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Pilot Scale Limestone Bed Treatment of the Seep 1 Waste Rock Drainage

Minnesota DEPARTMENT OF NATURAL RESOURCES

Minnesota Department of Natural Resources
Division of Minerals
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Pilot Scale Limestone Bed Treatment of the Seep 1 Waste Rock Drainage

1989 Status Report

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0. Executive summary

A limestone bed was constructed in 1988 to treat the mildly acidic Seep 1 stockpile drainage at the LTV Dunka mine. The cylindrical bed contained 2020 kg of high-calcium limestone (-1/4 inch), and was 1.3 m in diameter and a 1 m deep. The objectives of this project were to

1) elevate the pH and alkalinity while reducing the acidity and trace metal concentrations in the Seep 1 drainage.
2) describe the variation of treatment efficiency with the volume of drainage treated; and
3) describe the variation of treatment efficiency as a function of detention time, or equivalently, flow rate.

The bed received 6600 cubic meters of flow, at rates of 0.032 to 1.514 L/s, from April 26 until October 31, 1989. The average flow was 0.41 L/s or about 25 bed volumes per day. The bed raised the median pH from 5.0 to 6.85 and the median net alkalinity from -51 to +24 mg/L. Copper concentrations were reduced by almost 50%, while nickel, cobalt, and zinc concentrations were reduced by about 10%.

The rate of alkalinity release (k) by the Seep 1 bed was used to quantify treatment efficiency. This release rate varied from 4.5 to 144 mg/s, with a mean value of 32 mg/s. Multiplying this release rate by the 188 days of operation indicates that a limestone mass of 0.52 T was dissolved. The release rate was independent of the volume of treatment, indicating that the treatment capacity of the bed was not taxed. The release rate did increase with flow, indicating that for the range of flows observed, the bed raised the influent alkalinity to an apparent equilibrium value.

1. Objectives

Laboratory column experiments indicated that alkaline solids increased the pH and alkalinity of Seep 1 drainage, while reducing concentrations of acidity and trace metals (Lapakko and Antonson, 1989a). The experiments further indicated that contact time and treatment capacity under field conditions were key variables in treatment bed design. Based on these observations the following objectives were formulated for a pilot scale field study of Seep 1 drainage treatment by a limestone bed.

1) Elevate the pH and alkalinity while reducing the acidity and trace metal concentrations in the Seep 1 drainage.
2) Describe the variation of treatment efficiency of the limestone as a function of the cumulative volume of drainage treated. This may yield the treatment capacity for the limestone under field conditions.
3) Describe the variation of treatment efficiency as a function of detention time under field conditions.

This report presents results from 1989. Results from September 26 to October 28, 1988 are presented in an earlier report (Lapakko and Antonson, 1989b).

2. Site description

Flow was estimated, and occasionally gaged, from 1976 until 1987 when a Stevens Type F (68) continuous stage recorder was installed at the site. (A weir was installed on November 11, 1985.) The estimated annual flow volumes from 1976 to 1987 typically ranged from 6000 to 13,000 cubic meters. In 1987 the flow during the nonfrozen season ranged from 0.14 to 4.2 L/s. This continuous flow record is short and a maximum flow of 6.2 L/s was assumed to provide an additional example for the field design. Exceeding the hydraulic capacity of the system will not preclude attainment of the desired objectives.

Biweekly water quality samples have been collected from Seep 1 since 1976 (appendix 3). Over time the drainage pH has decreased while copper and nickel concentrations have increased (figure 1). In 1987 the drainage pH ranged from

5.05 to 6.35, with a median value of 5.5. Trace metal concentrations were elevated, with median copper and nickel concentrations of 0.38 and 13.5 mg/L, respectively (table 1).

Flow to and from the treatment bed was transmitted by gravity and, therefore, surface and bedrock elevations influenced placement and design. There was an elevation drop of 0.57 meters (1.87 feet) from the bottom of the v-notch weir to a point 18 meters (60 feet) down gradient. About 3 meters (ten feet) down gradient from the weir the bed rock elevation was lowest, about 1.5 m (5 feet) below the bottom of the Seep 1 weir v-notch (figure 2).

3. Methods

3.1. Limestone bed

The limestone bed consisting of limestone chips (table 2), was housed in a polyethylene tank (d = 132 cm = 52 in; h = 152 cm = 60 in). The polyethylene tank was placed into a steel tank to eliminate damage by freezing soil in the winter months. The bed was located 3.05 m (10 feet) downgradient from the Seep 1 weir. At this point the bedrock elevation is lowest and, therefore, allows the maximum bed depth (figure 2). Some problems were encountered during installation due to the high water table in the area.

Seep 1 stockpile drainage flowed from the v-notch weir into a 6-in (15 cm) ID PVC pipe which was cut in half along the first 30.5 cm (one foot). A saddle was constructed to hold the pipe up and against the weir. The midpoint of the pipe cross section was placed at the bottom of the v-notch, such that flow drops 7.6 cm (three inches) into the delivery pipe. Consequently, this pipe flowed no more than half full (figure 3).

The delivery pipe sloped 2.54 cm (1 inch) over the 3.05 m (10-ft) distance from the Seep 1 weir to the bed. The input dropped from the delivery pipe onto a splash plate in the center of the bed, and into a layer of water 25 cm (10 in) below the delivery pipe. This 25 cm freeboard height allowed flow storage, as well as increased head to enhance flow through the bed during times of high flow. The 5.1-cm depth of water above the limestone bed was designed to dissipate the energy of the input water, provide a well-mixed input, and permit uniform flow throughout the cross section of the bed. The flow path through the limestone bed to the midpoint of the underdrain was 100 cm long. An additional 4 cm of limestone lay below this point (figure 3). Mirafi mesh was added to the top of the bed on April 25, 1989, to inhibit the suspended solids input to the bed.

The collection arms of the underdrain were sections of 2-inch schedule 80 PVC well screen with 0.25-inch slots (figure 4). Flow passed from the collection pipes into a 4-inch PVC pipe across the bed diameter, into a pipe passing up through the center of the bed, then exited the housing through a horizontal discharge pipe just above the bed surface and entered a channel which flowed to Unnamed Creek. The discharge pipe extended about 17.5 m downstream of the bed, at which point its elevation was higher than that of the ground surface (figure 3). Estimated flow capacities of the delivery pipe, bed, and outlet pipe are presented in an earlier report (Lapakko and Antonson, 1989b).

2020 kg (4450 lbs) of limestone was added to form a bed 104 cm deep (41 in). This produced a bed volume of 1.4 cubic meters (1400 liters) and a bulk density of 1.5 g/cu cm. Assuming a limestone density of 2.7 g/cu cm yields a porosity of 0.45 and a pore volume of 0.63 cubic meters. Laboratory tests on the limestone indicated a hydraulic conductivity of 0.96 cm/sec (STS Consultants LTD., 1988). For the average monthly Seep 1 flow in 1987, the detention times based on the overall bed volume and on the pore volume were 54 minutes and 22 minutes, respectively (table 3). The estimated values for annual flow and acidity load were 4800 bv (5700 m^3) and 0.34 T as $CaCO_3$, respectively (table 4).

3.2. Sampling and analysis

Water quality was examined by analyzing grab samples taken from the weir and the limestone bed discharge. Samples were analyzed for specific conductance, pH, alkalinity, and acidity. Selected samples were also analyzed for filtered copper, nickel, cobalt, zinc, iron, calcium, magnesium, and sulfate. Specific conductance was analyzed using a Myron L conductivity meter, and an Orion SA 720 pH meter was used for pH analysis. Alkalinity and acidity were analyzed using standard techniques for endpoints of 4.5 and 8.3, respectively (AHPA et al., 1975). Metals were analyzed with a Perkin Elmer 603 atomic absorption spectrophotometer. Sulfate was analyzed using the barium sulfate turbidimetric technique (AHPA et al., 1975). Flow was measured by bucket gaging of the outflow and overflow from the bed. Flow was also metered using the recording gage (Stevens Type F, 68) at the Seep 1 weir.

4. Results and discussion

4.1. Flow

From April 26 until October 31, 1989 the total Seep 1 flow volume was estimated as 10,000 cubic meters, a value within the typical range for annual Seep 1 flow. About 3400 cubic meters exited the tank as overflow, prior to contact with the limestone. The bed overflowed after 25 days of operation (May 22) and about 1000 cubic meters of input flow. The water was pumped out of the bed through the central standpipe, in an attempt to eliminate solids which might have been plugging the bed. Although the bed was pumped several times from 5/25 to 6/2 and solids were removed in the process, overflow recurred. The bed was pumped seven other times during June and July in response to bed overflow. During these two months flow through the bed averaged 28.6 bed volumes per day (bv/d), and reached a minimum of about two bv/d when the bed was overflowing.

To more effectively clean the bed, water was pumped from Unnamed Creek and down through the central standpipe. Flow proceeded through the underdrain and up through the bed, rather than downward as in standard operation. The upper layer of limestone was stirred with a shovel during this process, in order to suspend the fine solids. When the water reached the level of the overflow pipe, the water and suspended solids were pumped out with a second pump. This backwashing procedure was initially used on 8/3, and applied more thoroughly on 8/11. Flow impedance by the bed resulted in overflow on 8/31. Overflow was common in September, although flow through the bed averaged about 23 bv/d.

The bed was cleaned for the last time in 1989 on 9/28 and 9/29. The limestone was stirred with a shovel and the solids suspended were pumped from the bed along with the water. This process was repeated several times. The water was provided by the normal flow from the Seep 1 weir rather than upflow through. No overflow was observed until 10/30, the day before the bed was drained and disconnected. The flow during this period averaged about 14 bv/d.

Several factors could contribute to plugging the bed, and evidence exists for the first three possibilities. Solids could enter the bed with the inflow from Seep 1. The presence of such solids was indicated by observation of solids entrained in the Mirafi on top of the bed. It is possible that the Mirafi was not entirely effective and some solids passed through or around the mesh. A second source of fine solids is the limestone itself. Two percent of the 2020 kg limestone in the bed, was less than 1.7 mm in diameter (Table 2). This represents about 40 kg of relatively fine material. A third source of fines is precipitates which form as a result of the contact between the drainage and the limestone. The primary precipitate would most likely be calcium sulfate, with some copper carbonate/hydroxides and iron oxyhydroxides. Sulfate concentrations decreased slightly after passing through the bed, which would be expected with calcium sulfate precipitation. Finally, the evolution of carbon dioxide gas may contribute to the plugging. The gas is a product of the reaction of limestone and acid. Gas evolved may become trapped in the pores of the limestone bed and inhibit subsequent flow.

Bucket gagings of the bed discharge indicated the flow through the bed ranged from 0.032 to 1.514 L/s, with an average of 0.41 L/s or about 25 bv/d (n = 85, Appendix 1). This represents a detention time (based on bed volume = 1400 L) of about 15 minutes to 12 hours, with an average of 57 minutes (1400 L/[0.41 L/s] = 3414 s = 57 min). The average detention time is considerably shorter than the 4.8 hour value used in the column experiments. Total flow through the bed over the 188 days was approximately 6600 cubic meters (6,600,000 liters, 4700 bed volumes, Table 5).

4.2. Neutralization

The bed elevated the pH and net alkalinity of the acidic Seep 1 input during the entire period of operation. The median pH was raised from 5.0 to 6.85. Input pH ranged from 4.65 to 5.88 as compared to an effluent range of 6.20 to 7.45. The influent pH was around 5.8 at the beginning of May, then decreased and remained fairly consistently in the range of 4.8 to 5.1. The effluent pH was fairly constant, typically between 6.7 to 7.1 (figure 5).

The median value for the input net alkalinity was -51 mg/L as $CaCO_3$, indicating that acidity exceeded alkalinity by 51 mg/L (net alkalinity = alkalinity - acidity). The median effluent value was +24 mg/L, indicating an increase of 75 mg/L. The influent values followed a trend similar to input pH (figure 5). No temporal trends were apparent for the effluent values, which typically ranged from 15 to 35 mg/L (figure 5). The fairly constant effluent pH and net alkalinity suggest that these values were not highly dependent on the volume of flow treated or the detention time.

Detention time (t_d) was calculated based on the measured flow rate (Q) using the equation $t_d = 1400/Q$. The 1400 liter value in the numerator represents the volume of the entire bed, including both solids and the pores. The pore volume is about 40% of 1400 L or 560 L. Using the pore volume for the calculation yields detention times which are 40% of those calculated using the 1400 L bed volume. Flow rate will be used as the dependent variable rather that detention time since it is equally valid, and for purposes of this presentation, is more convenient.

Treatment efficiency can be quantified as the rate of alkalinity release from the limestone bed. This is calculated as the difference between effluent and influent net alkalinity multiplied by the rate of flow:

$$k = ([Nalk]_{eff} - [Nalk]_{inf})*Q, \text{ where} \qquad (1)$$

k = rate of alkalinity release (mg/s),

[Nalk] = net alkalinity of effluent or influent (mg/L), and

Q = flow (L/s).

The value of k varied from 4.5 to 144 mg/s, with a mean value of 32 mg/s. Multiplying this release rate by the 188 days of operation indicates that a limestone mass of 0.52 T was dissolved. To determine the dependence of the alkalinity release rate on cumulative volume of drainage treated and flow, linear regression analysis was conducted. The volume of flow treated was 6600 cubic meters or 4700 bed volumes. As previously mentioned, flow ranged from 0.032 to 1.51 L/s, with an average of 0.41 L/s. Over 90 percent of the flow values ranged from 0.17 to 1.51 L/s.

There was little correlation between the release rate and cumulative flow volume ($r = 0.005$). This indicates that over the 1989 season the treatment at the end of the season was not significantly different the that at the beginning of the season (Figure 6). This suggests that the treatment capacity of the bed has not been greatly taxed.

The rate of alkalinity release was dependent on the flow rate, increasing as flow increased (Figure 7). The relationship was defined by the linear equation

$$k = 70.2*Q - 0.143 \quad (r = 0.85, \quad n = 46) \qquad (2)$$

This equation implies that over the flow range of 0.032 to 1.51 L/s, 70.2 mg of alkalinity was released to every liter of flow. This is consistent with the observed difference of 75 mg/L net alkalinity between the median influent and effluent concentrations. Furthermore, in conjunction with the fairly constant effluent pH and net alkalinity, this suggests that the bed raised these values to an apparent equilibrium for this flow range. Clogging of the bed may have decreased treatment efficiency by eliminating flow through portions of the bed, but this hypothesis is difficult to evaluate.

4.3. Metal removal

The flow weighted mean influent concentrations of filtered copper, nickel, cobalt, and zinc were 0.97, 15.6, 1.2, and, 2.8 mg/L. The percent copper removal was the highest at 48 percent, while removals for the remaining three trace metals were all about 10 percent. The trace metal removal was the result of pH elevation, and the greater degree of copper removal reflects a greater pH dependence for copper solubility. The effluent flow weighted mean concentrations of the trace metals ranged from 0.5 mg/L for copper to 14.2 mg/L for nickel (Table 6; Figure 8).

Influent iron concentrations averaged about 0.14 mg/L, 77 percent of which was removed as flow passed through the bed. Iron concentrations are highly pH dependent. The Seep 1 drainage pH was lower than in 1988 and the iron concentrations increased in response. Despite the increased input concentrations, the bed was effective in reducing the effluent level to 0.035 mg/L. The iron removal was evidenced by rust staining on some of the limestone in the bed. This staining was limited to a fairly small fraction, less than five percent, of the particles observed in the top 0.5 m of the bed.

Flow weighted mean calcium concentrations increased from 240 to 280 mg/L as the flow passed through the bed. This was a reflection of limestone dissolution, as was the increase in alkalinity and the decrease in acidity. There was little change in the concentrations of magnesium and sulfate. The slight decrease in sulfate may have been due to calcium sulfate precipitation. The water quality of the influent and effluent, as well as flow data, are presented in Appendix 1. A timeline for 1989 is presented in Appendix 2.

5. Summary

The flow through the bed in 1989 averaged 25 bv/d, which is about five times the rate used in laboratory tests on Seep 1 drainage. Indeed, the total flow through the bed since September 1989 is over 5100 bed volumes, which is almost twice the average of 2700 bed volumes for the three laboratory columns. Despite the high volume treated and the elevated flow rate, the bed elevated the drainage pH to at least 6.2 and typically above 6.7. The pH elevation apparently led to reduction in trace metal concentrations. Concentrations of copper were reduced by almost 50 percent, while those of nickel, cobalt, and zinc were reduced by about 10 percent.

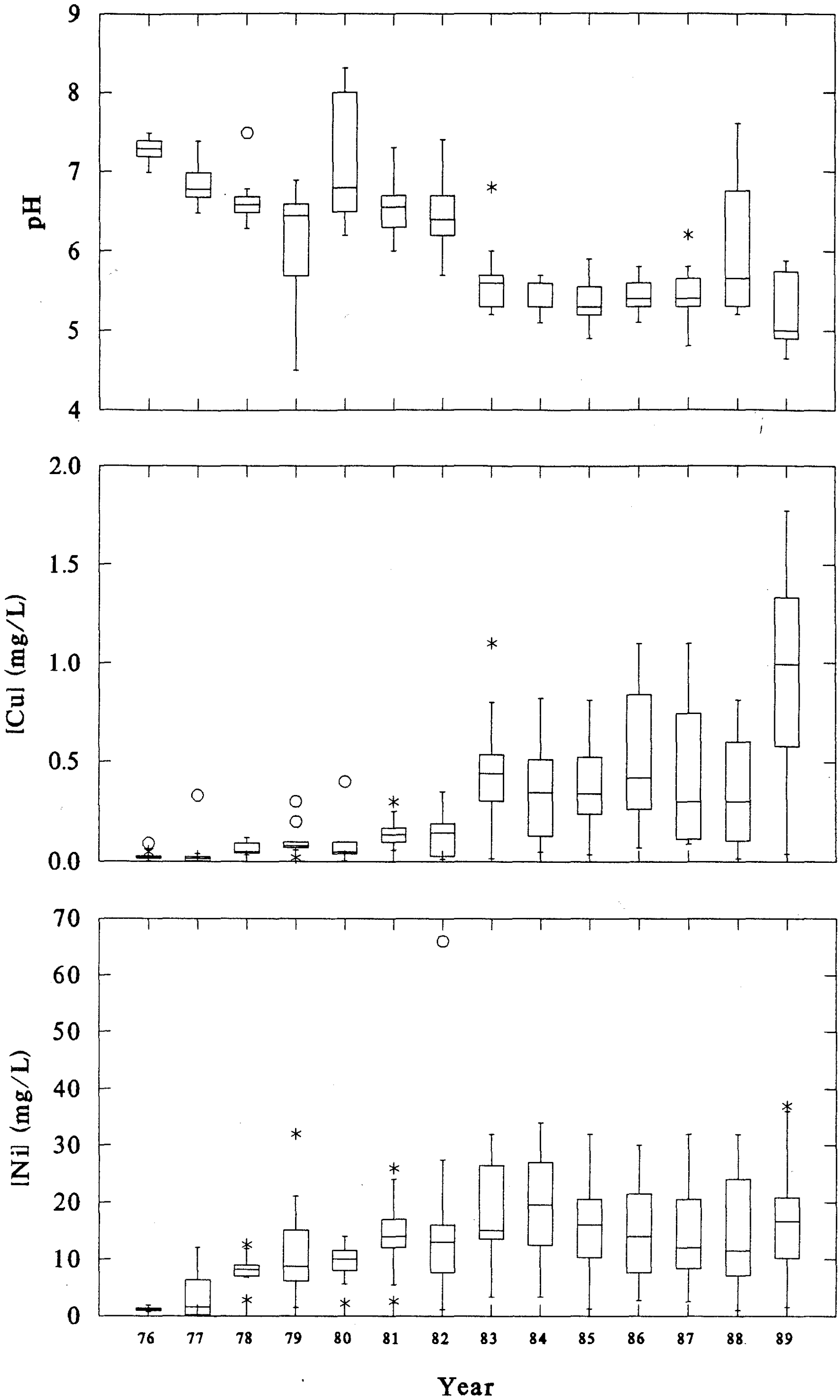
The mean rate of alkalinity release from the Seep 1 bed was 32 mg/s., implying that a limestone mass of 0.52 T was dissolved. The release rate was independent of the volume of treatment, indicating that the treatment capacity of the bed was not taxed. The release rate did increase with flow, indicating that for the range of flows observed, the bed raised the influent alkalinity to an apparent equilibrium value.

Although the bed provided acceptable elevation of pH and net alkalinity, as well as some reduction in trace metal concentrations, the observed flow impedance is a problem which must be addressed. A larger size of limestone may reduce the extent of this problem by yielding a larger pore size. A larger pore size may permit small solids to be transported through the bed rather than being entrapped in the pores. About 70 percent of the solids in the bed range from 0.067 to 0.13 inches in diameter. By using particles in the range of 0.5 to 0.75 inches, the pore size would increase. It would furthermore be beneficial to maintain a small range of particle size. The use of larger particles would, however, require a larger bed, since the dissolution of the larger particles would be slower due to the decreased limestone surface area.

The neutralization of acidity from Seep 1 reduces the tax on the natural buffering capacity of the Unnamed Creek system. Similarly, the reduction in trace metal concentrations reduces the stress on the natural capacity to assimilate trace metals, for example by adsorption, and reduces the release from the watershed. Seep 1 contributes about 15 percent of the nickel to Unnamed Creek. The 10 percent reduction in release at Seep 1 represents a 1.5 percent reduction for the entire watershed.

Perhaps more importantly, the bed provides an immediate source of buffering in the event of the seepage becoming more acidic. The pH at Seep 1 has decreased slowly over time, but rapid declines in pH have been observed both at Seep 1 and Seep 3. The laboratory column experiments indicate that a limestone bed can effectively neutralize drainage which is more acidic than that presently observed at Seep 1. The treatment can remove very high levels of copper, and provide lesser removals of nickel, cobalt, and zinc. If the Seep 1 drainage pH declines further, a limestone bed can neutralize this drainage and reduce the attendant elevated trace metal concentrations (particularly copper).

Bed design for this site should consider both the present situation and potential changes in drainage water quality and flow. Operation of the bed will continue next year to further pursue the objectives presented in section 1. The use of larger particles, as well as the use of horizontal beds or ponds, is being considered for these tests. The horizontal beds or ponds may be more practical than the vertical cylindrical bed used in the present study, since they can be designed on a scale large enough for long term treatment.



Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 1. Seep 1 drainage pH and copper and nickel concentrations vs time.

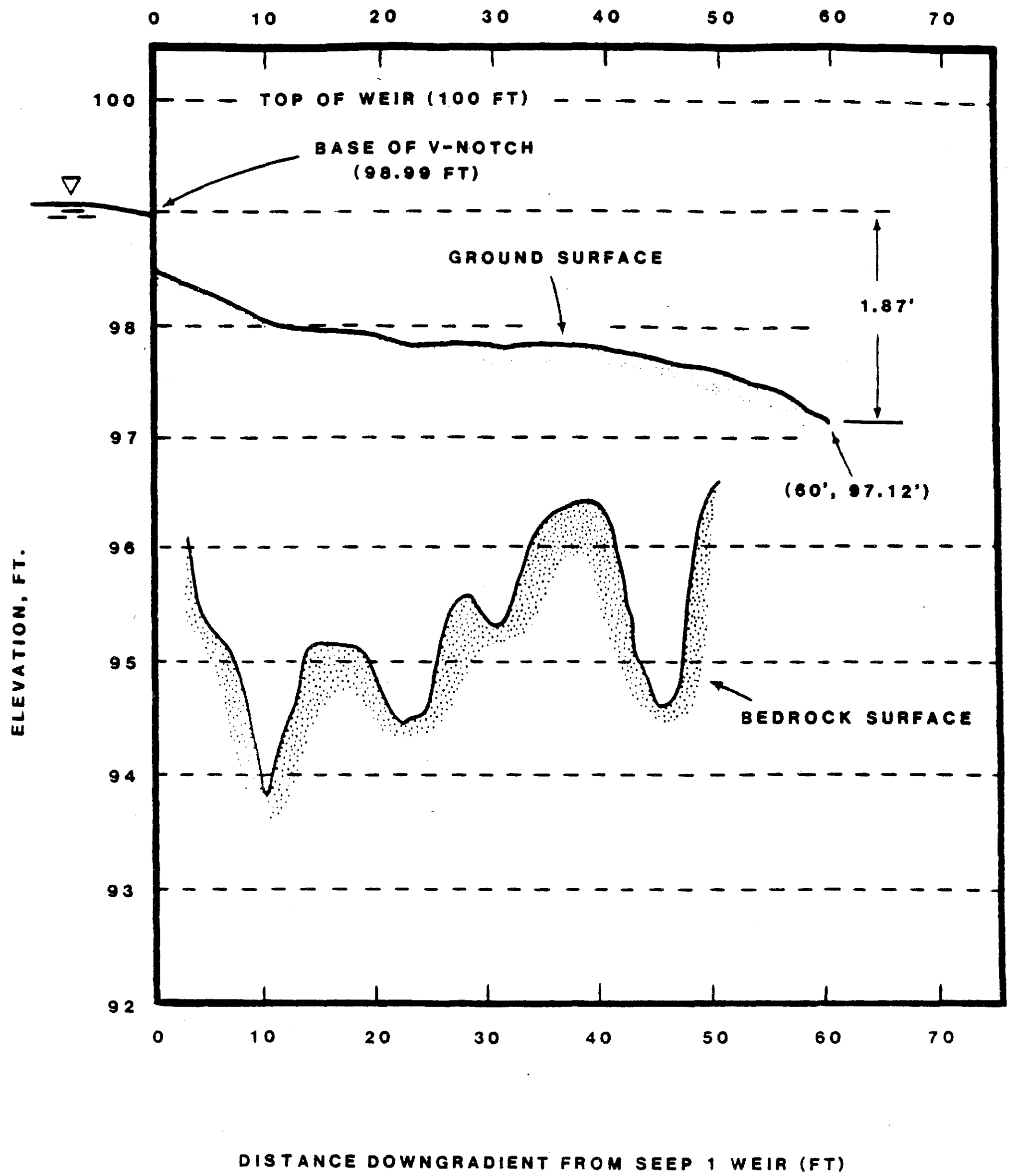
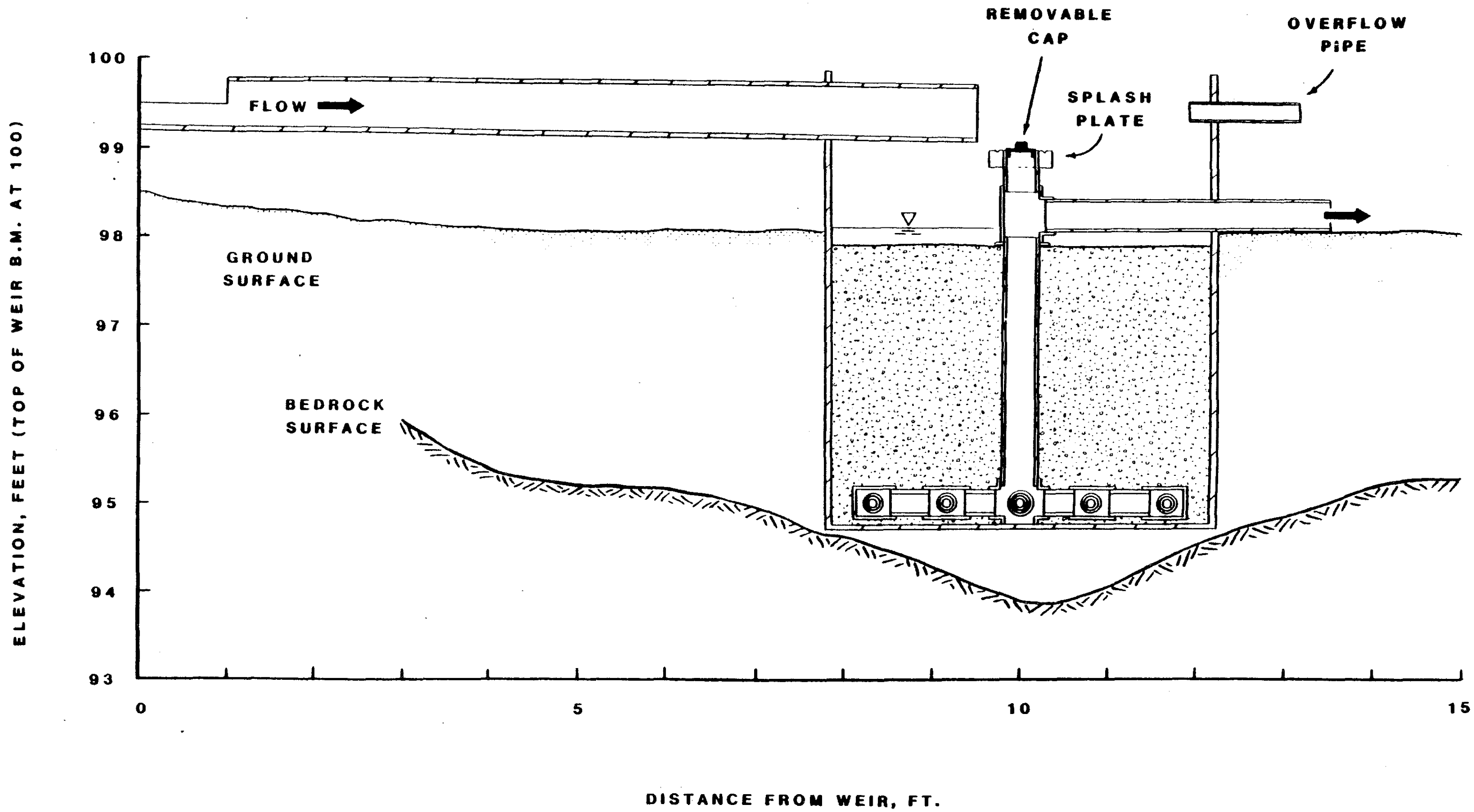


Figure 2. Surface and bedrock elevations downgradient from the Seep 1 weir.



(The bottom of the v-notch and the drainage
pipe are 0.5 ft. lower than depicted)

Figure 3. Seep 1 weir and treatment bed.

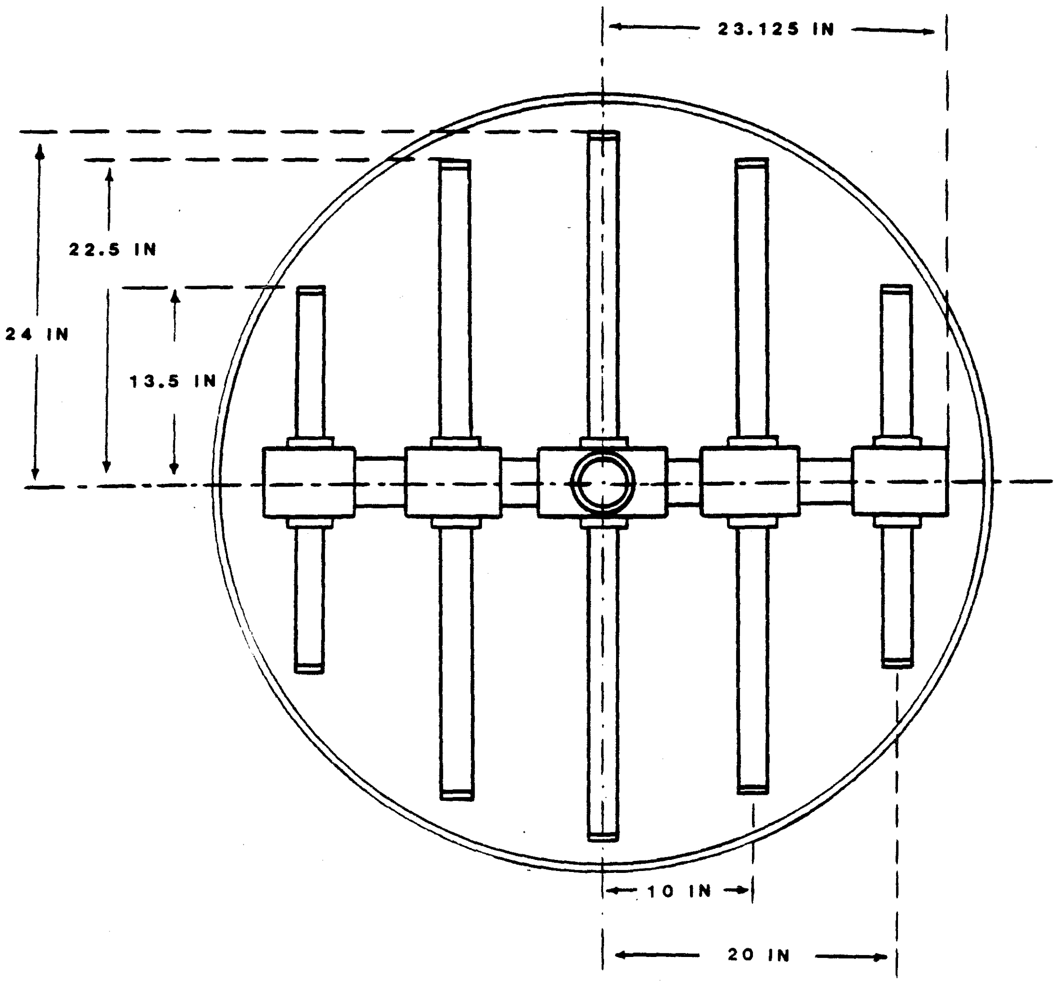


Figure 4. Treatment bed underdrain assembly.

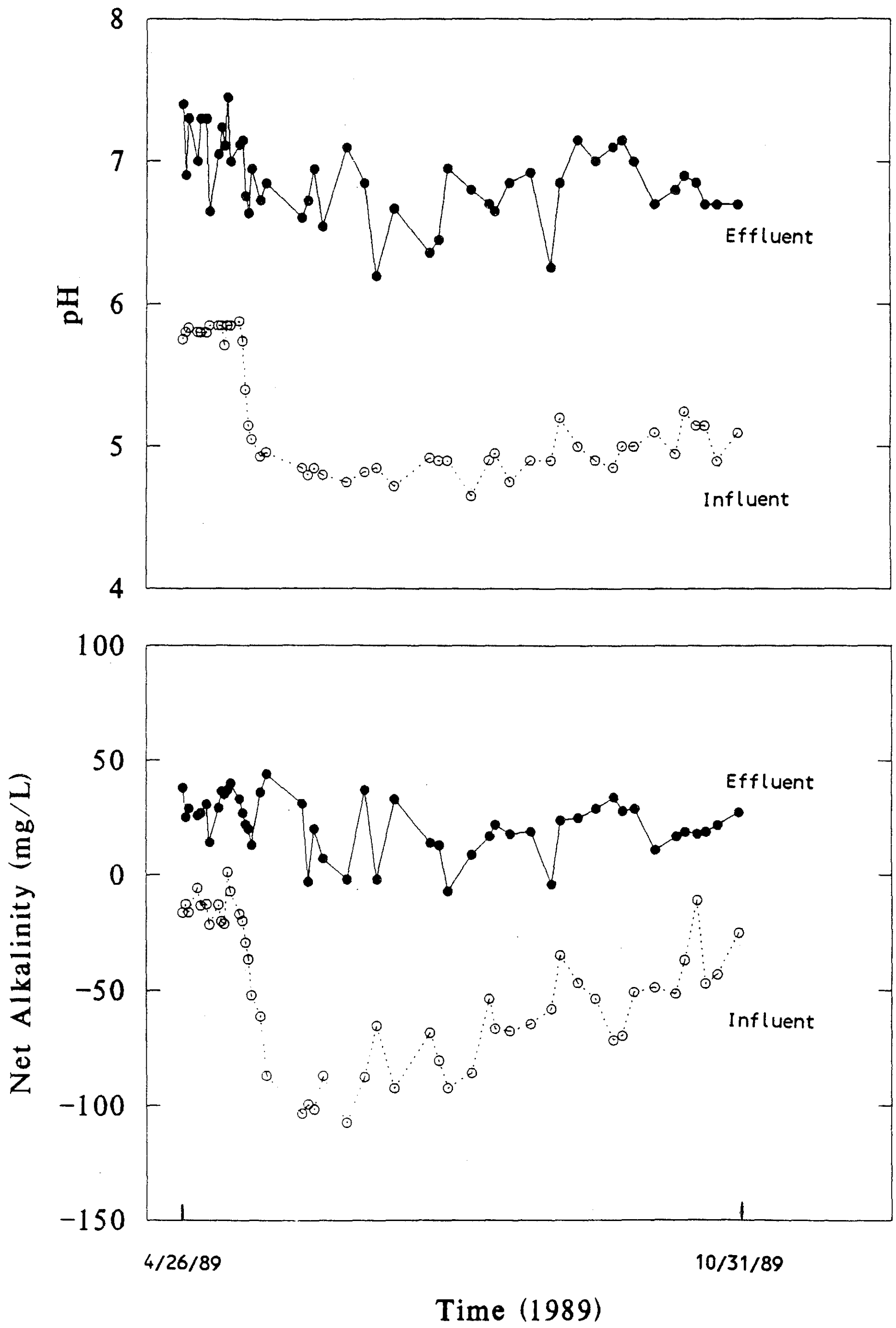


Figure 5. pH and net alkalinity vs time: 1989.

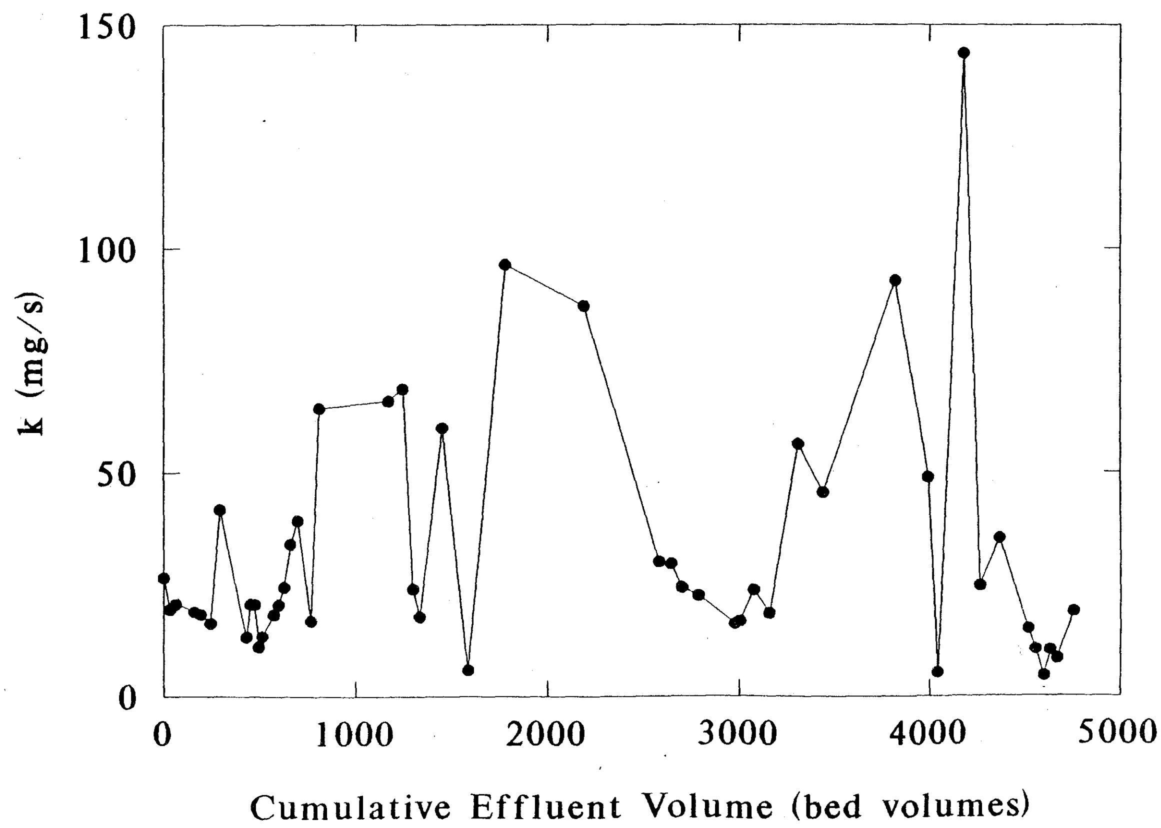


Figure 6. Alkalinity release rate (k) vs cumulative effluent volume.

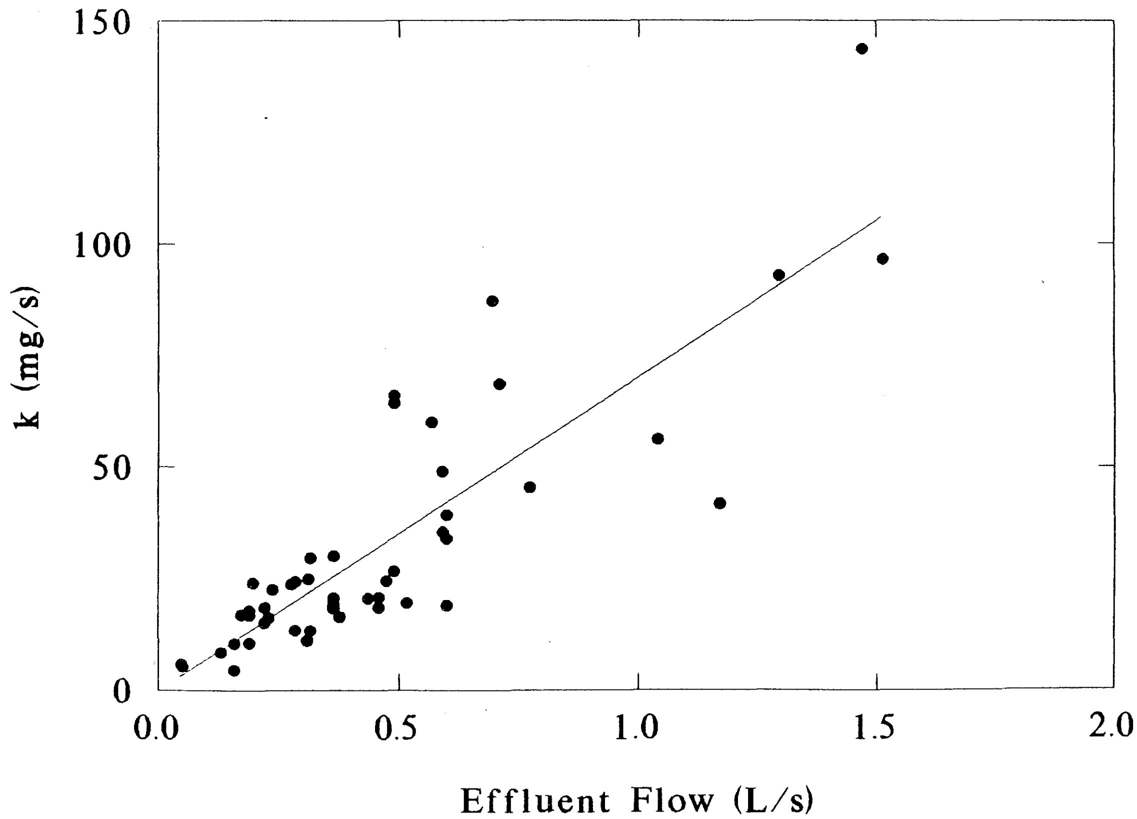


Figure 7. Alkalinity release rate (k) vs effluent flow.

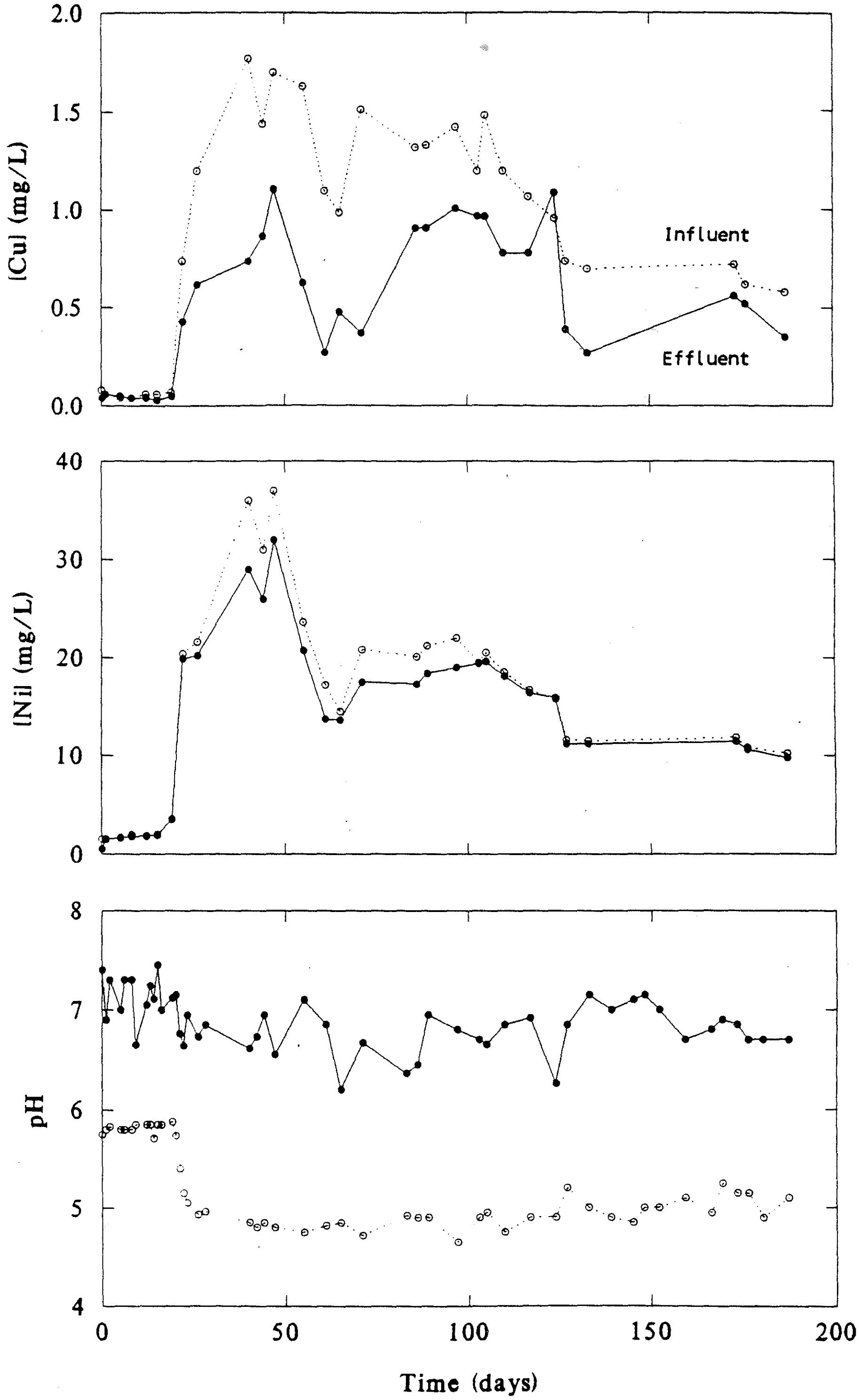


Figure 8. Copper, nickel and pH vs time: 1989.

Table 1. Water quality at Seep 1 in 1987. Summary data for 8 samples[1].

	Minimum	25 pct	50 pct	75 pct	Maximum
pH	5.05	5.35	5.5	6.0	6.35
Cu	.10	.11	.38	.74	1.0
Ni	3.1	8.4	13.5	22	26
Co	.3	.92	1.25	1.8	1.9
Zn	.38	.54	1.0	1.7	2.0
SO_4	790	1400	1490	1675	2175
SC	1462	2225	2288	2550	2550

[1]Metal and sulfate concentrations in mg/L, pH in standard units, and SC represents specific conductance in uS.

Table 2. Screen and chemical analysis of high calcium limestone chips from Hurlbut Calcium and Chemicals.

SCREEN ANALYSIS

Diameter mm	Pct pass
6.4	100%
3.4	72%
1.7	2%

CHEMICAL ANALYSIS

Component	Weight percent
Silica	0.75
Alumina	.19
$CaCO_3$	97.0
CaO	54.39
MgO	.86

Table 3. Flow from Seep 1 during 1987 and associated detention times.

	Flow			Detention min	
	cfs	gpm	L/s	t_d [1]	t_{dp} [2]
Assumed maximum	0.22	100	6.3	3.2	1.3
1987 maximum	.15	68	4.3	4.7	1.9
1987 average	.013	5.7	.36	54	22
1987 monthly minimum[3]	.0049	2.2	.14	143	57

[1]Calculated using entire bed volume: ($t_d = LA_x/Q = 3.25 \times 13/Q = 42.25/Q$).
[2]Calculated using pore volume ($t_{dp} = pLA_x/Q = 0.4 \times 3.25 \times 13/Q = 16.9/Q$).
[3]October 1987 flow.

Table 4. Additional features of treatment bed and Seep 1 drainage.

Bed volume

Using actual bed dimensions

$$bv = 3.14\ [(26/12)^2 - (2.125/12)^2]\ ft^2 \times 3.41\ ft \times 0.3048\ m^3/ft^3$$
$$= 1.4\ m^3$$

Using a cross sectional area of 13 ft^2:

$$bv = 3.41 \times 13 = 44.36\ ft^3 = 332\ gal = 1.26\ m^3.$$

Estimated annual flow:

Using the average 1987 flow of 0.013 ft^3/s

$$V = (0.013\ ft^3/s \times 86{,}400\ s/day \times 180\ day)/42.25\ ft^3 = 4800\ bv =$$
$$= 12{,}000 \text{ pore volumes.}$$
$$= 200{,}000\ ft^3$$
$$= 5700\ m^3$$

The average of estimated and measured annual flow volume from 1978 through 1987 was 10,000 m^3

Total solids required:

$$M = 1.51 t/m^3 \times 3.14 \times [(26/12)^2 - (2.125/12)^2] ft^2 \times 3.4 ft \times 0.3048^3 m^3/ft^3$$
$$= 2.2 \text{ metric tons.}$$

Estimated annual acidity (assuming 60 mg/L acidity):

$$ACY = 60\ g/m^3 \times 5700\ m^3 = 342{,}000\ g/yr = 0.34\ T/yr.$$

$$ACY = 60\ g/m^3 \times 10{,}000\ m^3 = 0.60\ T/yr.$$

Table 5. Flow data summary.

	1988	1989
Period of operation	9/26 - 10/28	4/26 - 10/31
Days of operation	32	188
Q min (L/s)	0.039	0.032
Q max (L/s)	.591	1.514
Q med (L/s)	.21	.41 = 25 bv/d
t_d min	40 minutes	13 minutes
t_d max	10 hours	10 hours
t_d med	110 minutes	49 minutes
V (m^3)	580	6636
V (bv)	410	4740

Table 6. Chemical input and removal at Seep 1 limestone bed, 1989.

Parameter	Input (kg)	Output (kg)	Removal (kg)	C_i[1] (mg/L)	C_e[1] (mg/L)	Reduction %
Cu	6.43	3.34	3.09	0.97	0.50	48
Ni	104	94.1	9.44	15.6	14.2	9
Co	8.0	7.1	.83	1.2	1.1	10
Zn	19	17	2.04	2.8	2.5	11
Fe	0.9	0.2	0.7	0.14	0.035	77
SO_4	7670	7560	110	1160	1140	1.7
Ca	1600	1880	-280	241	282	-17
Mg	1204	1222	-18	181	184	-1.7
Alk	26.7	273	-246	4.0	41	-1025
Acy	436	135	301	66	20	70

[1] Flow weighted mean concentration for influent and effluent.

ACKNOWLEDGEMENTS

LTV Steel Mining Company, under the direction of Toivo Maki, surveyed the treatment bed site, provided the steel bed housing, and excavated for bed installation. Gene Halberg of LTV contributed to bed installation and other aspects of the field work. Cal Jokela assisted in water quality sampling and analysis of specific conductance, pH, acidity, and alkalinity. Trace metal and sulfate analyses were conducted by Albert Klaysmat and Jean Drotts, respectively. Tony Deneka and Jon Wagner were responsible for the computer management of data. Financial assistance was provided by LTV Steel Mining Company.

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APPENDIX 1

Treatment Bed Influent and Effluent

Water Quality and Flow: 1989

Table A1.1. Treatment bed influent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Gage Ht. (m)	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
4/26/89	1.110	0.489	610	5.75	6.6	23	-16.4	0.08	1.53	0.21	0.44	0.1	40	48	276
4/27/89	1.120	0.516	590	5.80	7.2	20	-12.8	0.06	1.54	0.21	0.43	0.1	52	50	310
4/28/89	1.150	0.457	600	5.83	7.7	24	-16.3	.	.	.	.	.	.	.	.
5/1/89	1.220	0.600	650	5.80	8.3	14	-5.7	0.04	1.65	0.21	0.39	-0.1	54	56	310
5/2/89	1.190	0.457	650	5.80	7.7	21	-13.3	.	.	.	.	.	.	.	.
5/4/89	1.200	0.376	690	5.80	4.4	17	-12.6	0.04	1.98	0.22	0.55	-0.1	58	56	326
5/5/89	1.290	1.170	610	5.85	1.5	23	-21.5	.	.	.	.	.	.	.	.
5/8/89	1.180	0.315	800	5.85	10.0	23	-13.0	0.06	1.80	0.19	0.45	-0.1	68	66	370
5/9/89	1.180	0.363	775	5.85	8.8	29	-20.2	.	.	.	.	.	.	.	.
5/10/89	1.180	0.363	825	5.71	7.7	29	-21.3	.	.	.	.	.	.	.	.
5/11/89	1.180	0.309	800	5.85	11.0	9.8	1.2	0.06	1.95	0.22	0.47	-0.1	72	70	390
5/12/89	1.180	0.284	820	5.85	8.8	16	-7.2	.	.	.	.	.	.	.	.
5/15/89	1.200	0.363	1190	5.88	11.0	28	-17.0	0.07	3.57	0.33	0.66	-0.1	112	98	775
5/16/89	1.200	0.435	1490	5.74	11.0	31	-20.0	.	.	.	.	.	.	.	.
5/17/89	1.220	0.473	1650	5.40	6.6	36	-29.4	.	.	.	.	.	.	.	.
5/18/89	1.240	0.599	1720	5.15	4.4	41	-36.6	0.74	20.40	1.74	2.75	-0.1	170	160	1075
5/19/89	1.240	0.599	1650	5.05	6.6	59	-52.4	.	.	.	.	.	.	.	.
5/22/89	1.220	0.457	1820	4.93	4.4	66	-61.6	1.20	21.60	1.84	3.31	-0.1	192	168	1275
5/24/89	1.210	0.930	2000	4.96	5.7	93	-87.3	.	.	.	.	.	.	.	.
6/5/89	1.220	0.852	2400	4.85	3.3	107	-103.7	1.77	36.00	2.04	4.13	0.1	196	266	1630
6/7/89	1.250	0.820	2290	4.80	4.4	104	-99.6	.	.	.	.	.	.	.	.
6/9/89	1.220	0.489	2075	4.85	1.1	103	-101.9	1.44	31.00	1.66	3.30	-0.1	178	232	1440
6/12/89	1.260	0.851	2600	4.80	2.6	90	-87.4	1.70	37.00	2.00	4.04	0.1	212	280	1700
6/13/89	1.360	1.198	.	.	.	.	.	.	.	.	.	.	.	.	.
6/16/89	1.260	0.884	.	.	.	.	.	.	.	.	.	.	.	.	.
6/20/89	1.230	1.136	2250	4.75	0.5	108	-107.5	1.63	23.60	1.70	3.70	0.11	140	242	1640
6/23/89	1.270	1.073	.	.	.	.	.	.	.	.	.	.	.	.	.
6/26/89	1.260	0.922	1900	4.82	2.2	90	-87.8	1.10	17.20	1.21	2.89	0.12	212	172	1320
6/30/89	1.320	1.514	1650	4.85	3.3	69	-65.7	0.99	14.50	1.02	2.63	0.16	166	148	1200
7/6/89	1.250	1.325	2100	4.72	2.4	95	-92.6	1.51	20.80	1.45	3.70	0.12	230	206	1550
7/18/89	1.200	0.363	1920	4.92	4.4	73	-68.6	.	.	.	.	.	.	.	.
7/21/89	1.190	0.315	2220	4.90	3.3	84	-80.7	1.32	20.10	1.39	3.65	0.13	236	218	1880
7/24/89	1.180	0.284	2325	4.90	5.5	98	-92.5	1.33	21.20	1.48	3.83	0.16	252	230	1700
7/26/89	1.180	0.276	.	.	.	.	.	.	.	.	.	.	.	.	.
7/27/89	1.180	0.284	.	.	.	.	.	.	.	.	.	.	.	.	.
7/31/89	1.180	0.237	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A1.1. Treatment bed influent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Gage Ht. (m)	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
8/1/89	1.180	0.237	2300	4.65	2.1	88	-85.9	1.42	22.00	1.59	3.94	0.15	256	236	2050
8/3/89	1.310	1.451	.	.	.	.	.	.	.	.	.	.	.	.	.
8/4/89	1.220	0.520	.	.	.	.	.	.	.	.	.	.	.	.	.
8/7/89	1.180	0.229	2300	4.90	4.2	58	-53.8	1.20	19.50	1.78	4.36	0.13	302	226	1800
8/8/89	1.170	0.205	.	.	.	.	.	.	.	.	.	.	.	.	.
8/9/89	1.170	0.284	2500	4.95	4.2	71	-66.8	1.48	20.50	1.85	4.68	0.09	324	232	1870
8/14/89	1.180	0.276	2225	4.75	3.2	71	-67.8	1.20	18.50	1.66	4.17	0.09	314	210	1700
8/15/89	1.180	0.237	.	.	.	.	.	.	.	.	.	.	.	.	.
8/16/89	1.170	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
8/17/89	1.160	0.150	.	.	.	.	.	.	.	.	.	.	.	.	.
8/18/89	1.160	0.142	.	.	.	.	.	.	.	.	.	.	.	.	.
8/21/89	1.180	0.221	2050	4.90	4.2	69	-64.8	1.07	16.70	1.49	3.68	0.08	302	200	1700
8/22/89	1.160	0.071	.	.	.	.	.	.	.	.	.	.	.	.	.
8/23/89	1.160	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
8/24/89	1.160	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
8/25/89	1.150	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
8/28/89	1.230	1.040	2190	4.90	5.9	64	-58.1	0.96	15.80	1.39	3.36	0.14	296	194	1590
8/29/89	1.240	0.757	.	.	.	.	.	.	.	.	.	.	.	.	.
8/30/89	1.200	0.457	.	.	.	.	.	.	.	.	.	.	.	.	.
8/31/89	1.250	0.773	1625	5.20	4.2	39	-34.8	0.74	11.60	1.00	2.36	0.11	222	144	1180
9/6/89	1.340	1.293	1600	5.00	4.2	51	-46.8	0.70	11.50	0.96	2.46	0.11	226	144	1100
9/7/89	1.240	0.568	.	.	.	.	.	.	.	.	.	.	.	.	.
9/8/89	1.230	0.552	.	.	.	.	.	.	.	.	.	.	.	.	.
9/12/89	1.230	1.096	1950	4.90	4.2	58	-53.8	.	.	.	.	.	.	.	.
9/14/89	1.190	0.327	.	.	.	.	.	.	.	.	.	.	.	.	.
9/18/89	1.180	0.250	2300	4.85	4.2	76	-71.8	.	.	.	.	.	.	.	.
9/21/89	1.300	1.521	1820	5.00	4.2	74	-69.8	.	.	.	.	.	.	.	.
9/22/89	1.260	0.844	.	.	.	.	.	.	.	.	.	.	.	.	.
9/25/89	1.190	0.579	1975	5.00	3.2	54	-50.8	.	.	.	.	.	.	.	.
9/27/89	1.180	0.276	.	.	.	.	.	.	.	.	.	.	.	.	.
9/28/89	1.180	0.264	.	.	.	.	.	.	.	.	.	.	.	.	.
10/2/89	1.210	0.591	1950	5.10	4.2	53	-48.8	.	.	.	.	.	.	.	.
10/4/89	1.180	0.379	.	.	.	.	.	.	.	.	.	.	.	.	.
10/5/89	1.180	0.315	.	.	.	.	.	.	.	.	.	.	.	.	.
10/6/89	1.190	0.331	.	.	.	.	.	.	.	.	.	.	.	.	.
10/9/89	1.160	0.221	2000	4.95	2.6	54	-51.4	.	.	.	.	.	.	.	.

Table A1.1. Treatment bed influent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Gage Ht. (m)	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
10/11/89	1.170	0.221	.	.	.	.	.	.	.	.	.	.	.	.	.
10/12/89	1.160	0.189	2000	5.25	4.2	41	-36.8	.	.	.	.	.	.	.	.
10/13/89	1.160	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
10/16/89	1.160	0.158	2100	5.15	4.2	15	-10.8	0.72	11.80	0.93	2.48	0.04	360	244	1470
10/17/89	1.150	0.173	.	.	.	.	.	.	.	.	.	.	.	.	.
10/19/89	1.150	0.158	2110	5.15	1.0	48	-47.0	0.62	10.80	0.86	2.36	0.03	340	234	1280
10/20/89	1.150	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
10/23/89	1.140	0.130	1900	4.90	2.1	45	-42.9	.	.	.	.	.	.	.	.
10/24/89	1.150	0.118	.	.	.	.	.	.	.	.	.	.	.	.	.
10/25/89	1.140	0.125	.	.	.	.	.	.	.	.	.	.	.	.	.
10/26/89	1.140	0.134	.	.	.	.	.	.	.	.	.	.	.	.	.
10/30/89	1.200	0.363	1900	5.10	3.0	28	-25.0	0.58	10.20	0.84	2.13	0.06	320	220	1150
10/31/89	1.180	0.260	.	.	.	.	.	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.2. Treatment bed effluent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
4/26/89	0.489	600	7.40	44	6.1	37.9	0.04	0.55	0.08	0.10	-0.1	56	40	256
4/27/89	0.516	625	6.90	32	7.0	25.0	0.06	1.55	0.21	.	.	.	.	.
4/28/89	0.457	650	7.30	35	6.1	28.9	.	.	.	.	.	.	.	.
5/01/89	0.600	690	7.00	33	7.1	25.9	0.05	1.68	0.20	0.38	-0.1	62	54	316
5/02/89	0.457	675	7.30	33	6.1	26.9	.	.	.	.	.	.	.	.
5/04/89	0.376	700	7.30	37	6.1	30.9	0.04	1.80	0.21	0.34	-0.1	70	56	320
5/05/89	1.170	620	6.65	24	9.8	14.2	.	.	.	.	.	.	.	.
5/08/89	0.315	820	7.05	39	9.8	29.2	0.04	1.87	0.19	0.47	-0.1	80	64	370
5/09/89	0.363	800	7.24	42	5.5	36.5	.	.	.	.	.	.	.	.
5/10/89	0.363	800	7.11	42	6.7	35.3	.	.	.	.	.	.	.	.
5/11/89	0.309	850	7.45	42	4.9	37.1	0.03	2.00	0.19	0.49	-0.1	86	66	390
5/12/89	0.284	860	7.00	40	0	40.0	.	.	.	.	.	.	.	.
5/15/89	0.363	1200	7.12	43	9.8	33.2	0.05	3.53	0.33	0.64	-0.1	126	94	725
5/16/89	0.435	1500	7.15	39	12	27	.	.	.	.	.	.	.	.
5/17/89	0.473	1620	6.76	39	17	22	.	.	.	.	.	.	.	.
5/18/89	0.599	1800	6.64	37	17	20	0.43	19.90	1.68	2.59	-0.1	186	162	1100
5/19/89	0.599	1700	6.95	35	22	13	.	.	.	.	.	.	.	.
5/22/89	0.173	1870	6.73	48	12	36	0.62	20.20	1.65	2.98	-0.1	216	166	1125
5/24/89	0.489	2080	6.85	61	17	44	.	.	.	.	.	.	.	.
6/05/89	0.489	2500	6.61	55	24	31	0.74	29.00	1.58	2.91	0.1	234	276	1600
6/07/89	0.710	2380	6.73	36	39	-3	.	.	.	.	.	.	.	.
6/09/89	0.197	2125	6.95	44	24	20	0.87	26.00	1.31	2.40	-0.1	200	228	1430
6/12/89	0.189	2750	6.55	51	44	7	1.11	32.00	1.67	3.28	0.1	250	286	1750
6/13/89	0.252	.	.	.	.	.	.	.	.	.	.	.	.	.
6/16/89	0.032	.	.	.	.	.	.	.	.	.	.	.	.	.
6/20/89	0.568	2375	7.10	40	42	-2	0.63	20.70	1.44	3.17	0.03	248	242	1640
6/23/89	0.442	.	.	.	.	.	.	.	.	.	.	.	.	.
6/26/89	0.047	1930	6.85	59	22	37	0.27	13.70	0.97	1.63	0.06	212	174	1320
6/30/89	1.514	1700	6.20	23	25	-2	0.48	13.60	0.91	2.60	0.08	178	152	1180
7/06/89	0.694	2220	6.67	55	22	33	0.37	17.50	1.25	2.51	0.04	264	210	1580
7/18/89	0.363	2000	6.36	38	24	14	.	.	.	.	.	.	.	.
7/21/89	0.315	2250	6.45	39	26	13	0.91	17.30	1.17	2.89	0.05	208	220	1580
7/24/89	0.284	2375	6.95	44	51	-7	0.91	18.40	1.20	3.01	0.06	276	234	1580
7/26/89	0.276	.	.	.	.	.	.	.	.	.	.	.	.	.
7/27/89	0.166	.	.	.	.	.	.	.	.	.	.	.	.	.
7/31/89	0.071	.	.	.	.	.	.	.	.	.	.	.	.	.

Table A1.2. Treatment bed effluent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
8/01/89	0.237	.	6.80	35	26	9	1.01	19.00	1.30	3.11	0.07	280	236	1750
8/03/89	0.994	.	.	.	.	.	.	.	.	.	.	.	.	.
8/04/89	0.520	.	.	.	.	.	.	.	.	.	.	.	.	.
8/07/89	0.229	2375	6.70	34	17	17	0.97	19.40	1.71	4.25	0.02	354	228	1930
8/08/89	0.205	.	.	.	.	.	.	.	.	.	.	.	.	.
8/09/89	0.189	2550	6.65	47	25	22	0.97	19.60	1.76	4.62	0.02	354	228	1850
8/14/89	0.276	2300	6.85	38	20	18	0.78	18.10	1.59	3.93	0.03	332	232	1750
8/15/89	0.237	.	.	.	.	.	.	.	.	.	.	.	.	.
8/16/89	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
8/17/89	0.150	.	.	.	.	.	.	.	.	.	.	.	.	.
8/18/89	0.142	.	.	.	.	.	.	.	.	.	.	.	.	.
8/21/89	0.221	2190	6.92	40	21	19	0.78	16.40	1.45	3.58	0.02	326	204	1630
8/22/89	0.071	.	.	.	.	.	.	.	.	.	.	.	.	.
8/23/89	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
8/24/89	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
8/25/89	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
8/28/89	1.040	2190	6.26	21	25	-4	1.09	15.90	1.41	4.08	0.05	302	198	1600
8/29/89	0.757	.	.	.	.	.	.	.	.	.	.	.	.	.
8/30/89	0.457	.	.	.	.	.	.	.	.	.	.	.	.	.
8/31/89	0.773	1675	6.85	39	15	24	0.39	11.20	0.94	1.88	0.03	246	144	1230
9/06/89	1.293	1600	7.15	42	17	25	0.27	11.20	0.89	2.02	0.03	246	142	1180
9/07/89	0.363	.	.	.	.	.	.	.	.	.	.	.	.	.
9/08/89	0.237	.	.	.	.	.	.	.	.	.	.	.	.	.
9/12/89	0.591	2000	7.00	45	16	29	.	.	.	.	.	.	.	.
9/14/89	0.059	.	.	.	.	.	.	.	.	.	.	.	.	.
9/18/89	0.050	2300	7.10	55	21	34	.	.	.	.	.	.	.	.
9/21/89	1.470	1900	7.15	49	21	28	.	.	.	.	.	.	.	.
9/22/89	0.063	.	.	.	.	.	.	.	.	.	.	.	.	.
9/25/89	0.311	2000	7.00	43	14	29	.	.	.	.	.	.	.	.
9/27/89	0.039	.	.	.	.	.	.	.	.	.	.	.	.	.
9/28/89	0.043	.	.	.	.	.	.	.	.	.	.	.	.	.
10/02/89	0.591	1975	6.70	29	18	11	.	.	.	.	.	.	.	.
10/04/89	0.379	.	.	.	.	.	.	.	.	.	.	.	.	.
10/05/89	0.315	.	.	.	.	.	.	.	.	.	.	.	.	.
10/06/89	0.331	.	.	.	.	.	.	.	.	.	.	.	.	.
10/09/89	0.221	2050	6.80	34	17	17	.	.	.	.	.	.	.	.

Table A1.2. Treatment bed effluent water quality: 1989.

(all values mg/L unless noted otherwise)

Date	Flow (L/s)	Specific Conductance (uS/cm)	pH	Alk.	Acy.	Net Alk.	Cu	Ni	Co	Zn	Fe	Ca	Mg	Sulfate
10/11/89	0.221	.	.	.	.	.	.	.	.	.	.	.	.	.
10/12/89	0.189	2050	6.90	34	15	19	.	.	.	.	.	.	.	.
10/13/89	0.189	.	.	.	.	.	.	.	.	.	.	.	.	.
10/16/89	0.158	2150	6.85	36	18	18	0.56	11.40	0.91	2.42	0.01	380	246	1340
10/17/89	0.173	.	.	.	.	.	.	.	.	.	.	.	.	.
10/19/89	0.158	2200	6.70	40	21	19	0.52	10.60	0.83	2.40	0.01	380	236	1280
10/20/89	0.158	.	.	.	.	.	.	.	.	.	.	.	.	.
10/23/89	0.130	1925	6.70	40	18	22	.	.	.	.	.	.	.	.
10/24/89	0.118	.	.	.	.	.	.	.	.	.	.	.	.	.
10/25/89	0.125	.	.	.	.	.	.	.	.	.	.	.	.	.
10/26/89	0.134	.	.	.	.	.	.	.	.	.	.	.	.	.
10/30/89	0.363	1900	6.70	39	11.5	27.5	0.35	9.76	0.80	1.68	0.01	360	222	1120
10/31/89	0.260	.	.	.	.	.	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

APPENDIX 2

Seep 1 Treatment Bed Timeline: 1989

Table A2.1. Seep 1 Treatment Bed Timeline, 1989.

4-25	Installed 2" PVC valve on outlet pipe Installed mirifi, covered with 2" of Limestone
4-26	Filled the bed, this took 36 min.
4-27	Thin ice behind weir
4-28	Thin ice behind weir
5-4	Detected a small leak around the weir overflow pipe.
5-5	Ice behind weir Repaired leak around weir overflow Some flow was being lost going around the weir, repaired it.
5-8	Small leak at weir overflow
5-9	Fixed leak at weir overflow
5-12	Ice behind weir
5-16	(NOTE): Normal H_2O level is 2 inches above bed or 11.5 in. below top of the overflow pipe. Water depth on 5-16 = 3.75 in.
5-17	H_2O depth = 4.75 in.
5-18	H_2O depth = 7.88 in.
5-19	H_2O depth = 11.12 in.
5-22	Bed is overflowing
5-24	Bed is overflowing
5-25	The bed had overflowed over the top of the bed, the overflow couldn't handle the flow. Opened up the weir overflow in order to pump the bed. Removed Mirifi, this was badly plugged. Pumped bed down, started filling bed, the bed filled rapidly, it was overflowing before any output flow was noticed. Opened the weir overflow and will resume pumping on 5/31.
5-31	Pumped bed empty, didn't notice anything unusual about effluent. Let bed fill up, outflow was insufficient. H_2O level rose rapidly towards overflow. Pumped bed a second time with same result. Then dug a crater into limestone, noticing a heavy red precipitate seeping into the crater. This continued to build almost to a mud slime consistency. Opened weir overflow.

Table A2.1. Seep 1 Treatment Bed Timeline, 1989 (continued).

6-2	Pumped bed empty. Closed weir overflow, the bed filled rapidly with no outflow. Pumped bed again, filled bed, H_2O rose rapidly above distribution plate. Decided to pump bed and direct pump outflow back inside tank to create a longer period of flush time. Stopped pump when bed was full of H_2O, noticed some outflow. Pumped bed 3 more times in this manner. Inspected after 2 hrs.
	H_2O depth = 5.25 in. Flow = 9.5 qts/15 sec.
6-5	Bed is overflowing
6-6	Bed is overflowing
	Pumped bed, with H_2O from weir still entering bed. When the H_2O got down towards the bottom, it started pumping a large amount of solids, the solids looked like sediment from the input H_2O. Filled the bed and pumped down again. The 2nd pumping was still clouded with solids, the 3rd pumping was much clearer, let the bed fill up.
6-7	Bed is overflowing
6-9	Bed is overflowing
	Pumped the bed, the H_2O seems to go down through the bed on the side facing the weir. When the pump slows down there is still H_2O standing on the surface of the limestone on the side of the bed away from the weir. When the bed fills, there is bubbling on the side facing the weir. Filled the bed, mixed up the limestone at the surface to try and suspend the solids. Pumped the water off the top of the bed to try and remove the solids. Inserted the hose down the center pipe and pumped the rest of the bed. Let the bed fill up.
6-12	Bed is overflowing
6-13	Bed is overflowing
6-16	Bed is overflowing
6-19	Bed is overflowing
6-20	Mixed the limestone up and pumped directly from the bed. A large amount of sediment was present in the bed since the 6/9 pumping. Pumped the bed down to just below the top of the limestone, let the bed fill back up. There is still a lot of suspended solids in the bed. Pumped top of bed again. Dug down about 1 1/2" on south side of

bed, pumped twice more. We then pumped out the center pipe. More solids were present than ever before. Let the bed fill up to the overflow and pumped from center pipe again. The H_2O looked cleaner this time. Let bed fill up.

H_2O depth = 2 in. (Normal)

6-23 Bed is overflowing

6-26 Bed is overflowing

6-30 Bed is completely plugged. Pumped bed down to just below limestone, mixing the bed while pumping. Outflow = 3 qts/15 sec. Let bed fill up and pumped 3 more times. Flow increased after each pumping. Pumped bed twice more from center pipe, installed mirifi and let bed fill up. H_2O depth = 7 in.

7-6 Bed is overflowing

7-18 Mixed bed and pumped H_2O level down below level of limestone. Plugging was eliminated but there is still a lot of solids in the bed. Pumped the top of the bed 4 more times, then 3 more times from center pipe. Each time the limestone was mixed during pumping. Let bed fill, H_2O depth = 2.75 in.

7-21 No overflow, but pumped bed down and installed new mirifi.

7-24 H_2O depth = 6.12 in.

7-26 H_2O depth = 11.31 in.

7-27 Bed is overflowing

7-31 Stirred the top of the bed and pumped, pumped the rest of the bed through the center pipe. Installed new mirifi.

8-1 H_2O depth = 3.75 in.

8-3 Bed is overflowing, mirifi is covered with algae. Pumped bed (Kim's notes) Pumped down center pipe.

8-4 H_2O depth = 4.38 in.

8-7 H_2O depth = 8 in.

8-8 H_2O depth = 10.5 in.

8-9 Bed is overflowing

8-11 Pumped bed, pumped down the center pipe. The solids were being mixed and pumped out the top of the bed.

8-14 H_2O depth = 3.5 in.

8-15 H_2O depth = 3.88 in.

8-16 H_2O depth = 3.88 in.

Table A2.1. Seep 1 Treatment Bed Timeline, 1989 (continued).

8-17	H_2O depth = 4.12 in.
8-18	H_2O depth = 4.75 in.
8-21	H_2O depth = 9.38 in.
8-22	Changed Mirifi, H_2O depth = 4 in.
8-23	H_2O depth = 3 in.
8-24	H_2O depth = 3.75 in.
8-25	H_2O depth = 4.5 in.
8-28	H_2O depth = 3.5 in.
8-29	Overflowing, Mirifi is very dirty, moved mirifi and H_2O level dropped to 1/8" below overflow pipe.
8-30	H_2O depth = 11 in.
8-31	Bed is overflowing
9-6	The mirifi plugged the overflow pipe and the entire bed overflowed. Adjusted the mirifi.
9-7	Bed is overflowing, changed mirifi
9-8	Bed is overflowing
9-12	Bed is overflowing
9-14	Bed is overflowing, white sediment behind weir and at outflow
9-18	Bed is overflowing
9-21	Bed is overflowing
9-22	Bed is overflowing
9-25	Bed is overflowing
9-27	Bed is overflowing
9-28	Bed is overflowing. Mixed the limestone up and pumped directly from the bed. After pumping there remained about 1/8" of precipitate settled on the limestone. Let the bed fill, mixed, and pumped 3 more times. Let bed fill, no increase in outflow. Pumped center pipe until H_2O was about 3" below the sump that was dug in the limestone. Flow into underdrain assembly wouldn't keep up with pumping, let bed fill up. Pumped bed again, the bed wouldn't pump down. Let bed fill and pumped again, let fill. There is a small increase in outflow, pumped bed again, the bed would still not totally empty. There are still a lot of solids in the bed.

Table A2.1. Seep 1 Treatment Bed Timeline, 1989 (continued).

9-29	Pumped bed from center pipe. Removed 1/4 of the limestone and mixed and pumped bed 6 more times.
10-4	H_2O depth = 4.25 in.
10-5	H_2O depth = 4.75 in.
10-6	H_2O depth = 5.12 in.
10-9	H_2O depth = 6.25 in.
10-11	H_2O depth = 6.75 in.
10-12	H_2O depth = 7 in. Replaced Mirifi
10-13	H_2O depth = 7.25 in.
10-16	H_2O depth = 8.25 in.
10-17	H_2O depth = 8.715 in.
10-19	H_2O depth = 9 in.
10-20	H_2O depth = 9 in.
10-23	H_2O depth = 9.25 in.
10-24	H_2O depth = 9 in.
10-25	H_2O depth = 9 in.
10-26	H_2O depth = 9.5 in.
10-30	Bed is overflowing
10-31	Pumped bed, done for the season.

APPENDIX 3

Seep 1 water quality data: 1976-1989

1976 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	9	9	9	9
MINIMUM	7.000	2324.000	161.000	0.004
MAXIMUM	7.500	4600.000	229.000	0.091
RANGE	0.500	2276.000	68.000	0.087
MEAN	7.289	3545.000	201.889	0.029
STANDARD DEV	0.190	628.336	22.784	0.027

	NI	CO	ZN	CA	MG
N OF CASES	9	4	8	7	3
MINIMUM	0.670	0.110	0.100	194.000	451.000
MAXIMUM	1.920	0.132	0.690	396.000	528.000
RANGE	1.250	0.022	0.590	202.000	77.000
MEAN	1.143	0.124	0.254	252.714	481.000
STANDARD DEV	0.379	0.010	0.190	65.711	41.219

	SO4
N OF CASES	9
MINIMUM	1839.000
MAXIMUM	3000.000
RANGE	1161.000
MEAN	2404.444
STANDARD DEV	367.369

Note: all metals are total values measured in mg/L.

1977 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	17	17	17	17
MINIMUM	6.500	500.000	46.000	0.003
MAXIMUM	7.400	7700.000	441.000	0.329
RANGE	0.900	7200.000	395.000	0.326
MEAN	6.812	3105.941	104.706	0.034
STANDARD DEV	0.226	2473.321	91.436	0.077

	NI	CO	ZN	CA	MG
N OF CASES	17	5	5	8	7
MINIMUM	0.053	0.110	0.040	46.000	119.000
MAXIMUM	12.000	0.870	2.400	346.000	652.000
RANGE	11.947	0.760	2.360	300.000	533.000
MEAN	3.471	0.478	1.290	175.625	307.714
STANDARD DEV	3.867	0.340	1.169	116.402	223.442

	SO4
N OF CASES	11
MINIMUM	149.000
MAXIMUM	5636.000
RANGE	5487.000
MEAN	2552.000
STANDARD DEV	2007.647

Note: all metals are total values measured in mg/L.

1978 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	10	10	0	10
MINIMUM	6.300	5000.000	.	0.034
MAXIMUM	7.500	5000.000	.	0.119
RANGE	1.200	0.000	.	0.085
MEAN	6.660	5000.000	.	0.063
STANDARD DEV	0.327	0.000	.	0.030

	NI	CO	ZN	CA	MG
N OF CASES	10	10	10	10	10
MINIMUM	2.800	0.300	0.180	38.000	400.000
MAXIMUM	12.500	1.000	2.300	350.000	1100.000
RANGE	9.700	0.700	2.120	312.000	700.000
MEAN	8.270	0.752	1.420	268.800	728.000
STANDARD DEV	2.699	0.216	0.600	85.706	230.063

	SO4
N OF CASES	10
MINIMUM	3275.000
MAXIMUM	5000.000
RANGE	1725.000
MEAN	4315.000
STANDARD DEV	584.190

Note: all metals are total values measured in mg/L.

1979 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	16	15	16	16
MINIMUM	4.500	1500.000	-2.000	0.020
MAXIMUM	6.900	5000.000	80.000	0.300
RANGE	2.400	3500.000	82.000	0.280
MEAN	6.106	4720.000	38.500	0.106
STANDARD DEV	0.772	904.118	28.636	0.070

	NI	CO	ZN	CA	MG
N OF CASES	16	0	16	16	16
MINIMUM	1.500	.	0.250	-1.000	1.000
MAXIMUM	32.000	.	17.000	640.000	9999.000
RANGE	30.500	.	16.750	641.000	9998.000
MEAN	11.231	.	3.348	136.313	1555.438
STANDARD DEV	7.841	.	4.153	216.538	2320.214

	SO4
N OF CASES	16
MINIMUM	1100.000
MAXIMUM	10000.000
RANGE	8900.000
MEAN	4281.250
STANDARD DEV	1920.840

Note: all metals are total values measured in mg/L.

1980 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	14	15	15	17
MINIMUM	6.200	2050.000	28.000	-0.010
MAXIMUM	8.300	4300.000	68.000	0.400
RANGE	2.100	2250.000	40.000	0.410
MEAN	7.107	3866.667	49.733	0.075
STANDARD DEV	0.763	594.218	11.997	0.089

	NI	CO	ZN	CA	MG
N OF CASES	17	2	17	17	17
MINIMUM	2.200	0.690	0.580	200.000	340.000
MAXIMUM	14.000	0.900	2.300	410.000	763.000
RANGE	11.800	0.210	1.720	210.000	423.000
MEAN	9.669	0.795	1.118	308.706	599.706
STANDARD DEV	3.011	0.148	0.426	57.250	117.811

	SO4
N OF CASES	15
MINIMUM	2500.000
MAXIMUM	3700.000
RANGE	1200.000
MEAN	3166.667
STANDARD DEV	359.894

Note: all metals are total values measured in mg/L.

1981 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	16	17	18	18
MINIMUM	6.000	1650.000	14.000	0.060
MAXIMUM	7.300	5000.000	96.000	0.300
RANGE	1.300	3350.000	82.000	0.240
MEAN	6.550	4406.471	32.333	0.144
STANDARD DEV	0.327	995.314	18.458	0.058

	NI	CO	ZN	CA	MG
N OF CASES	18	15	17	18	18
MINIMUM	2.600	0.050	0.540	140.000	180.000
MAXIMUM	26.000	2.300	5.000	380.000	860.000
RANGE	23.400	2.250	4.460	240.000	680.000
MEAN	14.506	0.995	3.205	302.222	695.556
STANDARD DEV	5.491	0.458	1.521	63.483	177.175

	SO4
N OF CASES	18
MINIMUM	440.000
MAXIMUM	4500.000
RANGE	4060.000
MEAN	3263.333
STANDARD DEV	1378.733

Note: all metals are total values measured in mg/L.

1982 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	18	16	0	18
MINIMUM	5.700	750.000	.	0.014
MAXIMUM	7.400	5000.000	.	0.350
RANGE	1.700	4250.000	.	0.336
MEAN	6.494	3421.875	.	0.142
STANDARD DEV	0.505	1727.519	.	0.106

	NI	CO	ZN	CA	MG
N OF CASES	18	18	18	18	18
MINIMUM	1.100	-0.100	0.160	45.000	62.000
MAXIMUM	66.000	2.400	6.300	460.000	960.000
RANGE	64.900	2.500	6.140	415.000	898.000
MEAN	15.306	0.831	2.949	267.222	524.556
STANDARD DEV	14.659	0.617	1.824	138.810	298.170

	SO4
N OF CASES	18
MINIMUM	360.000
MAXIMUM	4504.000
RANGE	4144.000
MEAN	2790.222
STANDARD DEV	1547.159

Note: all metals are total values measured in mg/L.

1983 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	10	11	0	11
MINIMUM	5.200	1550.000	.	0.016
MAXIMUM	6.800	4600.000	.	1.100
RANGE	1.600	3050.000	.	1.084
MEAN	5.660	3468.182	.	0.469
STANDARD DEV	0.470	981.586	.	0.289

	NI	CO	ZN	CA	MG
N OF CASES	11	11	11	11	11
MINIMUM	3.400	0.540	0.840	110.000	190.000
MAXIMUM	32.000	2.400	6.200	360.000	710.000
RANGE	28.600	1.860	5.360	250.000	520.000
MEAN	18.127	1.325	3.485	260.273	459.545
STANDARD DEV	8.573	0.684	1.492	86.433	146.739

	SO4
N OF CASES	11
MINIMUM	1100.000
MAXIMUM	3700.000
RANGE	2600.000
MEAN	2686.364
STANDARD DEV	831.893

Note: all metals are total values measured in mg/L.

1984 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	14	14	0	14
MINIMUM	5.100	775.000	.	0.050
MAXIMUM	5.700	3100.000	.	0.820
RANGE	0.600	2325.000	.	0.770
MEAN	5.471	2187.500	.	0.387
STANDARD DEV	0.220	840.830	.	0.263

	NI	CO	ZN	CA	MG
N OF CASES	14	14	14	14	14
MINIMUM	3.400	0.300	0.780	9.000	84.000
MAXIMUM	34.000	2.500	3.600	340.000	450.000
RANGE	30.600	2.200	2.820	331.000	366.000
MEAN	18.514	1.330	2.141	184.643	282.857
STANDARD DEV	10.469	0.775	0.917	95.477	128.604

	SO4
N OF CASES	14
MINIMUM	700.000
MAXIMUM	3100.000
RANGE	2400.000
MEAN	1597.143
STANDARD DEV	784.341

Note: all metals are total values measured in mg/L.

1985 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	15	15	0	15
MINIMUM	4.900	385.000	.	0.038
MAXIMUM	5.900	2700.000	.	0.810
RANGE	1.000	2315.000	.	0.772
MEAN	5.360	1999.000	.	0.393
STANDARD DEV	0.253	620.381	.	0.226

	NI	CO	ZN	CA	MG
N OF CASES	15	15	15	15	15
MINIMUM	1.200	0.120	0.300	28.000	30.000
MAXIMUM	32.000	2.100	2.400	240.000	380.000
RANGE	30.800	1.980	2.100	212.000	350.000
MEAN	15.747	1.101	1.451	173.200	226.667
STANDARD DEV	7.877	0.510	0.505	52.311	88.694

	SO4
N OF CASES	15
MINIMUM	200.000
MAXIMUM	2000.000
RANGE	1800.000
MEAN	1356.667
STANDARD DEV	413.118

Note: all metals are total values measured in mg/L.

1986 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	15	15	0	15
MINIMUM	5.100	960.000	.	0.070
MAXIMUM	5.800	2550.000	.	1.100
RANGE	0.700	1590.000	.	1.030
MEAN	5.440	1930.667	.	0.529
STANDARD DEV	0.213	491.771	.	0.350

	NI	CO	ZN	CA	MG
N OF CASES	15	15	15	15	15
MINIMUM	2.700	0.300	0.500	75.000	80.000
MAXIMUM	30.000	2.100	3.000	220.000	300.000
RANGE	27.300	1.800	2.500	145.000	220.000
MEAN	14.493	1.045	1.361	152.267	203.867
STANDARD DEV	8.493	0.598	0.723	50.286	69.395

	SO4
N OF CASES	15
MINIMUM	60.000
MAXIMUM	1800.000
RANGE	1740.000
MEAN	1198.000
STANDARD DEV	432.488

Note: all metals are total values measured in mg/L.

1987 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	15	15	0	15
MINIMUM	4.800	1225.000	.	0.090
MAXIMUM	6.200	2900.000	.	1.100
RANGE	1.400	1675.000	.	1.010
MEAN	5.473	2263.333	.	0.449
STANDARD DEV	0.339	402.987	.	0.379

	NI	CO	ZN	CA	MG
N OF CASES	15	15	15	0	0
MINIMUM	2.500	0.200	0.330	.	.
MAXIMUM	32.000	2.800	2.800	.	.
RANGE	29.500	2.600	2.470	.	.
MEAN	14.827	1.216	1.133	.	.
STANDARD DEV	9.387	0.657	0.741	.	.

	SO4
N OF CASES	15
MINIMUM	700.000
MAXIMUM	2650.000
RANGE	1950.000
MEAN	1502.333
STANDARD DEV	433.803

Note: all metals are total values measured in mg/L.

1988 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	16	16	1	16
MINIMUM	5.200	625.000	3.000	0.017
MAXIMUM	7.600	2925.000	3.000	0.810
RANGE	2.400	2300.000	0.000	0.793
MEAN	6.006	2040.000	3.000	0.349
STANDARD DEV	0.842	662.231	.	0.270

	NI	CO	ZN	CA	MG
N OF CASES	16	16	16	0	0
MINIMUM	1.000	0.090	0.250	.	.
MAXIMUM	32.000	2.500	2.600	.	.
RANGE	31.000	2.410	2.350	.	.
MEAN	14.281	1.123	1.266	.	.
STANDARD DEV	9.860	0.734	0.708	.	.

	SO4
N OF CASES	16
MINIMUM	340.000
MAXIMUM	2100.000
RANGE	1760.000
MEAN	1325.000
STANDARD DEV	507.599

Note: all metals are total values measured in mg/L.

1989 SUMMARY STATISTICS FOR SEEP 1

	PH	SC	ALK	CU
N OF CASES	49	49	49	29
MINIMUM	4.650	590.000	-107.500	0.040
MAXIMUM	5.880	2600.000	1.200	1.770
RANGE	1.230	2010.000	108.700	1.730
MEAN	5.196	1682.959	-49.778	0.891
STANDARD DEV	0.417	623.146	30.910	0.572

	NI	CO	ZN	CA	MG
N OF CASES	29	29	29	29	29
MINIMUM	1.530	0.190	0.390	40.000	48.000
MAXIMUM	37.000	2.040	4.680	360.000	280.000
RANGE	35.470	1.850	4.290	320.000	232.000
MEAN	15.390	1.154	2.666	203.517	174.138
STANDARD DEV	10.004	0.625	1.409	97.078	72.396

	SO4
N OF CASES	29
MINIMUM	276.000
MAXIMUM	2050.000
RANGE	1774.000
MEAN	1243.345
STANDARD DEV	551.146

Note: all metals are total values measured in mg/L.