1 on **Hoseanna** Creek.*

Bridge 3 seems to mirror that at Bridge 1 (Figure 6), as do chloride values. This indicates that the increase is not necessarily being caused by the mining activities in the lower portion of the valley, but possibly from precipitation, the increased weathering of materials (Collier et al., 1964), or from the gradual melting of permafrost which is prevalent in the basin (Wilbur, 1995), or other causes. It has been noted at another study site in Interior Alaska, that a disturbed area comprising 5% of the total basin area contributed 35% of the nutrients in basin-wide runoff (Kane, 1996). This illustrates the magnitude of effect that a small anomaly can have. One potential source of sulfate is Sanderson Creek. Parks (1983) analyzed water from several creeks in the basin and found that Sanderson Creek had sulfate concentrations in the range of 210 mg/L to 560 mg/L. Samples collected by the Division of Mining and Water Management in July 199 1 (unpublished data) also indicate elevated levels of sulfate in Sanderson Creek as well as Clear Creek, (formerly referred to as Mattielli Creek). As reported by Scully et al. (1981), Sanderson Creek is underlain by a composition of 80% schist and 20% tertiary sedimentary rocks. The schist in the area frequently contains pyrite-rich components, or even possibly massive sulfide mineralization (Bundtzen, 1997). This has yet to be fully investigated but could lend some insight into the source of the increasing sulfate in Hoseanna Creek. The data currently available do not conclusively verify the source of the sulfate concentrations in Hoseanna Creek.

Two seeps were sampled in the Two Bull Creek basin in September 1995. Although a preliminary seep survey had been completed by Golder Associates in fall 1994, only two

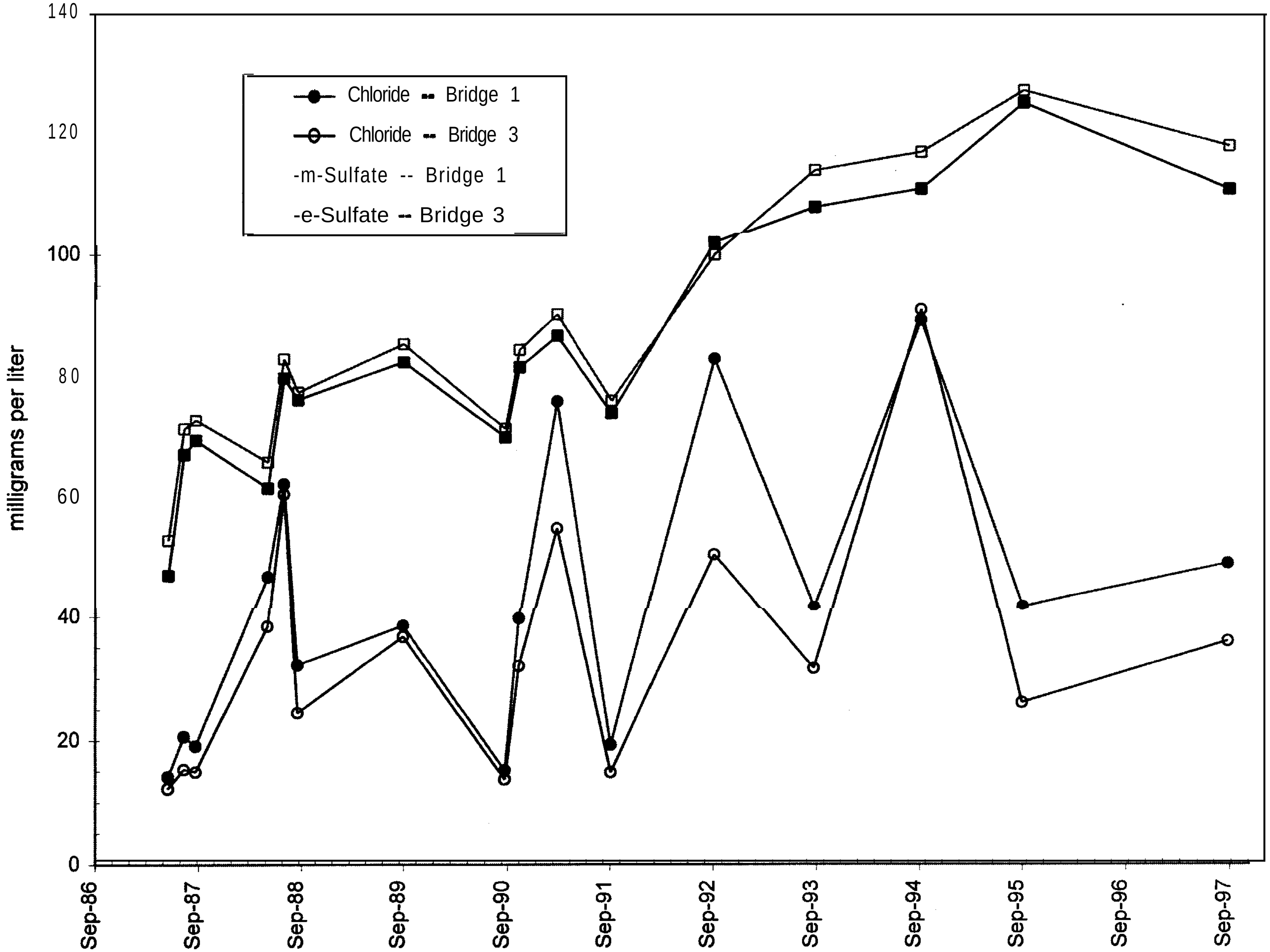
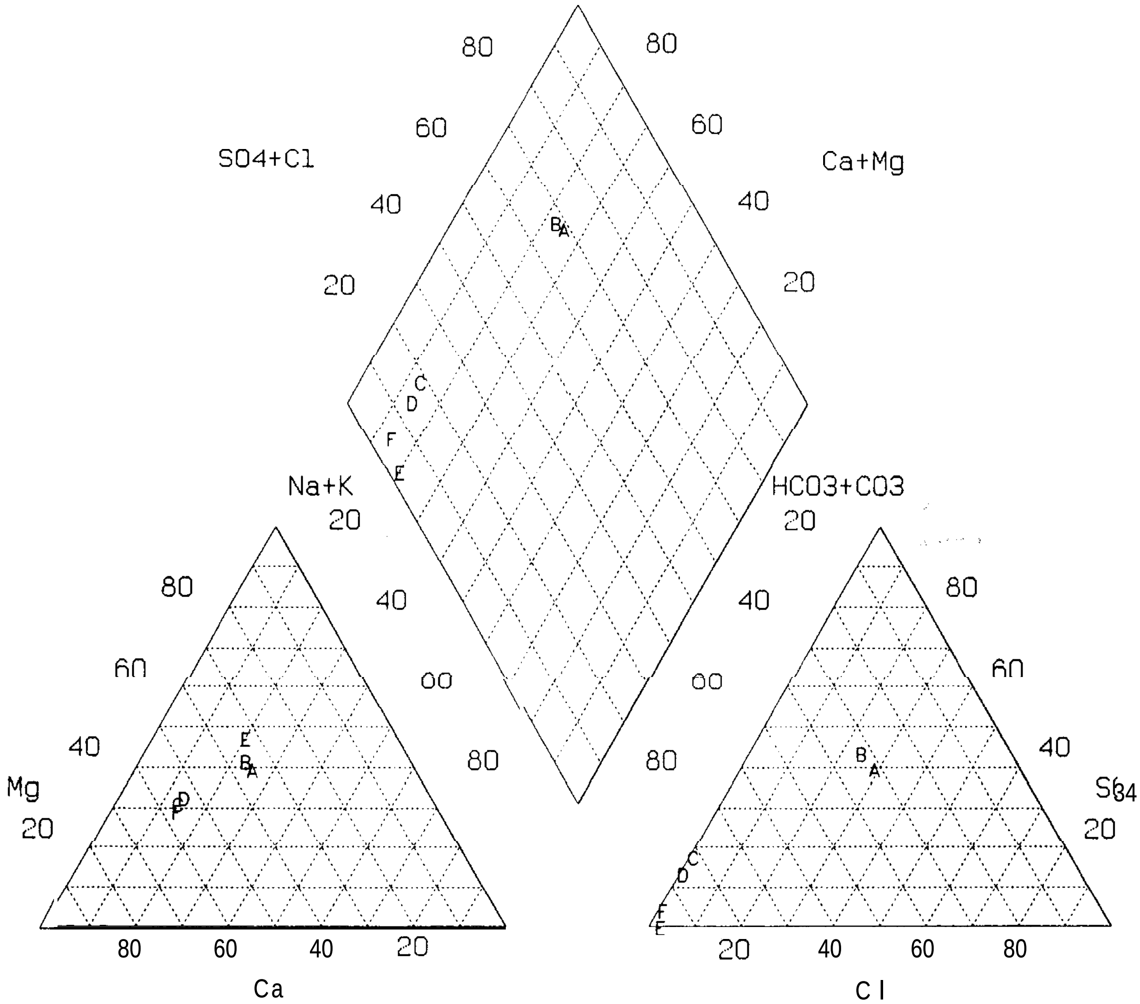


*Figure 6. Chloride and sulfate concentrations over time at Bridge I and Bridge 3 on **Hoseanna** Creek.*

locations had any measurable amount of flow when inspected during the September 1995 sampling. Analytical and field results are found in Appendix C. Figure 7 shows the chemical characteristics of these two waters in the form of a Piper diagram, in relation to Hoseanna Creek at Bridge 1 and Bridge 3 (averaged from sample years 1987-l 996), and Two Bull Creek (just above Hoseanna Creek) when sampled in March 1991 and July 1993 (Division of Mining and Water, unpublished data). Water from the two seeps sampled in 1995 is very 'light' in terms of ionic strength which seems characteristic of the Two Bull basin, and evidently the flow rates are quite variable in these ephemeral seeps. No sampling of these seeps was carried out in 1996.



A = Hoseanna Creek Bridge 1 -- average of 1987--1996 data
B = Hoseanna Creek Bridge 3 -- average of 1987--1996 data

C = Two Bull Creek -- July 1991
D = Two Bull Creek -- March 1993

E = Two Bull North Seep -- September 1995
F = Two Bull South Seep -- September 1995

Figure 7. Piper diagram comparing geochemistry of selected surface water sites in the Hoseanna Creek basin.

CONCLUSIONS

- Overall, the water chemistry for surface and ground waters analyzed has remained fairly consistent since the beginning of this monitoring series.

- Annual variations in the geochemistry of Hoseanna Creek are possibly attributed to sub-basin precipitation events, the effects of surface disturbance on runoff characteristics, or the seasonal hydrologic regime throughout the basin; further investigation into sub-basin geomorphology, water chemistry and precipitation monitoring could be used to predict or explain Hoseanna Creek chemistry.

- Seeps analyzed in the Two Bull Ridge area are of low ionic strength, and are similar in geochemistry to Two Bull Creek itself.

- Given the nature of wells such as GAMW-5, more research should be done to determine what remedial activities, if any, could be utilized to stabilize this well and others like it, located in unstable areas which seem prevalent in the Hoseanna Creek basin. Additionally, a more stable method for installing the well casings could be investigated.

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Appendix A

Surface Water Sampling Results (Historical)

Site	Date	Time	Tw	pH	Acidity	DO	% Sat	Color	TSS	Turbidity	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	444	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	54	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	3.05	9.8	73	30	131	60	tr	26.2
	23 Sep 92	1830	0.0	7.07		13.5		20	258	170	tr	
	12 Sep 93	2135	8.7	8.15	7.0				83.6	40	tr	18.6
	23 Sep 94	1608	5.2	8.19	2.0	13.2	100	10	39.0	22	tr	18.5
	22 Sep 95	0736	8.3	7.5	3.1	11.3	96	10	24.4	17	tr	37.4
	12 Sep 96	1113	3.4	6.7	2.1	13.5	97	180	108	55	tr	31.7
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	342	0.8	42.4
	19 Jul88	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
	23 Sep 92	1740	0.0	7.05		14.0	—	20	182	37	tr	
	12 Sep 93	2100	8.4	7.91	7.0		—	—	117	45	tr	17.2
	23 Sep 94	1415	4.9	7.90	2.0	13.2	100	10	34.3	21	tr	20.6
	22 Sep 95	0958	8.0	7.1	3.0	10.8	95	10	25.5	14	none	35.2
	12 Sep 96	1233	3.3	6.7	2.3	13.0	99	200	179	12	tr	28.1

All units are mg/L except:

Tw (water temp)	°C
pH	pH units
Color	PCU (platinum color units)
Turbidity	NTU (nephelometric turbidity units)
Settleable Solids (SS)	mL/L
Discharge (Q)	cfs (cubic feet per second)
Conductivity	umhos/cm at 25°C
Alkalinity	mg/L as $CaCO_3$

Appendix A (continued)

sire	Date	Cond	TDS	Ca	Mg	Na	K	Alkalinity	F	Cl	NO_3	SO_4	PO_4
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	322	36.3	32.6	6.78	1.03	106	0.63	47.0	0.21	61.6	<DL
	19 Jul 88	571	409	45.9	38.5	13.4	3.45	129	0.80	62.3	0.27	79.7	<DL
	08 Sep 88	570	372	36.2	24.9	30.9	4.58	130	0.81	32.2	1.41	76.2	<DL
	21 Sep 89	638	350	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
	23 Sep92	595	425	44.1	29.2	56.5	8.08	169	0.36	82.9	0.23	102	<DL
	12 Sep 93	604	349	42.1	32.3	32.8	4.27	146	0.30	41.9	0.15	108	co.05
	23 Sep 94	693	405	41.4	30.8	45.4	5.03	133	0.45	89.3	co.02	111	co.05
	22 Sep 95	607	352	47.2	32.8	30.4	5.09	175	0.29	42.1	co.02	125	<0.05
	12 Sep 96	616	373	36.0	31.7	37.6	5.35	136	0.28	49.2	0.25	111	co.04
HoseannaB3	08 Jun 87	441	184	25.6	18.2	14.6	3.80	94	0.09	12.2	0.23	53.0	<DL
	03Aug 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 Mar91	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
	23 Sep 92	535	363	41.6	29.4	37.7	6.29	161	0.35	50.6	0.24	100	<DL
	12 Sep 93	572	330	39.4	32.9	26.5	3.93	136	0.30	31.6	0.20	114	co.05
	23 Sep 94	632	406	39.9	31.6	36.9	4.85	133	0.49	91.0	co.02	117	co.05
	12 Sep 96	580	356	35.0	32.7	30.3	6.01	133	0.34	36.1	0.18	118	<0.04

Appendix A (continued)

Site	Date	Al	As	B	Ba	Be	Cd	Co	Cr
Hoseanna B1	08 Jun 87	0 . 0	<0.004	0.14	0.098	<1.0	<0.001	co.01	co.002
	03 Aug 87	0.057	<0.004	0.19	0.117	<1.0	<0.001	co.01	co.002
	14 Sep 87	0.050	co.004	0.19	0.116	<1.0	<0.001	co.01	co.002
	23 May 88	0.058	co.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	40.004	0.17	0.099	<1.0	<0.001	0.011	0.002
	21 Sep89	0.054	<0.004	0.16	0.087	<1.0	<0.001	0.005	co.002
	13 Sep 90					--	--		
	02 Nov 90	--	--			--	--		
	14 Mar91	--	--				--		
	25 Sep 91	--	-			--	--		
	23 Sep 92			-		--	--		
	12 Sep 93	0.14	0.014		0.11	<0.1	<0.001		0.004
	23 Sep 94		-				--		
	22 Sep 95						--		
	12 Sep 96	4.24	0.004		0.169	<0.0006	0.002		0.008
HoseannaB3	08 Jun 87	0.055	<0.004	0.13	0.089	<1.0	<0.001	co.01	co.002
	03Aug 87	0.066	co.004	0.17	0.096	<1.0	<0.001	co.01	co.002
	14 Sep 87	0.055	co.004	0.19	0.094	<1.0	<0.001	co.01	co.002
	23 May 88	0.057	co.004	0.12	0.091	4.0	<0.001	0.012	<0.002
	19 Jul 88	0.059	co.004	0.14	0.076	<1.0	<0.001	0.011	0.002
	08 Sep 88	0.059	co.004	0.16	0.064	<1.0	<0.001	0.012	0.005
	21 Sep89	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	--	--				--		
	23 Sep 92	--	--				--		
	12 Sep 93	0.14	0.012		0.09	<0.1	<0.001		0.003
	23 Sep 94	--	--				--		
	22 Sep 95	--	--				--		
	12 Sep 96	7.75	0.007		0.197	<0.0006	0.002		0.024

Appendix A (continued)

Site	Date	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
Hoseanna B1	08 Jun 87	co.01		0.09		0.20	0.021		co.03	1.92	co.02
	03Aug 87	co.01		co.03		0.24	0.022		co.03	2.31	co.02
	14 Sep 87	co.01		co.03		0.32	0.023		co.03	2.24	co.02
	23 May 88	co.01		0.08		0.47	0.019		co.03	5.52	co.02
	19 Jul 88	co.01		0.04		0.41	0.020	–	co.03	6.12	<0.02
	08 Sep 88	co.01		co.03		0.36	0.022		co.03	5.43	co.02
	21 Sep89	co.01		<0.03		0.40	0.029		co.03	6.28	co.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	co.03	0.33	0.19					–
	23 Sep 92	–	8.80	0.26	0.53	0.35		–	–		
	12 Sep 93	co.01	4.32	co.03	0.43	0.35		co.03	~0.001		0.29
	23 Sep 94		7.62	1.07	1.68	0.58					
	22 Sep 95	–	6.58	0.79	0.86	0.27					
	12 Sep 96	0.023	6.78	0.04	0.475	0.43		0.042	0.004		0.143
Hoseanna B3	08 Jun 87	<0.01	–	0.08	–	0.23	0.018	–	<0.03	1.91	<0.02
	03Aug 87	co.01		0.07		0.26	0.018		co.03	2.29	0.03
	14 Sep 87	co.01		co.03		0.33	0.023		co.03	1.72	0.04
	23 May88	co.01		0.07		0.41	0.019		co.03	5.54	co.02
	19 Jul 88	co.01		co.03		0.39	0.022		co.03	6.24	co.02
	08 Sep 88	co.01		co.03		0.38	0.020	–	co.03	5.43	co.02
	21 Sep89	co.01		co.03		0.39	0.025		co.03	6.06	co.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	co.03	0.33	0.18			–		
	23 Sep 92		8.92	0.14	0.41	0.22			–	–	
	12 Sep 93	<0.01	5.24	co.03	0.43	0.34		co.03	<0.001		0.30
	23 Sep 94		3.86	2.76	3.95	0.57					
	22 Sep 95		3.61	0.59	1.01	0.47					
	12 Sep 96	0.024	8.26	0.37	0.476	0.417	–	0.041	0.004		0.146

Appendix B

Ground Water Sampling Results (Historical)

Site	Date	Time	Tw	pH	Acidity	DO	% Sat	Color	TSS-	Turbidity	SS
GAMW 1C	20 Jul 88	1805	3.8	6.71	71.4	–	I.	–	–	–	
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	–					
	8 Oct 91	1300	2.5	6.05	154			–			
	23 Sep 92	1530		6.60	–					–	
	13 Sep 93	0900		6.10	350		–				
	23 Sep 94	1236	2.0	6.28	247						
	21 Sep95	1811	1.7	6.19	243					–	
	12 Sep 96	1436	1.1	5.4	220	–	–	–	–	–	–
GAMW4	25 May88	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						
	23 Sep 92	1710		6.22							
	12 Sep 93	1815		6.22	170						
	23 Sep 94	1048	4.2	6.21	174						
	21 Sep95	0810	3.9	6.10	161						
	12 Sep 96	1603	3.6	5.8	151	–	–	–	–	–	–
GAMW5	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						–
	24 Sep 92	2015		5.73							
	19 Sep 95	1850		7.30	174						
	12 Sep 96	–	–	–	I	–	–	–	–	–	–
MW-IA	07 Nov 89	1337	3.3	6.95	43.6						
	21 Jun 90	1600	3.9	7.15	34.5				–		
	10 Sep 90	1830	2.6	6.84	38.7						
	20 Sep 95	1455	3.0	6.20	32.1				–	–	
	4 Oct 96	1059	2.3	6.62	28.7	–	I.	I	–	–	–
MW-IC	21Jun 90	1745	3.9	7.19	32.5	–		..			–
	11 Sep 90	1112	3.0	7.12	34.1	–	–				–
	20 Sep 95	1440		–	–				..		
	4 Oct 96	1103	–	–	–	–	–	–	I.	–	–
MW-2	22 Jun 90	1025	3.8	6.83	28.4			–			
	11 Sep 90	1810	3.5	6.52	29.1			..		..	
	21 Sep 95	1400	3.6	6.17	30.7						
	4 Oct 96	1309	1.4	6.2	22.1						

Appendix B (continued)

Site	Date	Cond	TDS	Ca	Mg	Na	K	Alkalinity	F	Cl	NO_3	SO4	PO_4
GAMW 1C	20 Jul 88	3318	2038	52.2	57.1	661	64.4	1680	0.59	171	co.02	24.1	5.35
GAMW3	24 May 88	1562	826	64.8	35.9	164	19.3	346	0.80	248	co.02	85.4	<DL
	18 Jul 88	1538	820	55.6	18.6	195	20.5	354	0.81	245	co.02	71.7	<DL
	07 Sep 88	1645	795	45.9	22.4	187	27.6	373	0.84	201	co.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
	23 Sep 92	556	457	39.8	15.1	81.0	12.7	352	0.24	32.6	0.26	63.8	<DL
	13 Sep 93	1090	667	30.3	14.1	184	18.8	333	0.26	91.8	<0.02	88.0	co.05
	23 Sep 94	976	640	28.3	12.7	155	17.6	315	0.24	48.6	0.06	146	co.05
	21 Sep 95	830	627	5.79	2.43	80	16.5	334	0.19	50.4	co.02	102	co.05
	12 Sep 96	1436	630	58	70.8	160	40.7	302	0.16	106	0.01	133	0.09
GAMW4	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	co.02	21.8	<DL
	07 Sep 88	445	256	30.6	9.51	6.73	55.8	204	1.18	3.54	co.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	co.02	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
	23 Sep 92	421	249	6.91	2.77	73.5	15.5	208	0.58	7.60	<DL	17.4	<DL
	12 Sep 93	473	256	7.11	3.28	73.3	15.3	207	0.55	7.77	0.20	12.9	co.05
	23 Sep 94	424	270	6.90	3.00	82.6	24.3	203	0.48	6.49	0.16	15.1	co.05
	21 Sep 95	460	241	19.4	11.1	59.3	10.3	234	0.32	5.68	co.02	16.6	co.05
	12 Sep 96	487	290	5.9	2.92	86.5	14.8	232	0.49	8.58	co.02	16.5	<0.04
GAMW5	25 May 88	4013	3034	190	133	792	10.5	454	4.39	1570	co.02	61.7	<DL
	19 Jul 88	7841	3580	283	193	893	15.6	645	6.23	1730	co.02	72.0	<DL
	08 Sep 88	6905	3440	251	89.6	956	11.2	638	6.10	1680	co.02	63.1	<DL
	21 Sep89	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
	24 Sep 92	813	885	146	49.0	162	11.3	423	0.12	191	co.02	72.0	<DL
	19 Sep 95	4800	2517	327	84.6	187	18.7	1054	0.51	537	co.02	12.5	co.05
	12 Sep 96												
MW-IA	07 Nov 89	315	180	39.1	8.57	20.7	1.90	180	0.49	0.38	0.30	0.87	<DL
	21 Jun 90	257	104	24.3	6.37	6.60	1.10	104	0.34	0.63	0.13	1.83	<DL
	10 Sep 90	295	118	25.4	7.20	10.6	1.36	117	0.28	0.75	co.02	2.40	<DL
	20 Sep95	298	104	36.1	9.74	5.17	1.24	171	0.31	0.80	co.02	0.92	co.05
	4 Oct 96	315	183	33.6	8.91	15.0	1.39		0.04	0.20	0.02	1.26	0.04
MW-1C	21 Jun 90	319	171	22.7	6.24	38.6	2.38	163	0.57	1.28	0.49	0.58	<DL
	11 Sep 90	343	191	26.0	7.31	39.6	2.79	187	0.40	1.16	co.02	1.36	<DL
	20 Sep 95												
	4 Oct 96												
MW-2	22 Jun 90	246	139	36.8	10.3	4.87	1.25	138	0.49	0.83	0.93	0.44	<DL
	11 Sep 90	247	138	34.6	10.1	4.77	1.08	143	0.32	0.84	<DL	0.33	<DL
	21 Sep 95	254	124	21.8	7.91	5.81	0.93	148	0.28	0.22	co.02	0.14	co.05
	4 Oct 96	251	149	38.8	13.2	5.43	4.27		0.05	0.43	0.09	0.34	0.08

Appendix B (continued)

Site	Date	Al	As	B	Ba	Be	Cd	Co	Cr
GAMW 1C	20 Jul 88	0.294	<0.004	<0.01	0.245	<1.0	<0.001	0.023	0.002
GAMW3	24 May 88	0.287	co.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	co.004	2.82	0.242	<1.0	0.002	0.040	0.003
	20 Sep 89	0.260	co.004	2.26	0.121	<1.0	<0.001	0.024	<0.001
	12 Sep 90								
	08 Oct 91								–
	23 Sep 92								
	13 Sep 93	0.17	<0.001		0.18	<0.1	<0.001		0.002
	23 Sep 94		-			-			
	21 Sep 95						-		
	12 Sep 96	211	0.011		2.50	0.0016	0.003		0.391
GAMW4	25 May 88	0.175	0.009	0.45	0.420	4.0	0.017	0.009	<0.001
	18 Jul 88	0.211	co.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	co.004	0.38	0.114	<1.0	0.003	<0.001	<0.001
	12 Sep 90								
	24 Sep 91								
	23 Sep 92	-							
	12 Sep 93	0.12	<0.001		0.27	co.1	<0.001		<0.001
	23 Sep 94								
	21 Sep 95							-	
	12 Sep 96	1.04	0.005		0.252	<0.0006	0.0001		0.002
GAMW 5	25 May 88	0.271	0.010	1.53	1.37	4.0	<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								
	25 Sep 91							-	
	24 Sep 92								
	19 Sep 95								
	12 Sep 96								
MW-1A	07 Nov 89	0.049	co.004	0.05	0.317	4.0	<0.001	~0.001	~0.001
	21 Jun 90	0.015	0.009	0.08	0.627		<0.001	~0.001	~0.001
	10 Sep 90	0.012	0.006	0.09	0.495		<0.001	<0.001	<0.001
	20 Sep 95								
	4 Oct 96	<0.061	0.003		0.366	<0.0006	~0.0001		<0.002
MW-1C	21 Jun 90	0.024	co.004	0.09	0.600		<0.001	~0.001	<0.001
	11 Sep 90	0.028	<0.004	0.09	0.517		<0.001	<0.001	<0.001
	20 Sep 95			-			-		
	4 Oct 96				–				-
MW-2	22 Jun 90	0.005	co.004	0.10	0.600		<0.001	~0.001	<0.001
	11 Sep 90	0.013	0.004	0.09	0.660		<0.001	<0.001	~0.001
	21 Sep 95						..		
	4 Oct 96	13.2	0.004		0.65		0.0004		0.022

Appendix B (continued)

Site	Date	Cu	Fe (T)	Fe (D)	Mn (T)	Mn (D)	Mo	Ni	Pb	Si	Zn
GAMW 1C	20 Jul 88	c o . 0 1	6.35	0.28	0.12	0.032	<0.01	<0.04	0.05	6.79	
GAMW3	24 May 88	0.13	47.2	39.2	1.23	0.026	<0.01	co.04	0.109	8.98	0.21
	18 Jul 88	0.15	43.4	37.9	1.19	0.041	co.01	<0.04	0.111	5.34	0.23
	07 Sep 88	co.01	36.1	18.0	1.26	0.028	co.01	co.04	0.108	7.89	0.10
	20 Sep 89	co.01	29.5	25.1	1.01	0.028	co.01	co.04	0.085	8.07	co.02
	12 Sep 90		27.5	26.0	1.17	1.11				–	–
	08 Oct 91		124	24.8	2.40	0.92	–	–			
	23 Sep 92		155	4.95	2.67	0.84			–	–	
	13 Sep 93	co.01	82.1	40.0	3.42	1.19		co.03	<0.001	–	0.75
	23 Sep 94		40.6	38.2	2.84	1.52					
	21 Sep 95		38.2	33.7	2.97	1.09				–	
	12 Sep 96	0.279	6.38		0.05	0.378	–	325	<0.031	0.100	0.754
GAMW4	25 May 88	0.01	12.7	8.45	0.66	0.012	co.01	co.04	co.03	9.34	co.02
	18 Jul 88	0.02	12.1	7.12	0.78	0.017	<0.01	co.04	co.03	11.2	co.02
	07 Sep 88	0.81	7.75	3.78	0.58	0.013	co.01	co.04	co.03	8.57	co.02
	20 Sep 89	co.01	14.8	12.0	0.47	co.01	co.01	co.04	co.03	7.65	co.02
	12 Sep 90		12.3	11.4	0.59	0.57					
	24 Sep 91	–	15.5	12.6	0.66	0.56				–	
	23 Sep 92		14.6	11.4	0.55	0.48					
	12 Sep 93	co.01	14.7	12.0	0.73	0.65	–	0.04	<0.001		0.40
	23 Sep 94		34.2	12.1	2.45	0.85					
	21 Sep 95		21.4	11.7	1.08	0.77					
	12 Sep 96	<0.009	11.1	10.6	0.571	0.571	–	0.033	<0.002		<0.009
GAMW 5	25 May 88	0.13	57.7	45.8	10.9	0.143	co.01	<0.04	0.175	10.4	0.30
	19 Jul 88	0.02	59.2	46.1	7.32	0.124	co.01	co.04	0.168	12.4	0.34
	08 Sep 88	<0.01	42.8	22.7	8.30	0.112	co.01	<0.04	0.209	10.2	0.20
	21 Sep 89	co.01	41.2	34.0	3.91	0.121	<0.01	co.04	0.198	8.95	0.04
	22 Sep 89	co.01	56.9	50.0	6.39	0.142	<0.01	co.04	0.213	9.08	0.13
	13 Sep 90	–	43.0	41.3	4.66	4.55					
	25 Sep 91		34.0	20.4	3.46	2.05					
	24 Sep 92		29.6	28.2	3.68	3.64					
	19 Sep 95		31.4	30.5	3.21	3.06					
	12 Sep 96	–	– –			–	–	– –		–	
MW-1A	07 Nov 89	co.01	4.70	4.16	1.24	0.022		co.04	co.03	11.4	0.03
	21 Jun 90	co.01	6.54	5.88	1.84	1.57	co.01	<0.04	co.03	15.0	0.03
	10 Sep 90	co.01	4.54	1.58	1.66	1.28	co.01	<0.04	co.03	10.3	0.04
	20 Sep 95		5.01	2.73	1.59	1.33					
	4 Oct 96	<0.009	6.23	5.27	1.55	1.544		<0.031	<0.002	–	0.018
MW-IC	21 Jun 90	co.01	2.86	1.05	0.13	0.13	co.01	co.04	co.03	10.5	co.02
	llSep90	<0.01	4.91	0.74	0.18	0.15	co.01	co.04	co.03	14.5	0.02
	20 Sep 95		–								
	4 Oct 96	3 – – –	–		–	–		–			
MW-2	22 Jun 90	<0.01	57.7	0.33	0.97	0.14	co.01	co.04	co.03	12.3	0.02
	11 Sep 90	0.02	30.3	1.17	0.50	0.08	<0.01	<0.04	co.03	11.4	0.02
	21 Sep 95		36.5	1.08	0.66	0.17					
	4 Oct 96	0.01	8.63	0.25	0.143	0.056		co.031	co.002	–	0.053

Appendix C

Results of sampling seeps from Two Bull Basin

Site ID	Date	Time	Depth	Q (gpm)	pH	Conductivity	Alkalinity	Acidity
Two Bull North	21 Sep 95	1133	--	0.4	6.7	87	167	3.5
Two Bull South	21 Sep 95	1045	--	4.9	6.7	116	171	3.4

Site ID	Fluoride	Chloride	Nitrate	Phosphate	Sulfate	Calcium	Magnesium	Sodium	Potassium
Two Bull North	0.17	0.61	<0.02	<0.05	0.15	10.7	9.54	4.76	4.67
Two Bull South	0.19	0.29	<0.02	<0.05	1.22	13.3	4.27	3.30	0.82

Site ID	Iron	Iron(total)	Manganese	Manganese(total)	Turbidity	TSS	TDS
Two Bull North	0.51	2.15	0.34	0.39	500	3130	219
Two Bull South	0.27	1.78	0.50	0.41	3.8	18.1	207

All units are mg/L except:

Tw (water temp)	°C
pH	pH units
Color	PCU (platinum color units)
Turbidity	NTU (nephelometric turbidity units)
Settleable Solids (SS)	mL/L
Discharge (Q)	gallons per minute (gpm)
Conductivity	umhos/cm at 25°C
Alkalinity	mg/L as $CaCO_3$