Twenty Years of Water-Level and Water-Quality Sampling
Butte Underground Mines and Berkeley Pit
Butte, Montana

1982 - 2001

prepared for

The Montana Department of Environmental Quality
Remediation Division
and
U.S. Environmental Protection Agency
Region VIII

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prepared by

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TABLE OF CONTENTS

List of Figures

List of Tables

Executive Summary

The Record of Decision (ROD) for the Butte Mine Flooding Operable Unit (BMFOU) stipulates that a yearly update of data collected from the Post Remedial Investigation/Feasibility Study (RI/FS) monitoring program be prepared. The report is to incorporate the most recent year's data with the existing data. This report presents data collected during the year 2001, combined with data collected since 1982, when ARCO suspended underground mine dewatering and mining in the Berkeley Pit. In previous years, separate reports were produced for the water-level and water-quality updates; these reports have been combined into one for this year.

Major new observations and developments discussed in this report are:

1. Inflow of water from the Horseshoe Bend Drainage into the Berkeley Pit continued. This inflow continued the increased rate of rise in the Berkeley Pit and associated underground mines.

2. Installation of weir in Horseshoe Bend Drainage for improved flow-rate monitoring.

3. West Camp pumping activities continue to maintain the ground-water level below the 5,435-foot elevation, stipulated in the 1994 Record of Decision. The volume of water pumped in 2001 was down about 4 percent from 2000 (260 vs. 270 acre-feet). The water level decreased just over 1.5 feet throughout the system.

3. ARCO installed automated monitoring equipment at the West Camp pump station. This equipment allows remote monitoring of pumping rate, water-level elevation, and hydrogen sulfide concentrations.

4. The annual Berkeley Pit model update resulted in a one-year change in the projected date (time line) when the 5,410-foot water-level elevation would be reached at the Anselmo Mine. Water levels were predicted to reach this elevation in 2019, one year later than shown in the 2000 model. The addition of Horseshoe Bend Drainage water into the pit was considered in the model update. The decreased flow of water from the Horseshoe Bend Drainage is most likely responsible for this change.

5. Water-quality monitoring showed the presence of radionuclides in many of the sampled waters. Concentrations were considerably above recommended limits.

Water-level data are presented in the same order and manner as the previous reports (MBMG Open-File Reports No. 376, No. 410, No. 435 and No. 456) for the reader's convenience. Hydrographs for selected sites and total and yearly water-level changes for all sites are presented. Water-quality data follow the presentation of water-level data in each section where water-quality data are available, as not all sites were sampled.

Acknowledgments

The information contained in this report represents the work of many companies and agencies over the past 20 years. Without their cooperation, this report could not have been prepared. Numerous individuals have been responsible for actual data collection. It is fitting, with this being the Twentieth Anniversary of the flooding of the underground mines and Berkeley Pit, to pay special recognition to the former Anaconda Company employees who began the monitoring and sampling of the mines. Special acknowledgment is given to Phil Doughty, Sam Stephenson, and Roger Gordon. Their dedication and creativity in monitoring and sampling of mine waters more than 4,000 feet below ground surface provided the initial information that all future work and evaluations relied upon.

Montana Resources (MR) employees Frank Gardner (retired), Ray Tilman (retired), Steve Walsh, and John Burk continued to provide assistance to the numerous parties participating in future studies. Their cooperation and access to the MR mine area is greatly appreciated. To MR's contractor, ESE and particularly Joe Griffin, Jeff Martin, and Gary Pierce, and to Montana Bureau of Mines and Geology (MBMG) employees, Marvin Miller, John Sonderegger (retired), Fred Schmidt, Mike Kerschen and James Rose, a special thank you is given for their assistance. Former MBMG employees who participated in monitoring and sampling activities and who deserve special acknowledgment are Herman Moore, Jim Boren, and Oran Brazington.

Representatives of New Butte Mining and Montana Mining Properties continue to allow access to their properties for monitoring purposes. Special acknowledgment is given to the citizens of Butte who allow access to their private wells for monitoring purposes.

The State of Montana, Department of Environmental Quality (DEQ), and the U.S. Environmental Protection Agency (EPA) have provided funding for the MBMG to conduct monitoring and sampling activities and preserve continuity between various studies. The EPA has provided invaluable support of the MBMG activities, not only through continued funding via DEQ, but also in the realization that flexibility in the monitoring program is essential.

Errors and omissions remain the authors' responsibility.

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SECTION 1.0 SITE BACKGROUND

The Anaconda Company announced on April 23, 1982, that they were no longer going to operate their underground mine pump system, thus allowing the Butte underground mines and ultimately the Berkeley Pit to fill with water. The pump station located on the 3900 level of the Kelley Mine (figure 1-1) had until then pumped between 4,000 and 5,000 gallons of water per minute, collected from the underground mines, to the surface. The centralized pumping of underground mine water began in the early 1900's. The water, which was acidic and contained substantial concentrations of copper and other trace metals, was used in the leach pad and precipitation plant operations. Allowing water in the underground mines to rise resulted in a corresponding rise in water levels in the bedrock adjacent to the mines. The underground mine workings consisted of over 5,600 miles of interconnected mine workings (MBMG, 2001), extending to a depth greater than 1 mile below ground surface. Historic estimates of mine workings made by the Anaconda Company determined there were over 10,000 miles of mine workings when stopes and drifts were included (MBMG 1998). Figure 1-2 is a cross section showing the various underground mine levels and selected mine shafts.

The full nature of the influence that historic mine dewatering had on the local groundwater system was not well documented, thus a comprehensive water-level and water-quality monitoring network was established. Concerns about the site's long-term environmental impact on ground water and surface water led to the site being listed on the Federal EPA Superfund list. Current monitoring is the result of this listing.

Section 1.01 Introduction

The Butte Mine Flooding Operable Unit (BMFOU) Record of Decision (ROD) specifies that an annual review of water levels and water quality be performed. The first water-level review was completed in 1998 as a 15-year evaluation, from the beginning of flooding of the Butte underground mines and Berkeley Pit in 1982 through 1997 (Duaime, 1998); the present study is the fourth such report. Notable changes and a comparison of trends are discussed. Previous years had separate reports for water-level and water-quality evaluations; however, this report combines both topics.

This report does not present an overview of the history of mining on the Butte Hill, nor the Superfund processes that have followed since the Environmental Protection Agency (EPA) designated the flooding underground Butte mines and Berkeley Pit a Superfund site in 1987.

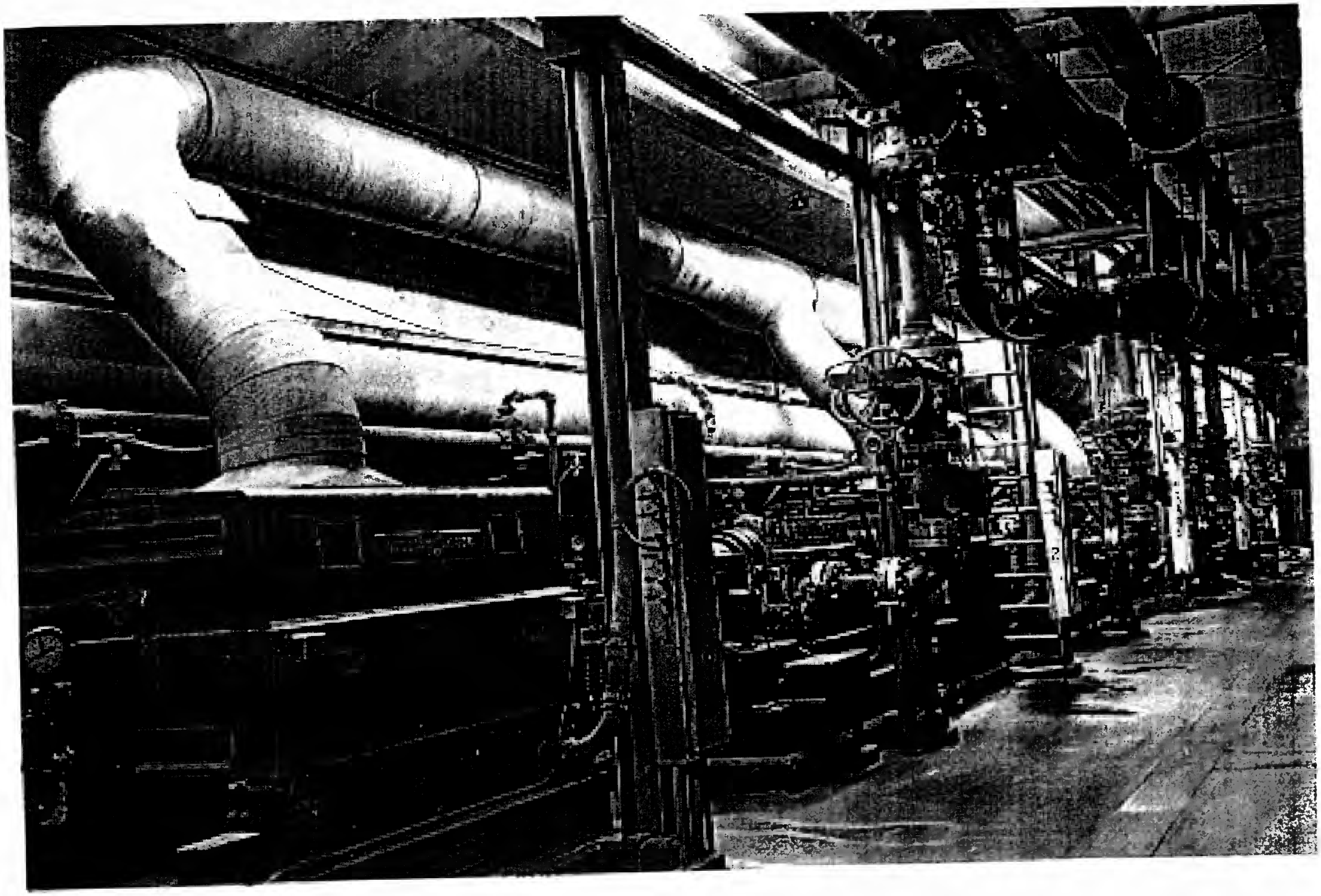


Figure 1-1. General view of Kelley Mine 3900-level pump station. (Photo courtesy of World Museum of Mining.)

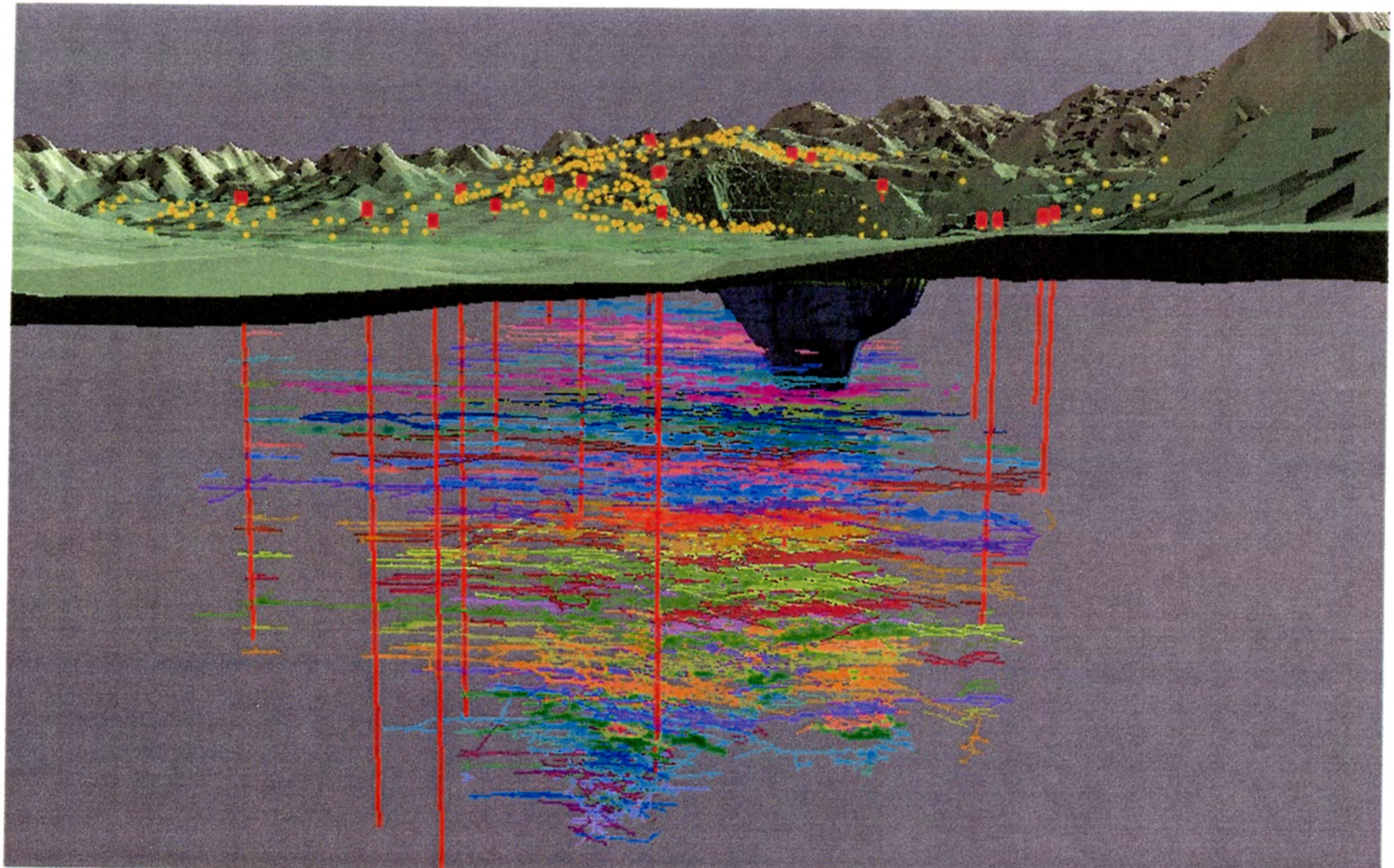


Figure 1-2. Cross section of underground mine workings, showing locations of selected mine shafts (red vertical lines). Yellow dots show location of numerous mines located on Butte Hill at some time.

The reader is referred to the Butte Mine Flooding RI/FS, Butte Mine Flooding ROD, or MBMG Open-File Report No. 376 for greater detail and information about the site.

Monitoring activities continued in 2001 in the East Camp, West Camp and Outer Camp systems (figure 1-3). The East Camp System includes mines and mine workings draining to the Kelley Mine pump station when mining and dewatering were suspended in 1982. The West Camp System includes workings that historically drained to the East Camp from the southwest portion of the Butte Mining District, but were hydraulically isolated by the placement of bulkheads in interconnected mine workings to separate the West Camp from the East Camp. The Outer Camp System consists of the western and northern extents of mine workings that were interconnected to the East Camp at some time, but have been isolated with water levels returning to, or near, pre-mining conditions. More than 85 percent of the underground mine workings had been inundated with water through 2001. By the time water levels in the underground mines reached the elevation of the bottom of the Berkeley Pit, more than 66 percent of the workings had already been flooded.

Section 1.1 Notable 2001 Water-Level and Water-Quality Changes and Monitoring Activities

(1) Montana Resources' (MR) June 30, 2000, suspension of mining and milling operations continued throughout 2001. As a result of this suspension, water from the Horseshoe Bend Drainage (HSB) discharged into the Berkeley Pit. This additional input of water into the pit resulted in the continued increased rate of rise in water levels in the associated underground mines and surrounding bedrock.

The addition of HSB water into the pit resulted in an increased rate of rise throughout the East Camp mine-bedrock system. The average monthly rate of rise for 2001 was slightly more than 1.5 feet. The input of HSB water resulted in an additional 1.08 billion gallons of water entering the East Camp system during 2001.

(2) Water pumped from the Continental Pit was allowed to flow into the Berkeley Pit through January, 2001. A total of 8 million gallons of water was pumped to the Berkeley Pit. MR stopped dewatering the Continental Pit the end of January 2001, allowing water to begin to accumulate in the bottom of this pit. Approximately 14 feet of standing water was in the pit bottom by the end of 2001. Water-quality differences were seen in water samples collected from the dewatering well and the standing water in the pit bottom.

(3) Water-quality sampling showed the presence of radionuclides in many of the sampled waters. Additional sampling took place with samples submitted to a second lab to verify that the elevated concentrations were real. Uranium and radium were commonly radionuclides exceeding recommended standards.

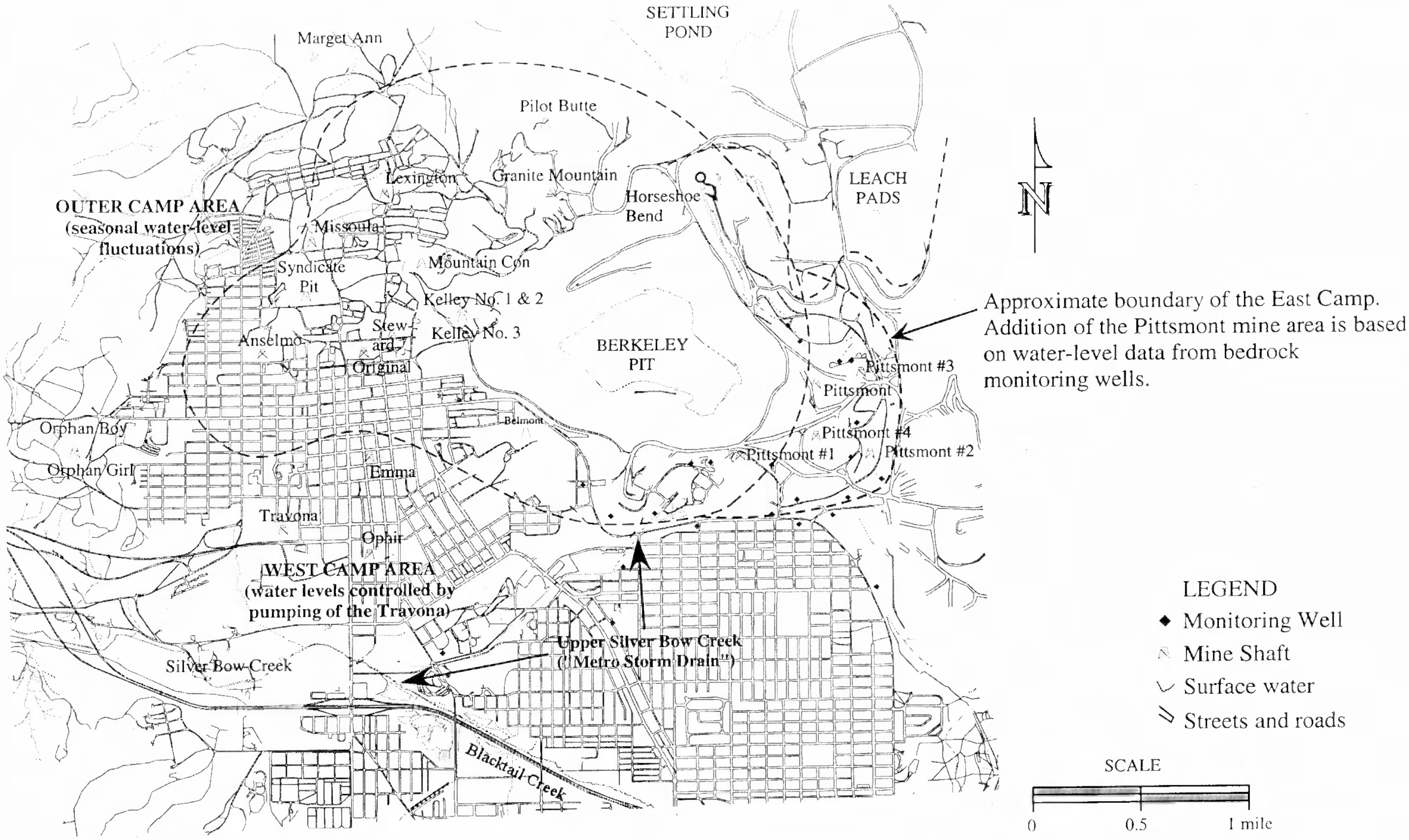


Figure 1-3. The mines of the Butte hill are presently considered in three groups: the East Camp, which includes the Berkeley pit and the area to the east; the West Camp in the southwest part of the hill; and the Outer Camp which includes the outlying mines.

(4) The final activity of note in 2001 was the installation of a weir in the Horseshoe Bend Drainage to enable better flow monitoring. It was determined that the flume previously used for flow monitoring had a submergence problem that affected accurate flow measurement. While it is possible to adjust the flow rates to account for this problem, it was decided to install a weir upstream of the flume for monitoring purposes. The weir was installed in early July 2001. HSB drainage flow rates for the last 6 months of 2001 are based upon monitoring of this site.

Section 1.2 Precipitation Trends

Precipitation during 2001 continued to be less than average. Total precipitation was 10.81 inches compared to the long-term average of 12.97 inches. This is a decline of 16 percent and is the third consecutive year of below-average moisture. Table 1.2.1 contains monthly precipitation totals from 1982 through 2001, while figure 1-4 shows this information graphically in comparison to the long-term yearly average. Overall precipitation totals, since flooding of the mines began, are very similar to the long-term average (13.09 inches vs. 12.97 inches). Figure 1-5 shows departure from normal for precipitation from 1895 through 2001.

Table 1.2.1 Butte NOAA Precipitation Statistics, 1982-2001

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVERAGE
Mean	**0.54**	**0.48**	**0.88**	**0.96**	**2.06**	**2.19**	**1.61**	**1.33**	**0.99**	**0.76**	**0.69**	**0.58**	**13.09**
Std. Dev.	0.36	0.29	0.39	0.57	0.77	1.36	1.23	0.91	0.71	0.52	0.40	0.42	
Maximum	1.40	1.26	1.84	1.80	3.88	4.62	4.18	3.10	2.50	1.73	1.50	1.99	
Minimum	0.10	0.11	0.25	0.00	0.95	0.50	0.00	0.15	0.07	0.00	0.15	0.01	
Number of years													20
Number of years precipitation greater than mean													6
Number of years precipitation less than mean													14

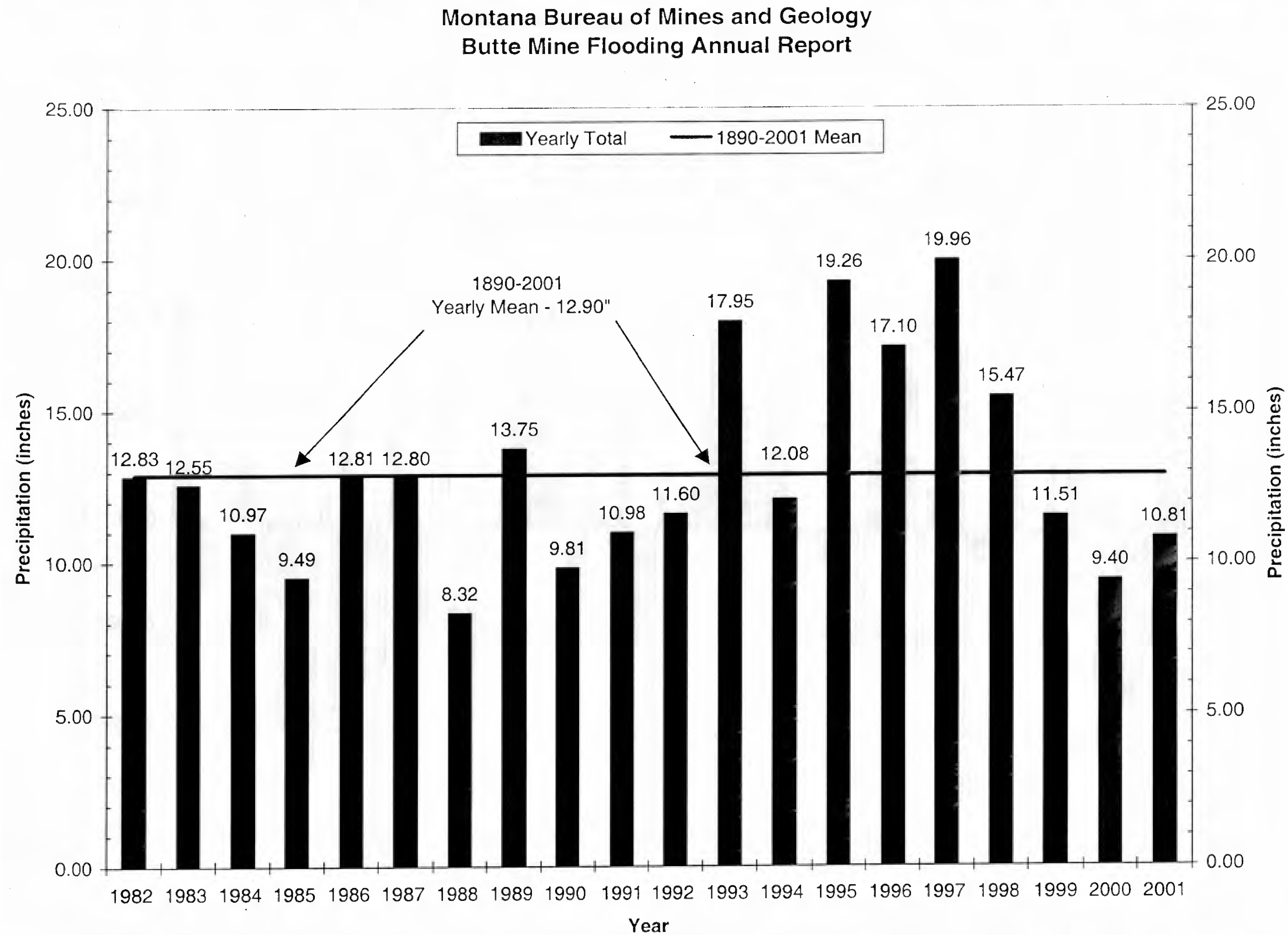


Figure 1-4. Yearly precipitation totals, 1982-2001, showing 1890-2001 yearly mean precipitation total.

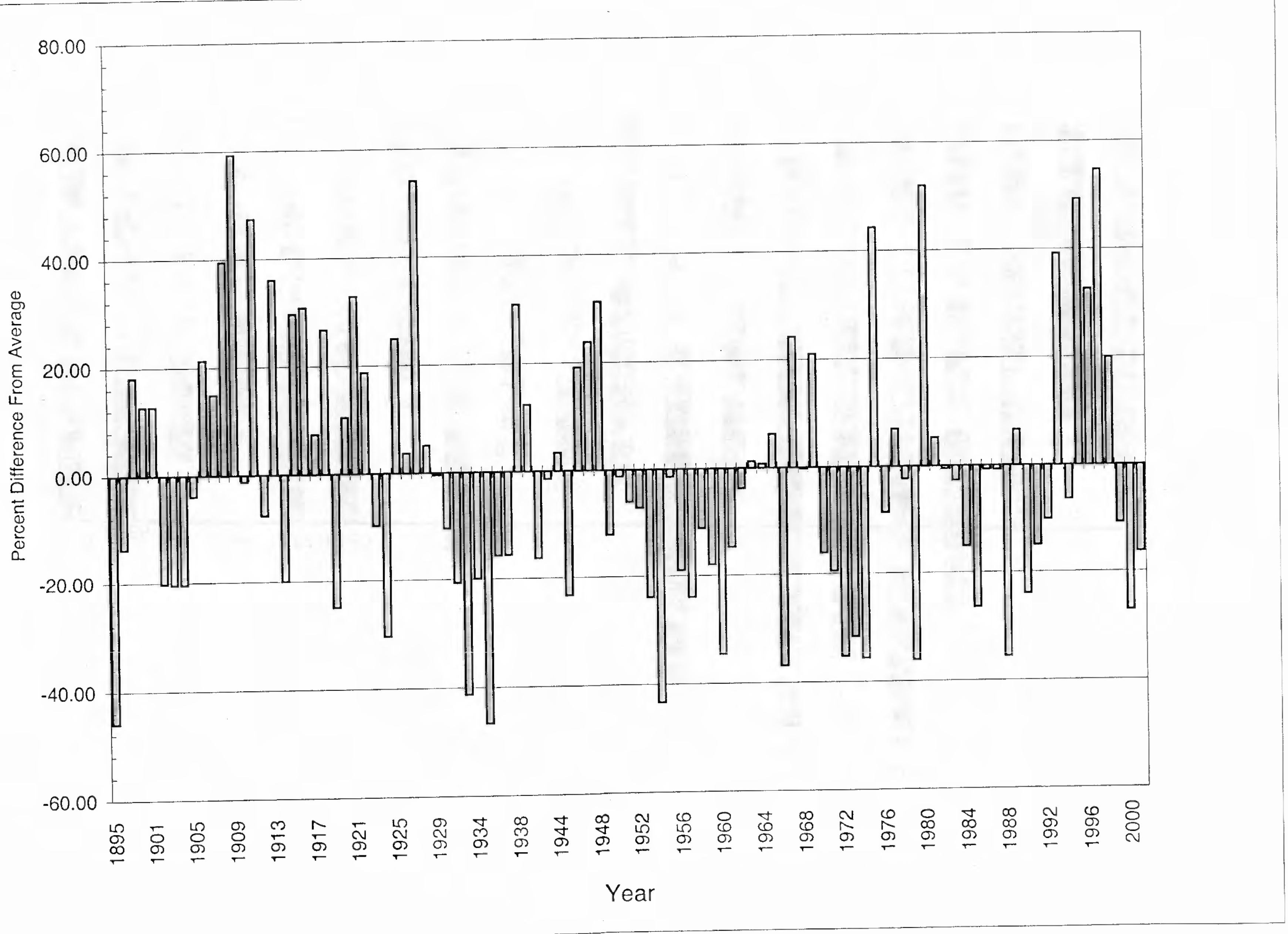


Figure 1-5. Percent precipitation variation from normal, 1895-2001

SECTION 2.0 EAST CAMP SYSTEM

The East Camp Monitoring System consists of the Anselmo, Belmont, Granite Mountain, Kelley, Steward, Lexington and Pilot Butte Mines, the Berkeley Pit and the mine workings associated with those sites. It also includes the East Camp bedrock system adjacent to the East Camp mines not affected by mine-water pumping and the shallow East Camp alluvial system (figure 2-1). The East Camp alluvial system is discussed first, followed by the East Camp bedrock system.

Section 2.1 East Camp Alluvial System

The East Camp alluvial monitoring system consists of a series of four different groups of wells. Each group of wells represents sites installed or monitored during different studies that have been incorporated in the BMFOU monitoring program. Water-level changes and monthly precipitation amounts are shown on hydrographs for selected wells. Water-quality results are shown and discussed for each well sampled. Unlike the water-level monitoring, water-quality sampling does not occur at each East Camp monitoring well and takes place only twice per year.

Section 2.1.1 AMC Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown on figure 2-2; table 2.1.1.1 lists the annual water-level changes for these sites. Water levels declined in 7 of the 10

Table 2.1.1.1 AMC Wells Annual-Water Level Changes

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-11	AMC-12	AMC-13	AMC-15	AMC-23	AMC-24
1983	-23.75	-2.30	-4.90	DRY	DRY	0.20	0.60	-5.80	0.00	-0.10
1984	-4.50	-2.55	-3.75	DRY	DRY	-1.80	-1.10	-3.40	0.00	0.18
1985	-3.40	-3.90	-3.00	DRY	DRY	-2.45	-1.85	-2.80	0.00	0.10
1986	8.70	3.90	-0.90	DRY	DRY	1.90	1.00	-2.10	0.50	0.40
1987	0.10	0.40	1.50	DRY	DRY	0.60	0.10	0.00	0.30	0.00
1988	0.20	-0.40	0.30	DRY	DRY	-0.10	-1.00	0.80	-0.10	-0.10
1989	-2.30	-0.80	-0.90	DRY	DRY	-0.20	-0.10	0.10	0.00	0.00
1990	0.20	0.10	0.30	DRY	DRY	1.10	0.00	-0.10	0.20	0.10
1991	0.00	0.30	0.80	DRY	DRY	-0.60	0.30	-0.30	0.10	0.00
1992	0.40	-0.40	0.50	DRY	DRY	-0.30	0.00	-0.10	0.00	0.00
1993	0.40	0.70	0.80	DRY	DRY	1.10	1.00	-0.40	0.40	0.10
1994	0.64	0.53	0.91	DRY	DRY	-0.19	-0.50	0.96	-0.32	0.07
1995	0.64	1.01	0.51	DRY	DRY	1.23	1.13	0.97	0.01	-0.07
1996	-0.05	0.62	2.14	DRY	DRY	0.74	0.69	2.60	0.38	0.12
1997	1.80	1.47	2.24	DRY	DRY	1.20	0.70	2.80	-0.36	-0.25
1998	-1.52	0.42	1.15	DRY	DRY	0.18	0.09	0.58	0.15	0.12
1999	-1.56	-2.03	-2.45	DRY	DRY	-1.56	-1.09	-1.50	-0.09	-0.18
2000	-2.46	-2.56	-3.88	DRY	DRY	-1.77	-1.17	-3.73	-0.14	-0.08
2001	-1.89	-1.92	-3.03	DRY	DRY	-0.55	-0.36	-2.34	-0.02	0.61
Net Change	*-28.35*	*-7.41*	*-11.66*	*0.00*	*0.00*	*-1.27*	*-1.56*	*-13.76*	*1.01*	*1.02*

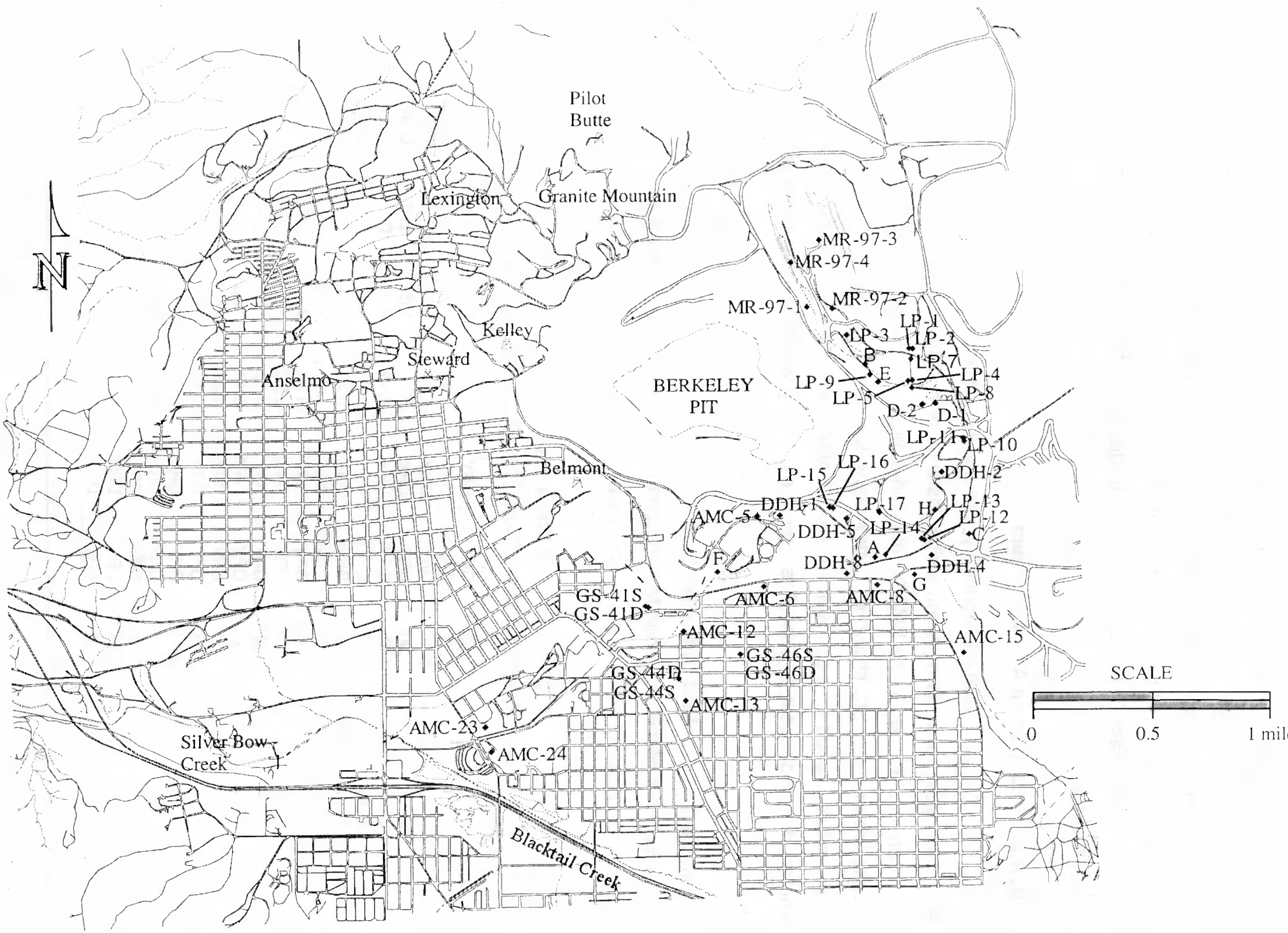


Figure 2-1. East Camp Monitoring Sites.

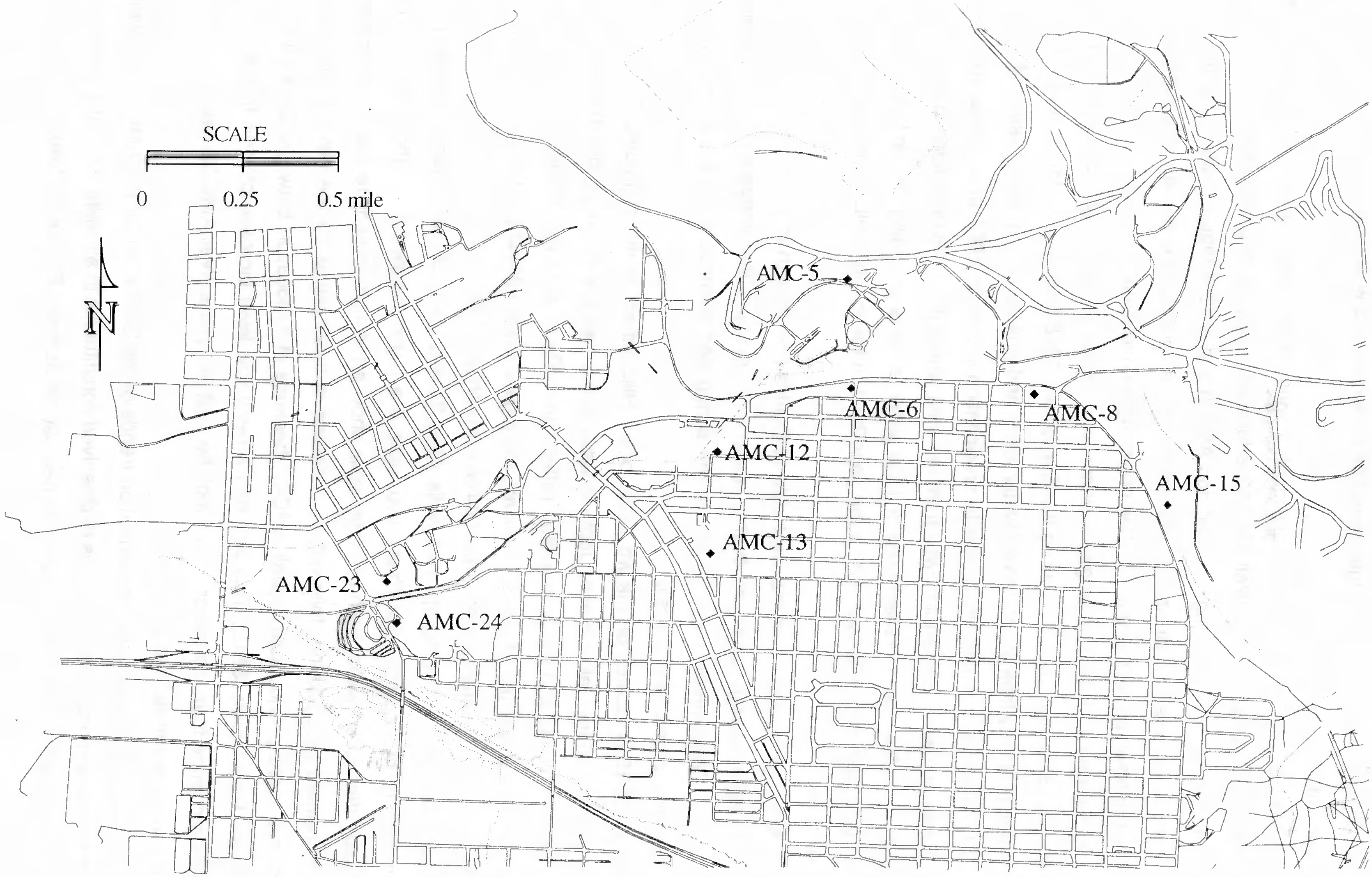


Figure 2-2. AMC well location map.

wells during 2001; however, the amount of decline was less than during 2000. Wells 10 and 11 remained dry. Net water-level changes from 1983 are rises in 2 wells, declines in 6 wells, and 2 wells remain unchanged (dry).

Wells AMC-5, AMC-6, and AMC-8 are located south of the active mine area and the Butte Concentrator facility (figure 2-2). Well AMC-12 is located southwest of these wells. Hydrographs for wells AMC-5 and AMC-12 (figure 2-3a) and AMC-6 and AMC-8 (figure 2-3b) show the long-term trends in the shallow alluvial ground-water system south of the pit. Monthly precipitation amounts are shown as bars and are plotted on the right-hand y-axis.

There were no noticeable changes in water-level trends for wells AMC-5 and AMC-8. The water-level decline that began following the September 1998 Berkeley Pit landslide continued. Precipitation had very little effect on well water levels and was very short lived. Wells AMC-6 and AMC-12 both showed greater response to precipitation events in 2001 than in the previous 2 years. These two wells are farther away from the area where the 1998 landslide occurred and it is possible the influence of this landslide on local water levels is lessening. Water levels declined between 0.55 feet and 3.03 feet during the year 2001 in these four wells. These are less than 2000 declines.

Well AMC-13 is located on the west side of Clark's Park, south of wells GS-44S and GS-44D. This well's hydrograph shows both a response to precipitation events and lawn watering (figure 2-4a). Water-levels begin to rise in the spring and continue throughout the summer, before starting to decline in the fall.

Well AMC-15 is located on the west side of the Hillcrest waste dump (figure2-2) in an area where reclamation has taken place. Depth to water in this well is very deep (<90 ft) compared to the other AMC wells and the hydrograph reflects this. There were minor seasonal changes in water-levels for a number of years. However, the recent below normal precipitation is shown by the steep decline in water-levels the past three years (figure 2-4b).

Figure 2-5 shows hydrographs of wells AMC-23 and AMC-24 with monthly precipitation amounts. The hydrographs for these two wells are much different than those for the four previously discussed wells. Both of these wells show an almost immediate rise in water levels after increased precipitation, followed by a decline in water levels by the next month. These events are more pronounced in well AMC-24 because of its location between Blacktail Creek and Silver Bow Creek (SBC). This well had a net-water level increase of 0.61 feet for 2001, which is a change from the minor declines of the past two years. Well AMC-23 lies north of SBC so it receives recharge from SBC only.

Table 2.1.1.2 summarizes concentration trends of the 2001 data for the AMC series wells. With a few exceptions, concentrations of dissolved constituents in all wells follow the same trend as in recent years. In well AMC-5, the well nearest the Berkeley Pit, concentrations of copper

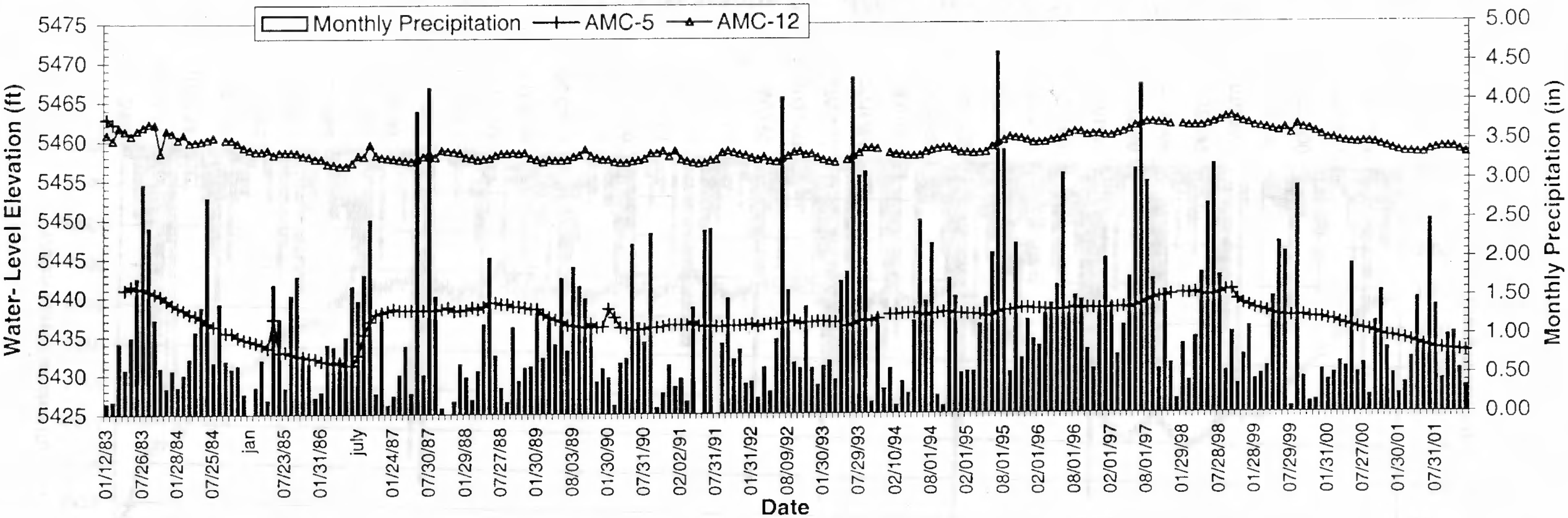


Figure 2-3a. Water-level hydrographs for AMC-5 and AMC-12 wells.

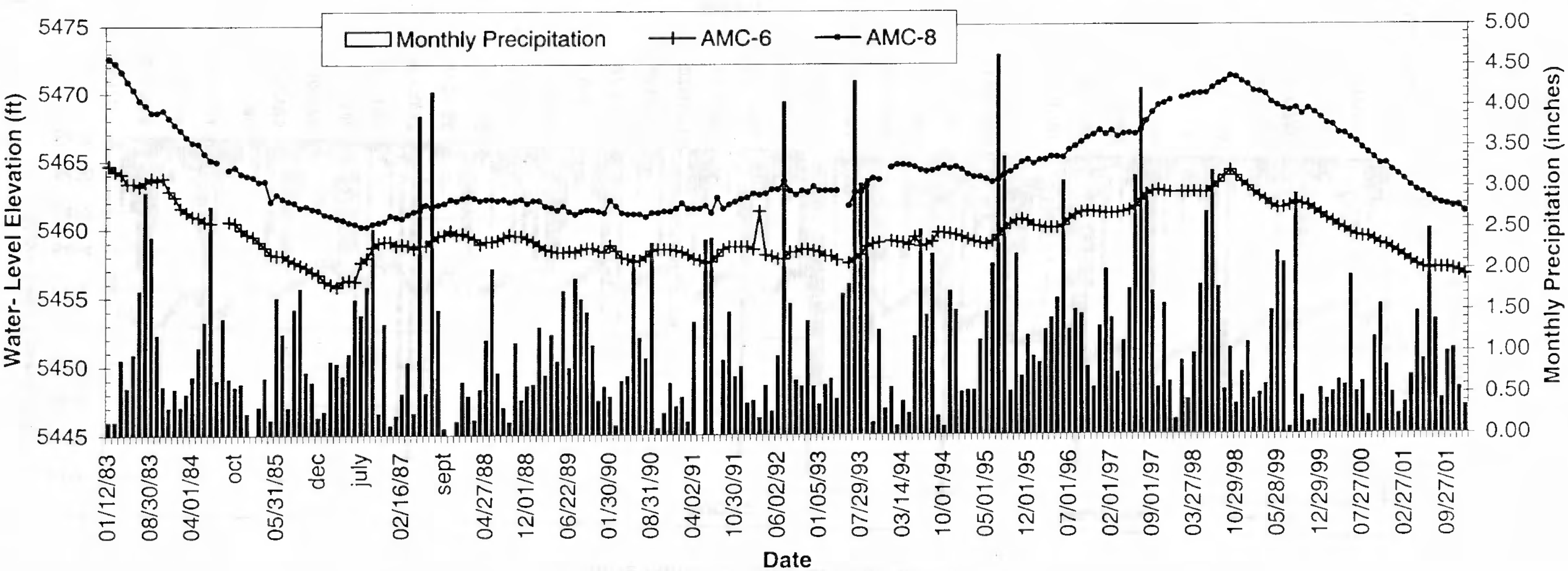


Figure 2-3b. Water-level hydrographs for AMC-6 and AMC-8 wells.

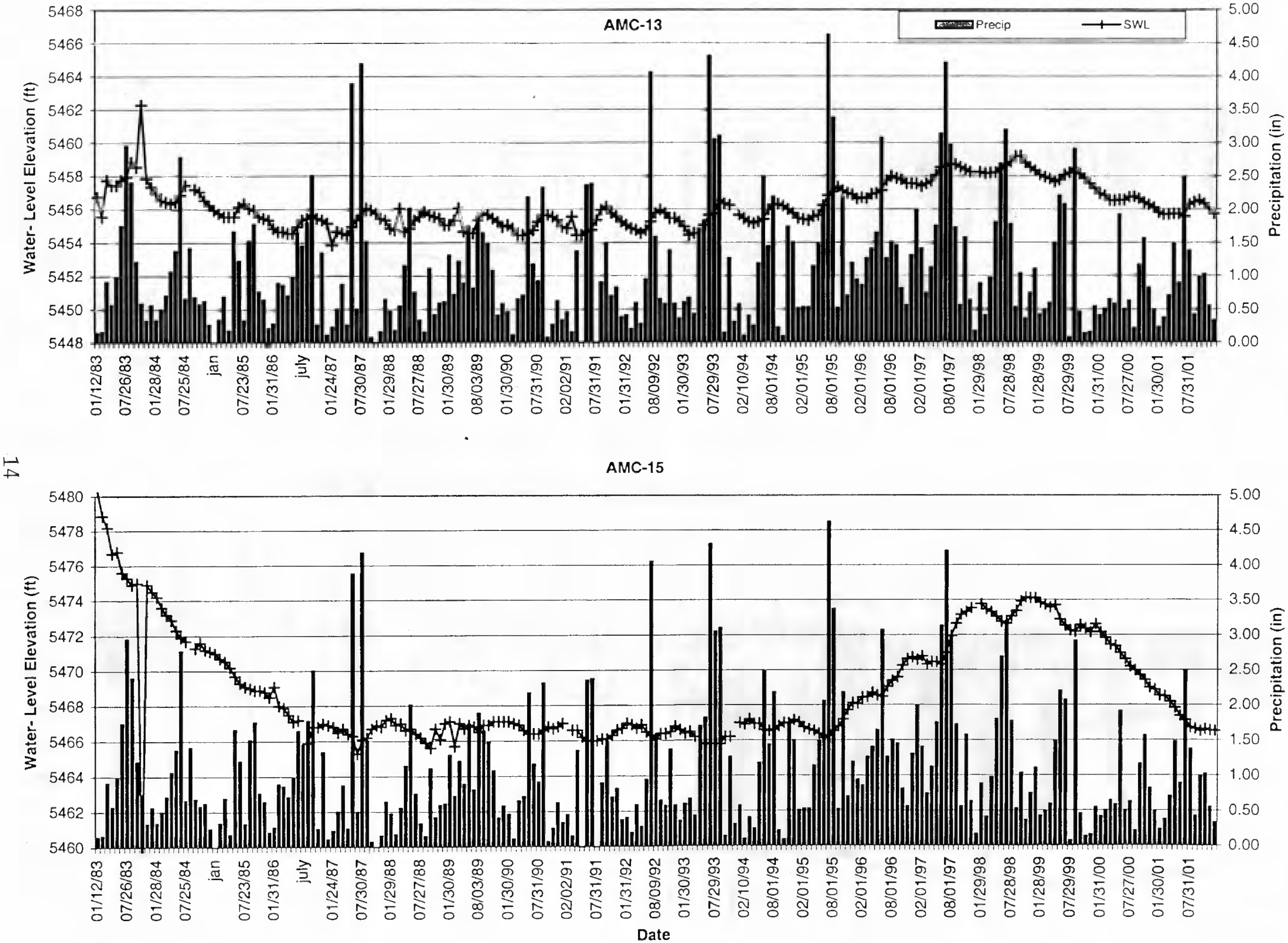


Figure 2-4. Water-level hydrographs for AMC-13 (a), and AMC-15 (b) wells.

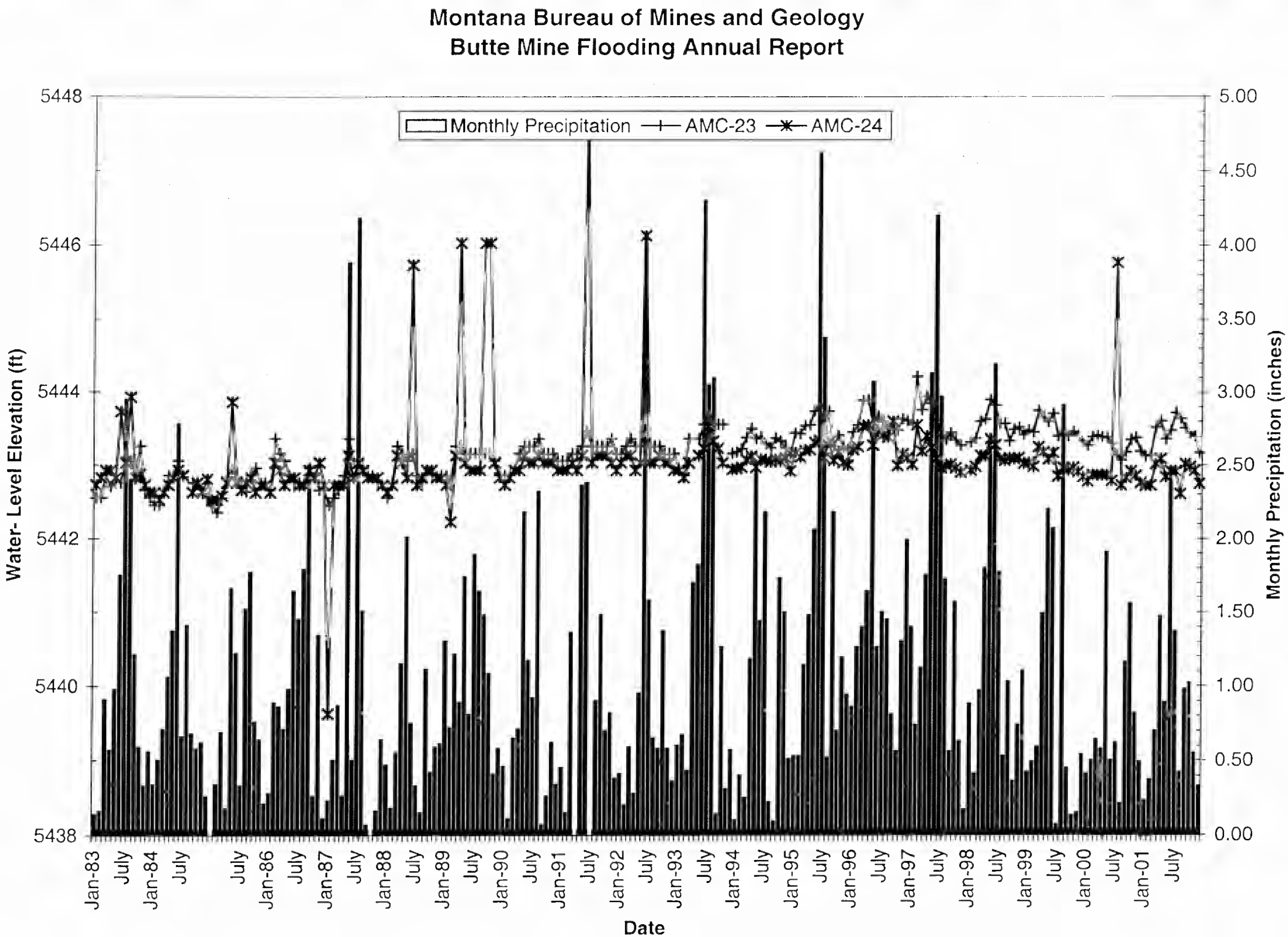


Figure 2-5. Water-level hydrographs for AMC-23 and AMC-24 wells.

(12,000 µg/L), iron (130 mg/L), and zinc (54,000 µg/L) exhibit a downward trend, but far exceed Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs). The concentration of sulfate in this well increased about 185 mg/L to 1,360 mg/L; this is a reverse from 2000 data, but tends to follow the long-term trend.

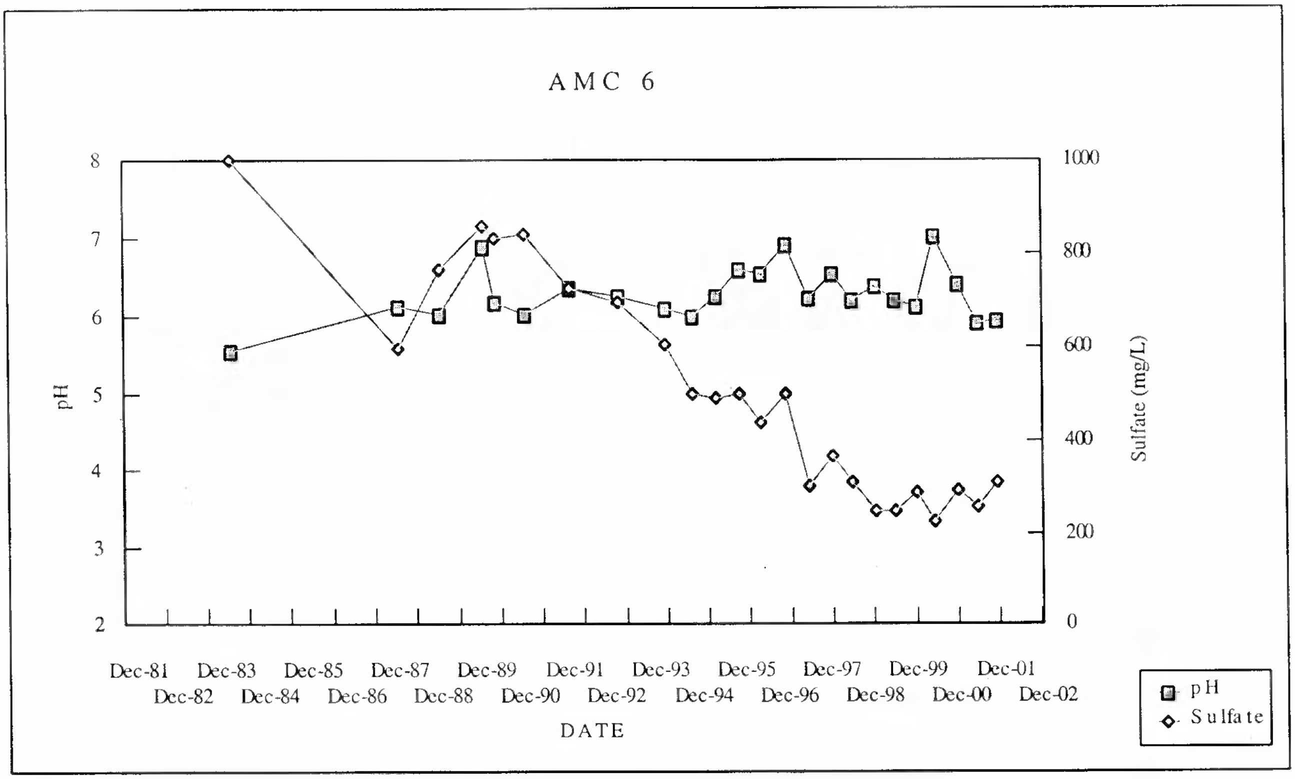
Wells AMC-6 and AMC-8, just south of the Berkeley Pit, continue to show a slight downward trend in the concentrations of nearly all the dissolved constituents. The concentration of sulfate in well AMC-6 has decreased about 800 mg/L over the 20-year period of record; there does, however, seem to be a slight reversal (increase) of this trend over the past two years (figure 2-6). Arsenic concentrations in both wells have increased over the period of record, but remain less than 10 µg/L. The same is true for wells AMC-12, AMC-13, and AMC-15. These wells show no great change in concentrations in the most recent data. AMC-24 shows the greatest variation in trend as well as the highest overall concentration of arsenic. Arsenic values have varied from 25 to 4 to 20 and most recently to 35 µg/L over the past two years (figure 2-6).

Table 2.1.1.2 Exceedences and Trends for AMC Series Wells, 2001

Well name	Exceedences (±1)	Concentration Trend	Remarks
AMC-5	Y	Downward	Slight trends, except for sulfate which increased by 185 mg/L
AMC-6	Y	Downward	Slight downward trend continues
AMC-8	Y	Downward	Slight downward trend continues
AMC-12	Y	Variable	Sulfate increased by 100 mg/L
AMC-13	Y	Variable	Net change is small, but decreasing overall
AMC-15	Y	Variable	Only sulfate exceeds SMCL; net change is small for all constituents
AMC-23	Y	Variable	Net change is small for all constituents
AMC-24	Y	Variable	Arsenic increased from 20 to 35 µg/L; the highest concentration since 1982.

As noted, the concentration of arsenic has increased over the period of record in all wells but AMC-23; the MCL for arsenic is exceeded in AMC-24. The concentration of iron varies by an order of magnitude between wells and in individual wells. No consistent trends are apparent except in well AMC-23 which shows a steady increase over the period of record. All of the AMC-series wells exceed the iron SMCL of 0.3 mg/L.

Zinc concentrations in the AMC series wells range from 54,000 µg/L in AMC-5 near the Berkeley Pit to about 40 µg/L in AMC-15 on the east margin of the valley. No strong trends are apparent in any wells; most show a slight downward trend over the period of record. Copper



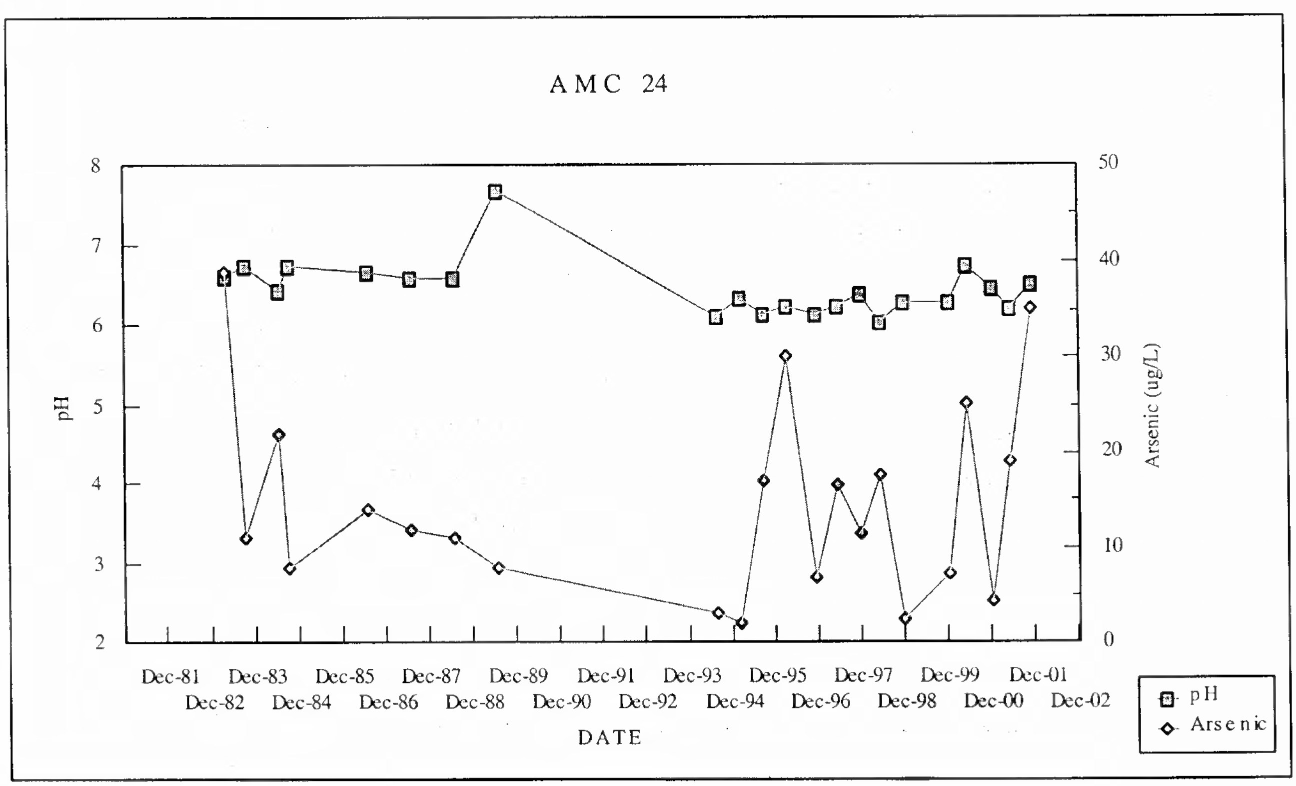


Figure 2-6. Sulfate concentrations for AMC-6 and arsenic concentrations for AMC-24

concentrations range from about 10,000 µg/L in AMC-5 to less than 10 µg/L in AMC-13, AMC-15, and AMC-24. With the exception of AMC-12, copper concentrations have generally decreased over the period of record. With the exception of AMC-8 and AMC-24, the concentrations of sulfate have decreased or remained nearly constant in the AMC series wells.

Section 2.1.2 LP Wells

The locations of the LP series monitoring wells are shown on figure 2-7. As discussed in MBMG OFR-376, these wells were installed in 1991 as part of the BMFOU RI/FS study. Monthly water-level monitoring and semi-annual sampling of the LP series wells continued. Table 2.1.2.1 contains a summary of annual water-level changes for these 17 sites. Water levels declined in 16 of the 17 wells during 2001. Water levels have a net decline in all 17 of these wells. Net water-level declines range from 1.6 feet to 38.8 feet in wells LP-14 and LP-08, respectively. Monitoring data through 2001 indicated that water levels in wells (LP-1 through LP-09) located to the north of the Pittsmont Waste Dump continued to decline more rapidly than in wells to the east and south of the Pittsmont Dump. Some of these declines were much greater than in previous years, most notably those at wells LP-01, LP-02, LP-04, LP-08, and LP-09.

The water level declines in the areas adjacent to wells LP-06 and LP-07 are greater than those shown in Table 2.1.2.1, as both of these wells are currently dry. The water levels measured in these wells are actually standing water in the well bottom, as the level had dropped below the well's screened interval.

The steep decline noted in some of these wells in 1999 following MR's deactivation of the leach pads, which continued throughout 2001. Based upon observed water levels since 1999, the operation of the leach pads had a major impact on the alluvial aquifer in this area. Water levels in these wells show only marginal influence, if any, by precipitation events.

Figures 2-8 through 2-10 show hydrographs from seven representative wells, along with monthly precipitation totals. LP-01 and LP-02 wells are located to the north of the site near the base of various leach pads and are screened in two different intervals. Well LP-01 is screened deeper than well LP-02. The wells which are screened at depths of 129-159 feet and 177-197 feet, respectively and are completed in the deeper portion of the alluvial aquifer. Water-level responses are similar in these two wells (figure 2-8). The downward water-level trend is very evident.

Wells LP-04 and LP-07 are located south of wells LP-01 and LP-02 and north of the Pittsmont Dump (figure 2-7). These wells are completed at different depths also. Well LP-04 is screened from 125-145 feet below ground surface while well LP-07 is screened from 90-95 feet below ground surface. Based upon these well-completion depths, well LP-07 would be

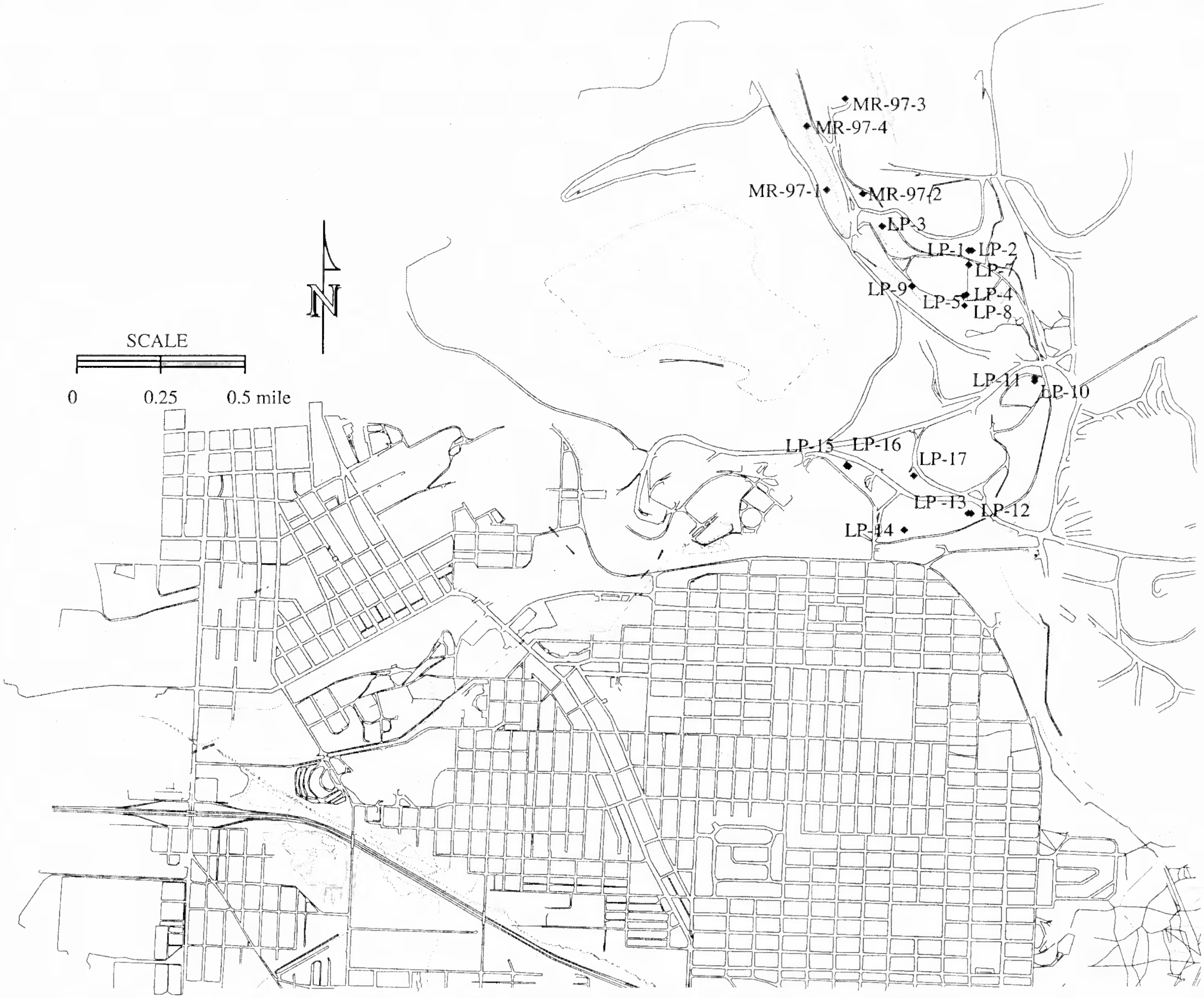


Figure 2-7. LP Series and MR97 Wells Location Map.

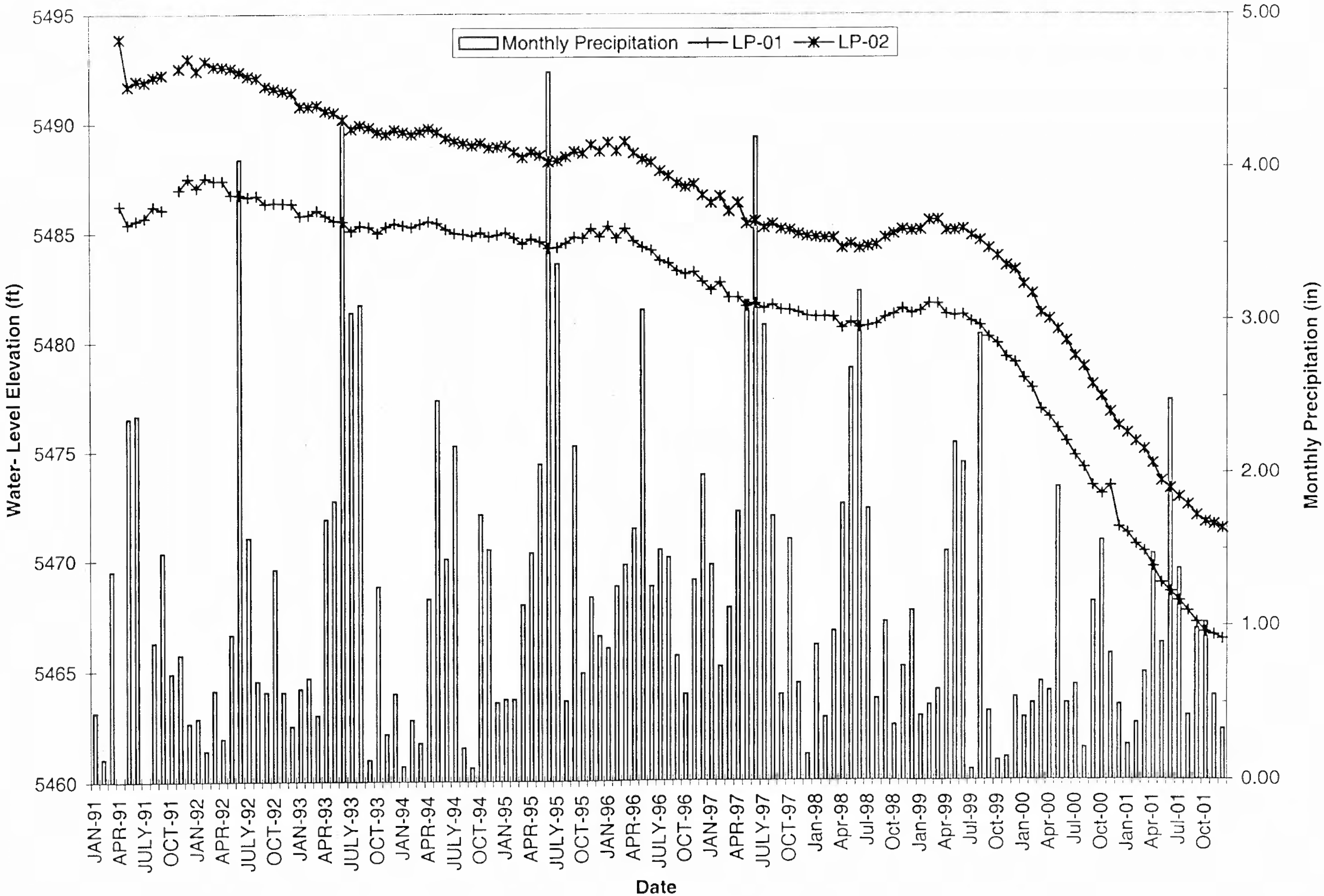


Figure 2-8. Water-level hydrographs for LP-01 and LP-02 wells.

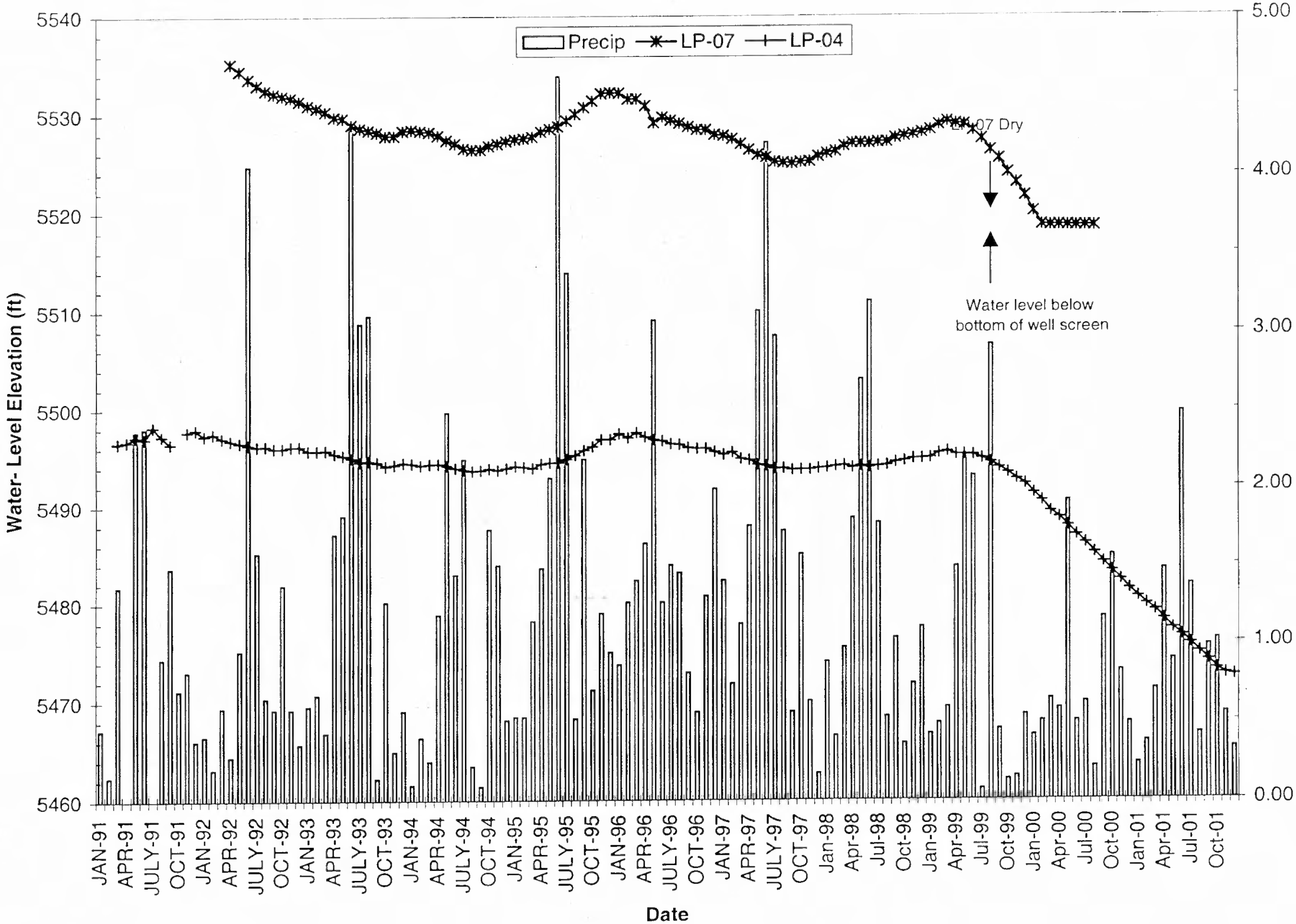


Figure 2-9. Water-level hydrographs for LP-04 and LP-07 wells.

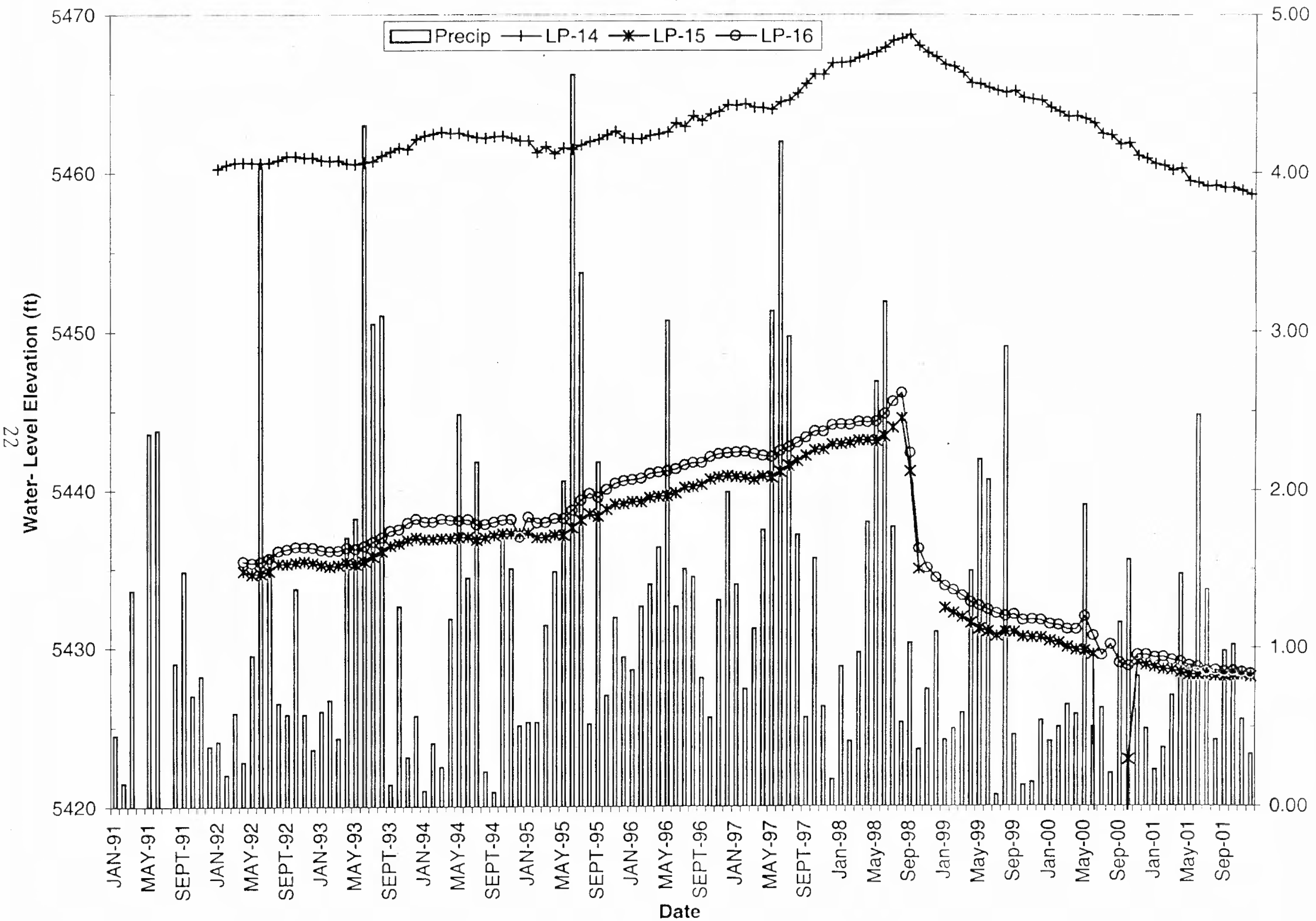


FIgure 2-10. Water-level hydrographs for LP-14, LP-15, and LP-16 wells.

Table 2.1.2.1 Annual Water-Level Change in LP Wells

Year	LP-01	LP-02	LP-03	LP-04	LP-05	LP-06	LP-07	LP-08	LP-09
1991	1.23	-0.91	-2.02	1.38	4.35	-0.46	-	-	-0.70
1992	-1.14	-1.56	-0.66	-1.75	-1.08	0.80	-3.79	-3.78	-7.16
1993	-0.91	-1.69	1.84	-1.69	-2.42	-0.53	-3.06	-4.83	-2.24
1994	-0.53	-0.80	-1.61	-0.57	-1.42	-2.28	-1.03	-2.11	-2.90
1995	-0.08	-0.19	-1.74	2.94	0.34	0.47	4.91	4.30	3.35
1996	-2.05	-2.00	-0.73	-1.28	-3.40	2.01	-4.30	-1.14	-1.49
1997	-1.58	-1.86	-0.09	-1.73	-3.32	-1.37	-2.24	-2.63	-0.29
1998	0.12	0.23	-2.03	1.01	-0.03	-0.58	2.44	0.99	1.60
1999	-2.24	-1.76	-7.44	-2.64	-3.15	-1.65	-6.47	-3.52	-3.77
2000	-7.55	-7.16	-5.45	-10.83	-7.87	-0.96	-3.10	-14.03	-13.28
2001	-5.13	-4.73	-9.51	-8.88	-5.47	Dry	Dry	-12.10	-3.04
Net Change	*-19.86*	*-22.43*	*-29.44*	*-24.04*	*-23.47*	*-4.55*	*-16.64*	*-38.85*	*-29.92*

Year	LP-10	LP-11	LP-12	LP-13	LP-14	LP-15	LP-16	LP-17
1991	-	-	-	-	-	-	-	-
1992	-0.50	-1.83	0.31	-0.07	0.70	0.54	0.89	-
1993	-0.83	-2.78	1.42	1.11	1.18	1.62	1.83	-
1994	-2.14	1.65	-1.41	-0.47	-0.09	0.26	-1.16	-
1995	-0.57	-0.23	-0.16	0.43	0.18	1.89	3.57	3.10
1996	1.20	0.23	1.87	1.74	2.07	1.79	1.77	1.66
1997	0.23	-0.09	2.42	2.24	2.64	1.99	1.77	2.32
1998	0.92	0.07	1.00	-0.62	0.39	-7.90	-9.69	-2.41
1999	-2.05	-2.12	-2.94	-2.36	-2.73	-4.39	-4.60	-3.95
2000	-1.37	-0.28	-3.60	-2.93	-3.64	-1.73	-2.18	-2.86
2001	0.51	P&A*	-1.16	-1.30	-2.31	-0.72	-1.18	-1.50
Net Change	*-4.60*	*-5.38*	*-2.25*	*-2.23*	*-1.61*	*-6.65*	*-8.98*	*-3.64*

(*) Plugged and abandoned

considered to be completed in the upper portion of the alluvial aquifer, while well LP-04 would be considered to be completed in the deeper portion of the alluvial aquifer. Water levels declined in a similar manner in well LP-04 during 2001 (figure 2-9). There was no noticeable effect of precipitation on the water level in this well. The water level in well LP-07 continues to be below the bottom of this well's casing, meaning the well has gone dry. This occurred about March 2000. Therefore, the total water-level decline in this area is not known.

Wells LP-14, LP-15, and LP-16 are located southwest of the Pittsmont Dump (figure 2-7). A consistent increase in water levels occurred in these wells following their installation in 1992, until the Berkeley Pit landslide of 1998 (figure 2-10). Since that landslide, water levels have continued to decline in a similar nature in all three of these wells. Wells LP-15 and LP-16 are located near one another and were completed as a nested pair, with well LP-15 being screened from a depth of 215-235 feet below ground surface and well LP-16 screened from 100-120 feet below ground surface. Water-level declines are similar in both of these wells. The magnitude of the 2001 decline was about one-half that of 2000.

MR installed a pump in well LP-15 shortly after the 1998 landslide in an attempt to stabilize the slide area by lowering water levels and relieving pressure along the southeast wall of the Berkeley Pit. They operated the pump in well LP-15 from late May through October 2000, pumping more than 8 million gallons of water. The pump did not operate during 2001.

The general observation made in the last two yearly reports, that wells between the leach pads and Pittsmont Waste Dump were affected by leach-pad operations, including the 1999 leach-pad dewatering and historic mine dewatering, remains true. The trend toward lower water levels seen since 1999 continued in 2001. Water levels in the LP series wells were either controlled by the operation and subsequent dewatering of the leach pads or by the depressed water levels in the Berkeley Pit, or a combination of both. The influence of precipitation is minimal at most on any of these wells.

Figure 2-11 is an alluvial aquifer potentiometric map constructed using December 2001 water levels. It shows how alluvial water levels are flowing towards the Berkeley Pit from the north, east and south. Water contaminated by historic mining activities (Metesh, 2000) is flowing towards and into the Berkeley Pit, ensuring that there is no outward migration of contaminated water into the alluvial aquifer outside the mine boundary.

Section 2.1.2.1 LP Wells Water Quality

Water-quality monitoring of the LP series wells includes only those east and south of the Pittsmont Dump (figure 2-7). Dissolved copper concentrations range from about 200 ug/L in well LP-10 to about 4,000 in LP-17. Arsenic concentrations are generally low in all the wells; although some individual sampling results indicated much higher concentrations in the past, most wells had concentrations less than 2 ug/L in 2001. Iron concentrations are also low–less than 1 mg/L in all of the 2001 samples. Zinc concentrations are below the MCL of 5,000 ug/L in all of the LP series wells except LP-17, which has a concentration of about 20,000 ug/L; LP-16 exceeded the MCL in the past, but had about 4,000 ug/L in 2001. All of the LP wells exceed the SMCL of 250 mg/L for sulfate except LP-10 (about 160 mg/L). Well LP-17 has the highest concentration with about 1,600 mg/L sulfate.

Overall, water-quality trends in 2001 reflected the trends of the previous year and are summarized in Table 2.1.2.2. Most notable are wells near the southeast corner of the Berkeley Pit where, as discussed previously, water levels have been declining since the landslide in 1998. Sulfate concentrations in Well LP-16 and LP-14 have reversed from an upward trend since 1998 and have decreased about 450 mg/L since the landslide. Well LP-17 exhibited decreasing sulfate concentrations until 1998 when the trend reversed and concentrations increased by about 500 mg/L. The latest water-quality data from LP-17 suggest another reversal of trend toward decreasing sulfate concentrations (figure 2-12).

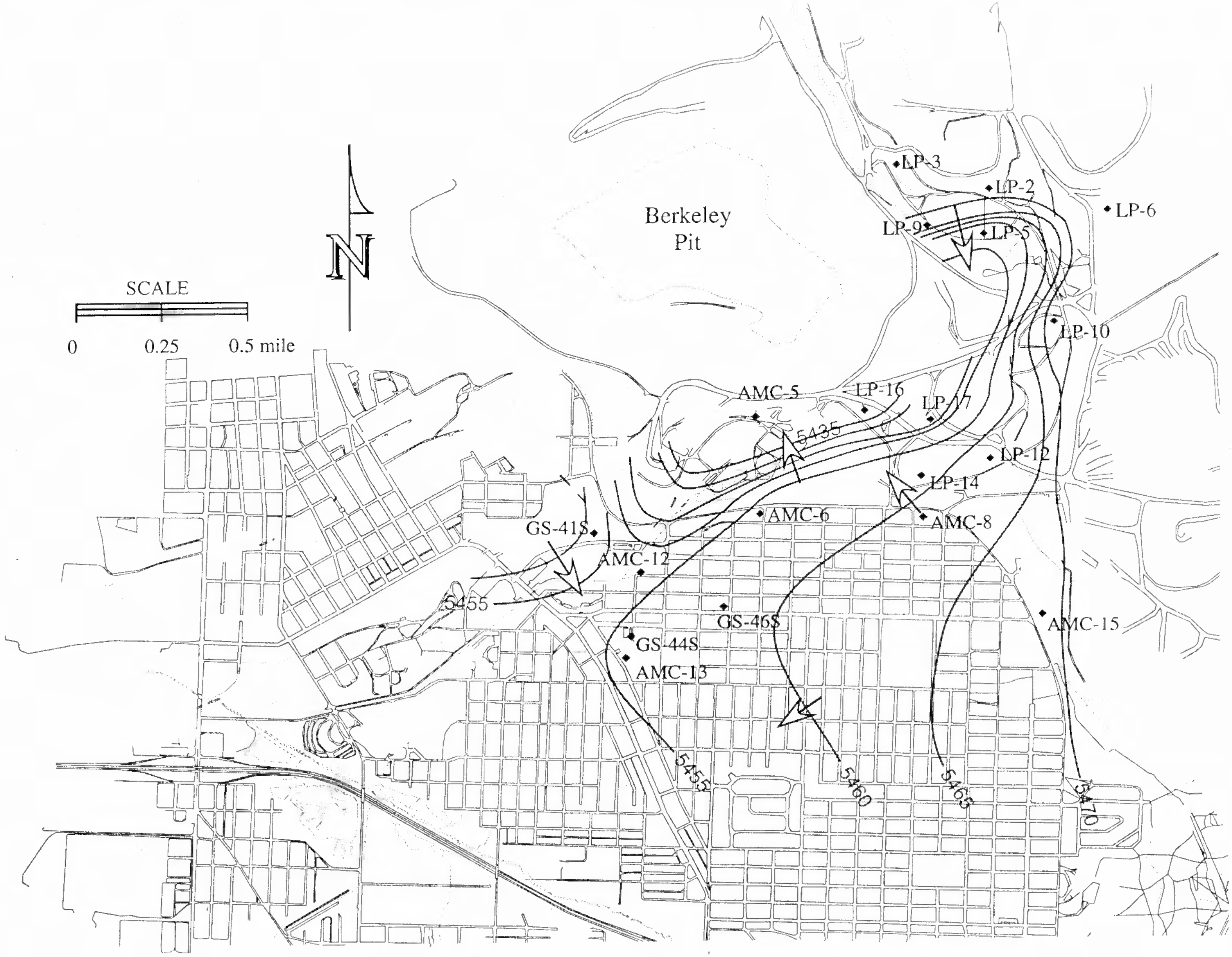
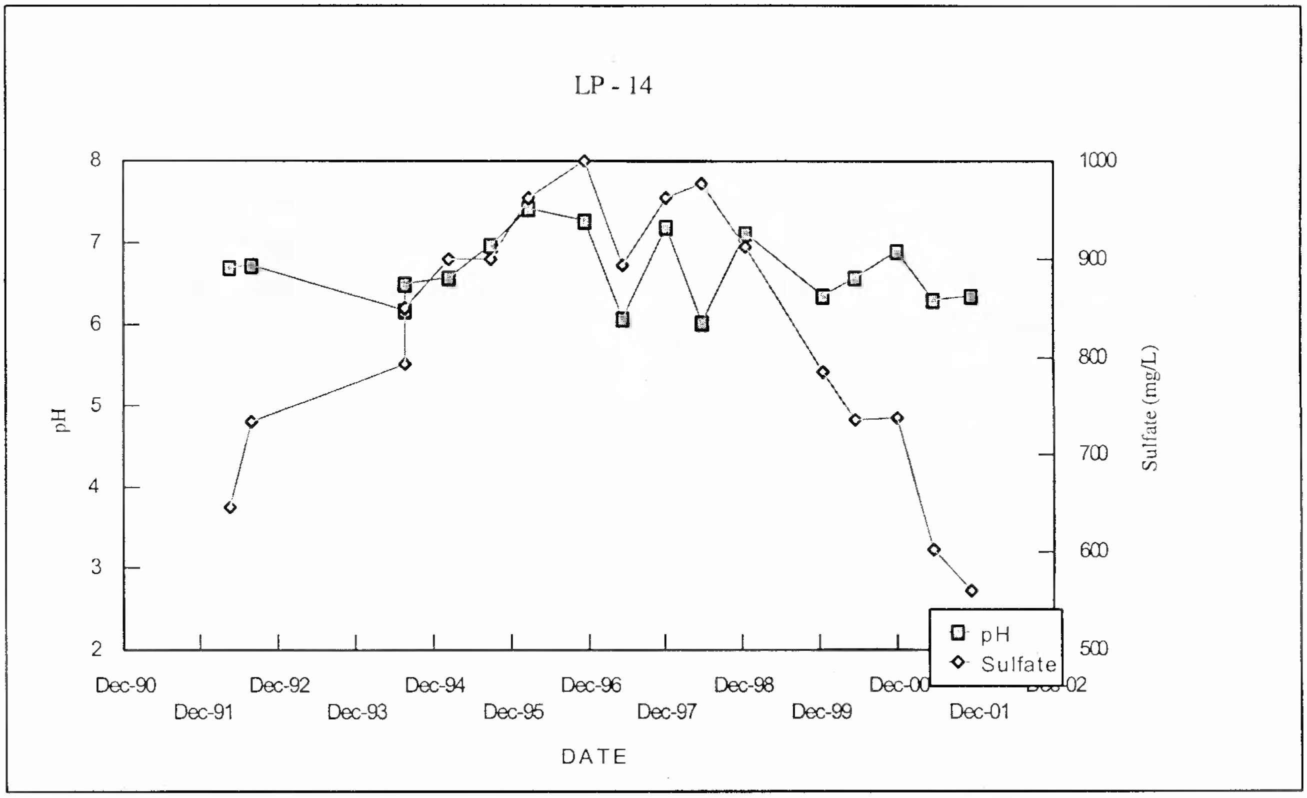


Figure 2-11. Alluvial Aquifer Potentiometric Map, December 2001; arrows indicate direction of ground-water flow implied by contours (contour interval is 5 feet).



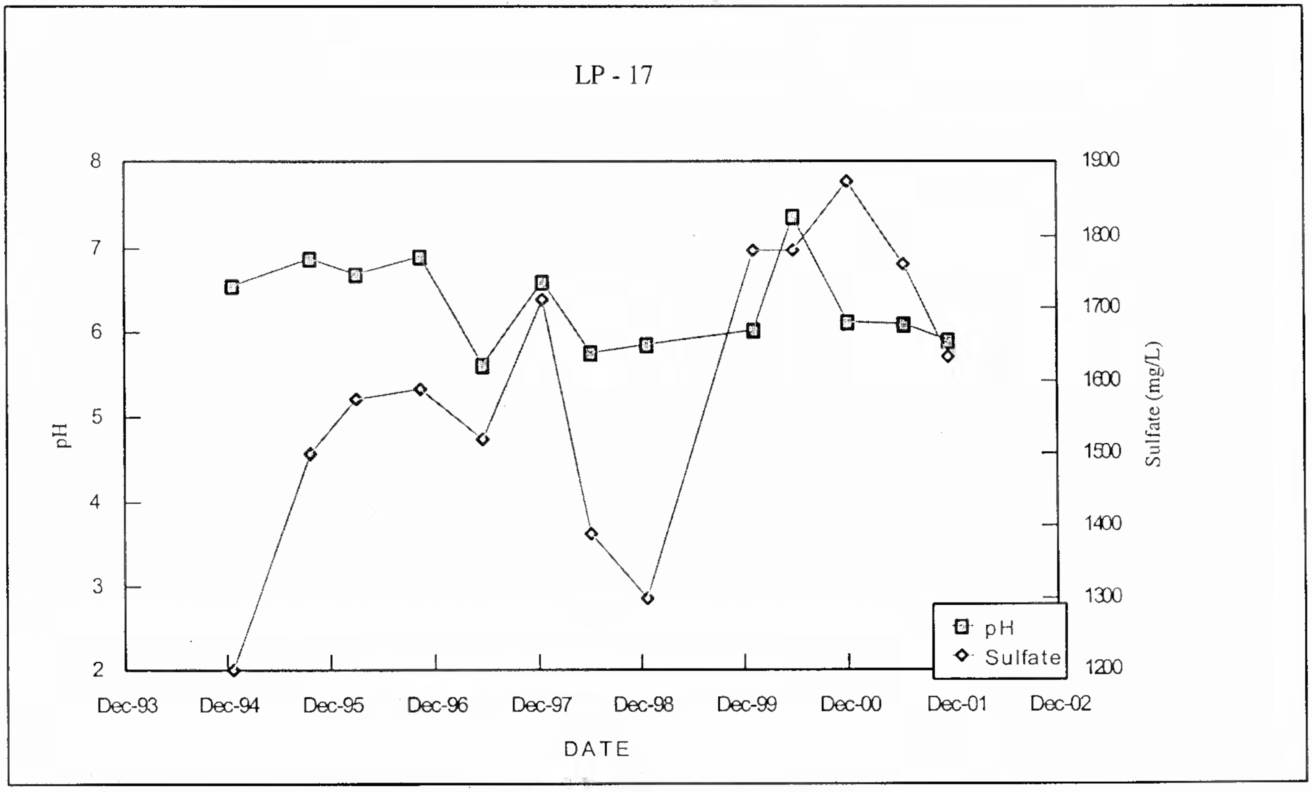


Figure 2-12. Sulfate concentrations for wells LP-14 and LP-17 near the Berkeley Pit.

Table 2.1.2.2 Exceedences and trends for LP Series wells (2000)

Well Name	Exceedences ($\pm$ 1)	Concentration Trend	Remarks
LP-10	N	Variable	Slight upward trend for As over period of record; downward for sulfate
LP-12	Y	Variable	No significant changes in 2001
LP-13	Y	Variable	Sulfate decreasing from 300 to 200 over period of record; trend continues in 2001
LP-14	Y	Variable	Apparent reversal of sulfate trend: 600 to 1000 to 560 mg/L over period of record
LP-15	Y	Variable	Net change is small for most analytes
LP-16	Y	Variable	Reversal of sulfate trend similar to LP-14
LP-17	Y	Upward	Sulfate varies by 500 mg/L over period of record, decreased by 240 mg/L in 2001; copper, arsenic, zinc increasing

Section 2.1.3 Precipitation Plant Area Wells

Wells MR97-1, MR97-2, MR97-3, and MR97-4 (figure 2-7) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Water-level changes appear to correspond to water levels and/or flow in these ditches and ponds. This was especially apparent in the 1999-2000 water levels when MR began to make operational changes in leaching operations. As a result, the amount and level of water in collection ditches became less and was reflected in a drop of water levels in wells 97-2 and 97-3, which are adjacent to collection ditches (figures 2-13 and 2-14). However, variations in water levels occurred in well MR97-1 (figure 2-15) when MR began to discharge water from their Berkeley Pit copper recovery project into the pit using the historic HSB drainage channel. These variations are characterized by an initial increase in water levels followed by a gradual decline before leveling off. The channel, which is adjacent to well MR97-1, had been unused since April 1996, when HSB drainage water was captured and prevented from flowing into the pit. Similar variations were observed in well MR97-1 during July 2001, when a weir was installed in the channel. The weir was installed to better determine the flow rate of water in this channel and the amount of water entering the Berkeley Pit. The water level in this well showed an almost immediate rise following the weir installation. The rise was the result of the pooled water that formed behind the weir. Figure 2-16 shows the weir installation and the pooled water behind the weir.

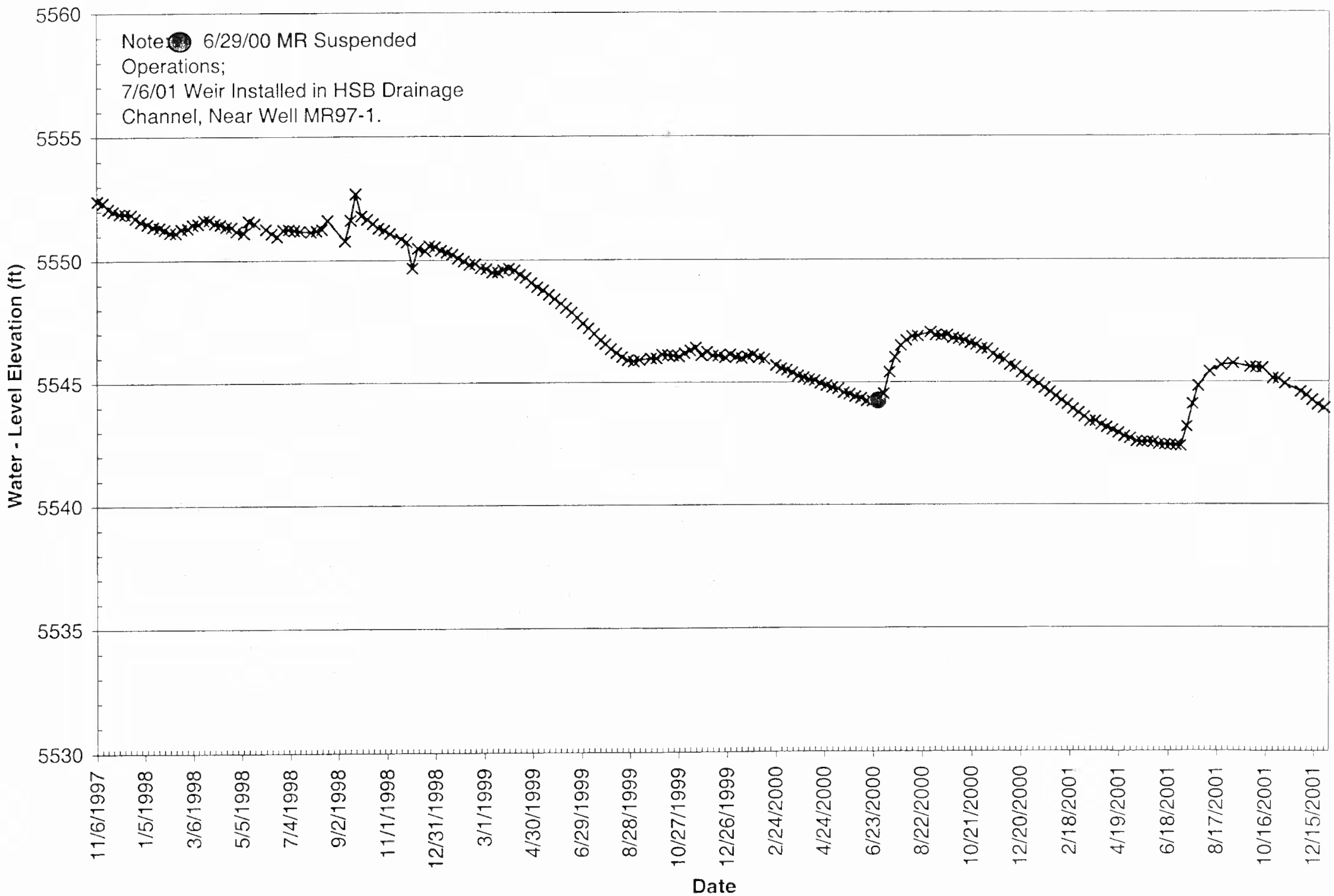


Figure 2-13. Water-level hydrograph for MR97-2 well.

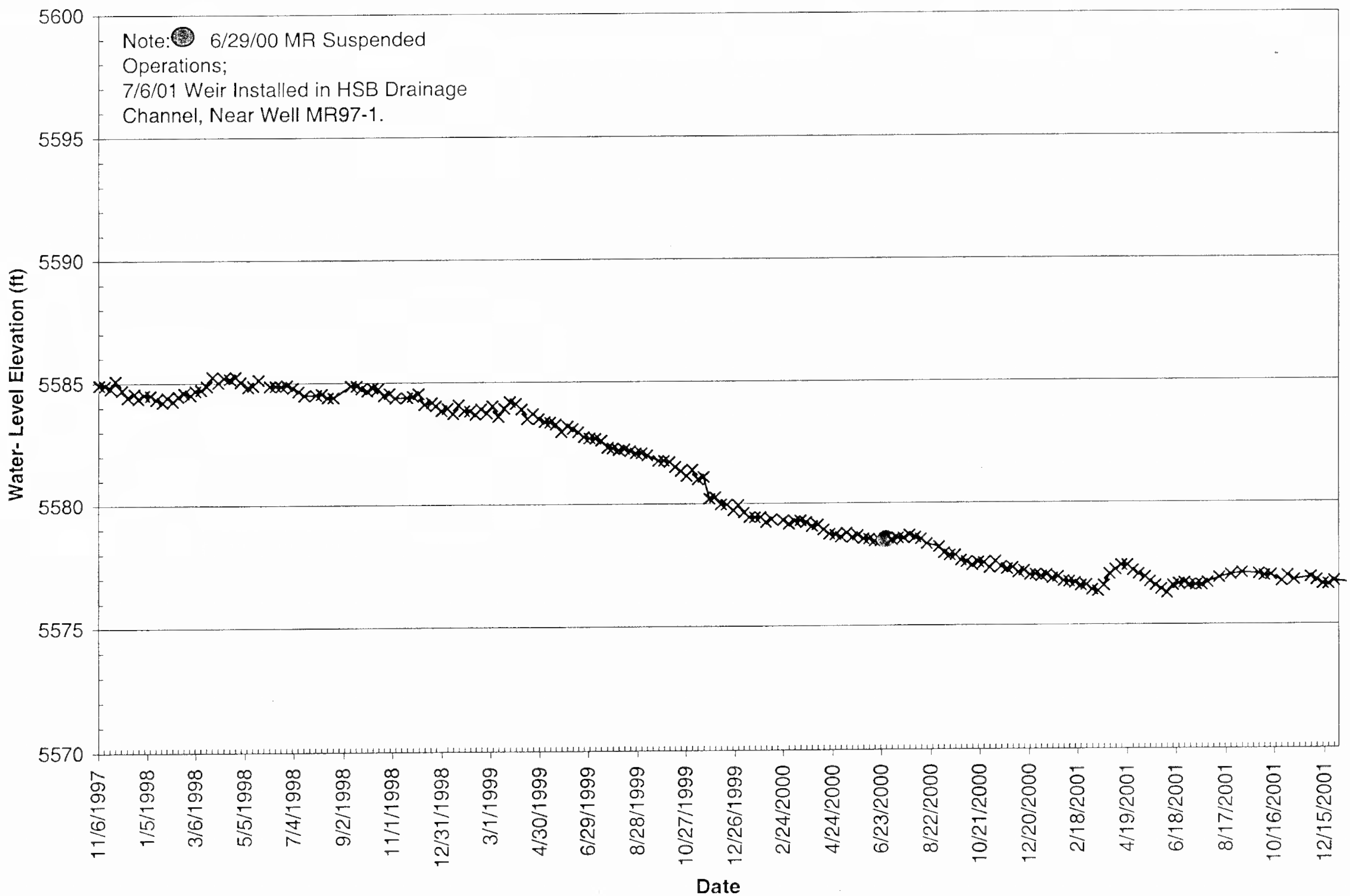


Figure 2-14. Water-level hydrograph for MR97-3 well.

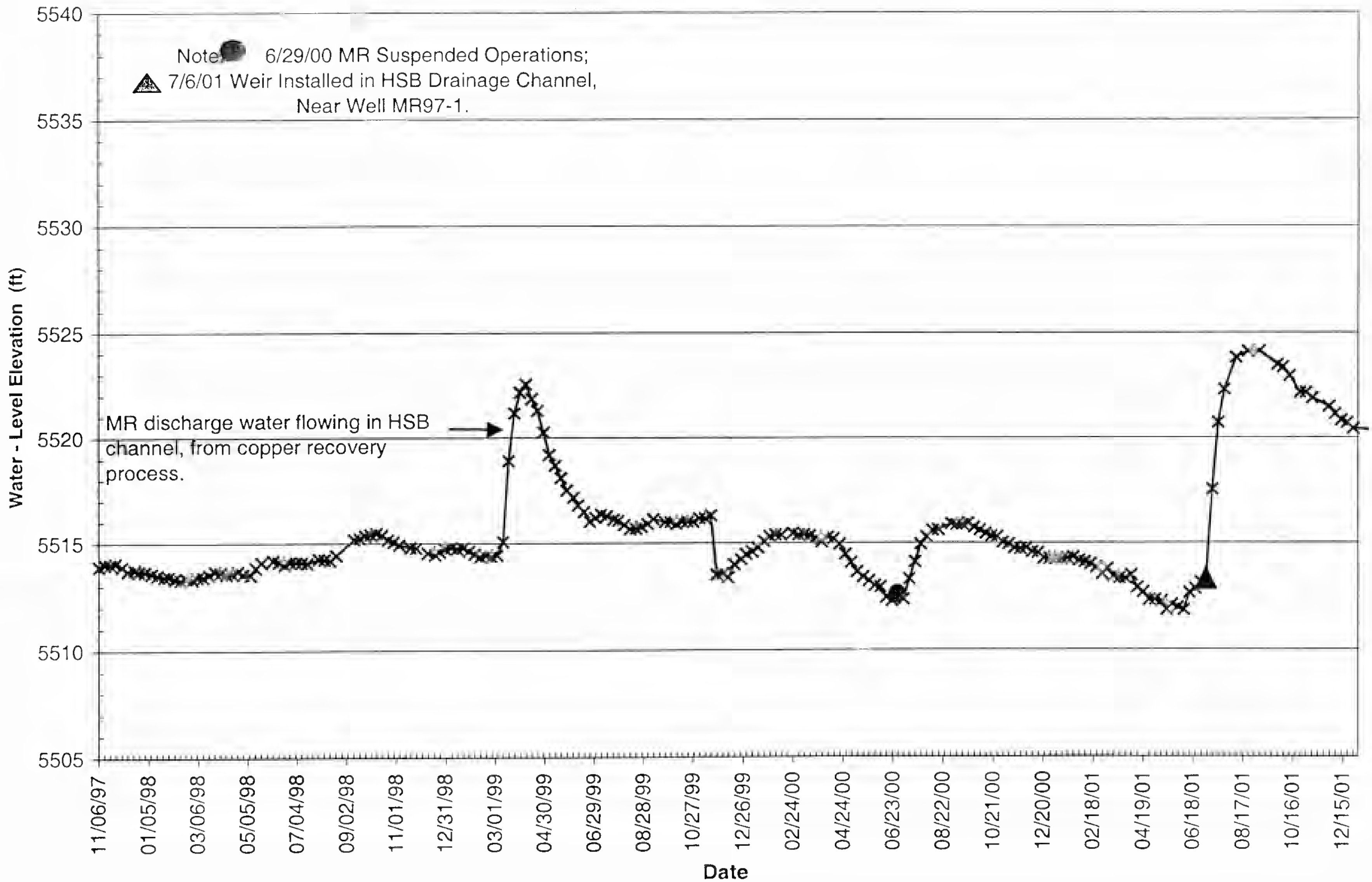


Figure 2-15. Water-level hydrograph for MR97-1 well.

Figure 2-16. Location of 2001 Horseshoe Bend Drainage weir installation, and pooled water behind it.

Similar variations in water levels occurred in 2000 following MR's suspension of mining, when HSB drainage water was allowed to flow into the pit using this same channel. Water-level increases were also seen in wells MR97-2 and MR97-4 following MR's suspension of mining. After an initial rise in water levels, a gradual decline continued over the remainder of 2000 in these two wells. A similar increase was seen in well MR97-2 following the 2001 weir installation. Well MR97-4 showed a minor water-level increase following the weir installation. It is apparent from the similarity between ground-water level changes and flow of water in collection ditches and channels, that there is a direct influence on ground-water recharge and operation of the leach pads and precipitation plant and associated facilities. Table 2.1.3.1 lists annual and net water-level changes for the four wells (MR97-1 through MR97-4).

The water level in well MR97-3 showed very little response to the 2001 weir installation. However, its rate of decline was less than in the previous three years. It is possible that the water that pooled behind the weir and the resulting rise in water levels adjacent to the channel caused a minor rise in the local water table that limited the overall decline in this well. The continued decline is most likely in response to the deactivation of the leach-pad operations. This conclusion is based upon the fact that this well is the closest to the leach pads and several collection ditches. It is also the MR series well farthest away from the HSB drainage channel.

Table 2.1.3.1 Annual Water-Level Changes in MR97-Series Wells

Year	MR97-1	MR97-2	MR97-3	MR97-4
1997	-0.25	-0.84	-0.40	0.35
1998	1.07	-1.04	-0.67	2.20
1999	-0.27	-4.40	-3.91	0.02
2000	-0.20	-0.89	-2.88	-0.03
2001	6.17	-1.32	-0.29	0.78
Net Change	*6.52*	*-8.49*	*-8.15*	*3.32*

Water levels have declined more than 8 feet in the two wells nearest the leach pads and ancillary facilities since their installation in 1997 (table 2.1.3.1), while having a net increase in the two wells nearest the precipitation plant and HSB drainage channel. It appears there is a direct influence on the shallow alluvial aquifer in this area by mining operations. Changes in mine operations affect ground-water recharge in this area. Other changes, such as the weir installation, have the potential to affect ground-water levels in the area.

No water-quality samples were collected from this group of wells in 2001. Previous sampling documented the presence of elevated metals in the area. This contamination is most likely the result of the leach pad and precipitation plant operations.

Section 2.1.4 GS Series Wells

Continuous and monthly water-level monitoring of the 6 GS wells continued throughout 2001. The locations of these wells are shown on figure 2-17. Table 2.1.4.1 contains annual water-level changes for these wells. Wells GS-41, GS-44, and GS-46 are nested pairs. That is, the wells are drilled adjacent to each other, but they are drilled and completed at different depths. The S and D identify the shallow and deep wells in each nested pair.

Figures 2-18 through 2-20 are water-level hydrographs with monthly precipitation totals shown for the well series GS-41, GS-44, and GS-46. The seasonal rise and fall in water levels closely follow monthly precipitation trends. Water levels begin a gradual increase in the spring as precipitation increases. There is a two- to three-month lag (delay) between peak rainfall and peak water levels.

Table 2.1.4.1 Annual Water-Level Changes in GS Series Wells

Year	GS-41S	GS-41D	GS-44S	GS-44D	GS-46S	GS-46D
1993	0.76	0.78	0.62	0.66	0.80	0.78
1994	0.20	0.23	0.00	0.00	0.18	0.24
1995	1.35	1.29	1.32	1.26	1.38	1.30
1996	0.59	1.65	1.12	0.89	0.98	1.20
1997	1.32	0.20	0.58	0.79	1.09	1.18
1998	-0.18	-0.06	0.09	0.07	1.17	0.24
1999	-1.41	-1.49	-1.28	-1.25	-2.41	-1.65
2000	-1.91	-1.78	-1.51	-1.39	-1.21	-2.07
2001	-0.28	-0.41	-0.22	-0.38	-1.78	-0.92
Net Change	*0.44*	*0.41*	*0.72*	*0.65*	*0.20*	*0.30*

Water-level changes in wells GS-41S and GS-41D were similar once again during 2001. However, the steep water-level decline that began following the September 1998 Berkeley Pit landslide (figure 2-18) did not continue throughout 2001 and the influence of precipitation was very noticeable. Water levels declined less than 0.5 feet in these two wells during 2001–a significant change from the almost two-foot decline seen in the previous year.

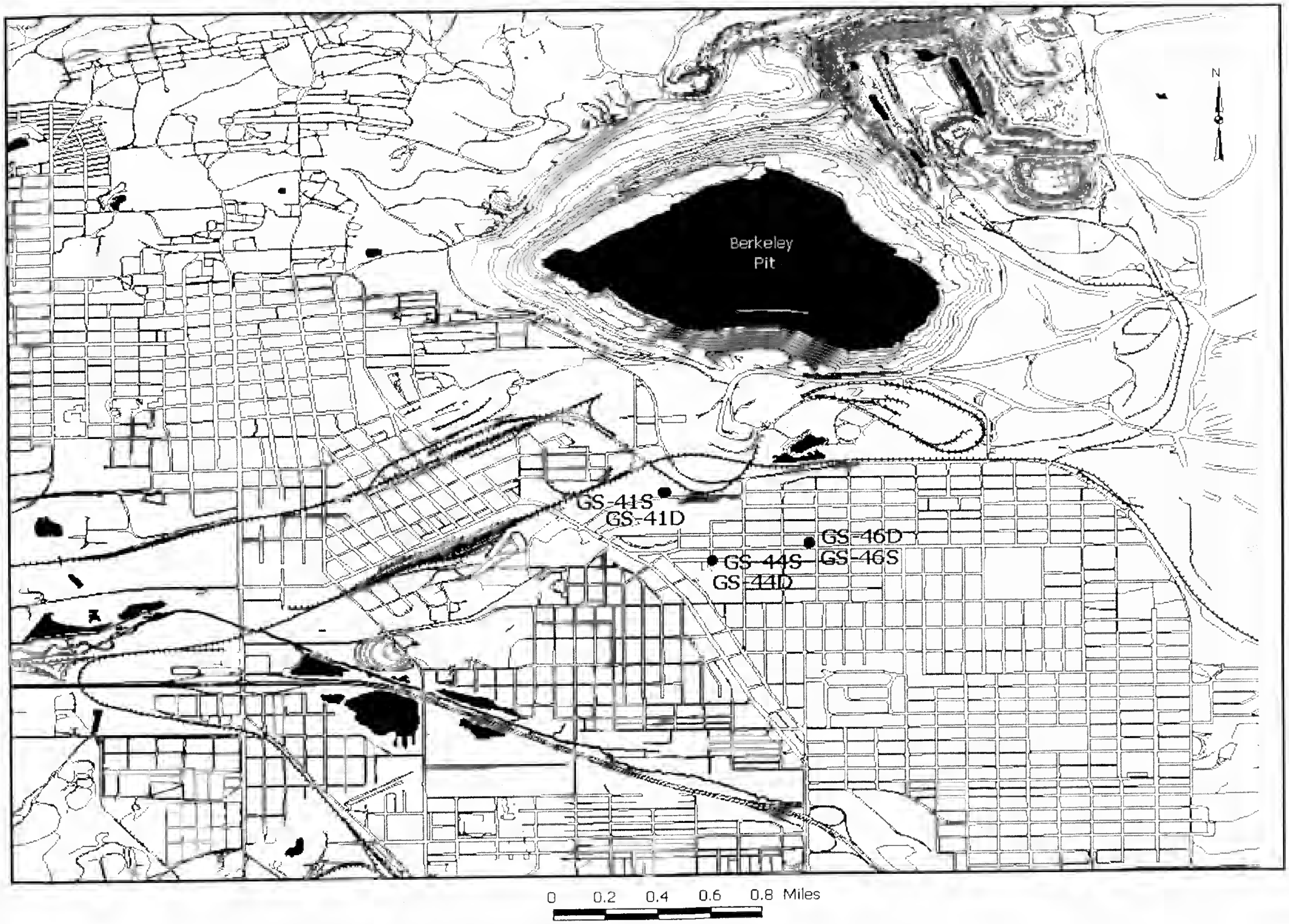


Figure 2-17. Locations of GS series monitoring wells.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

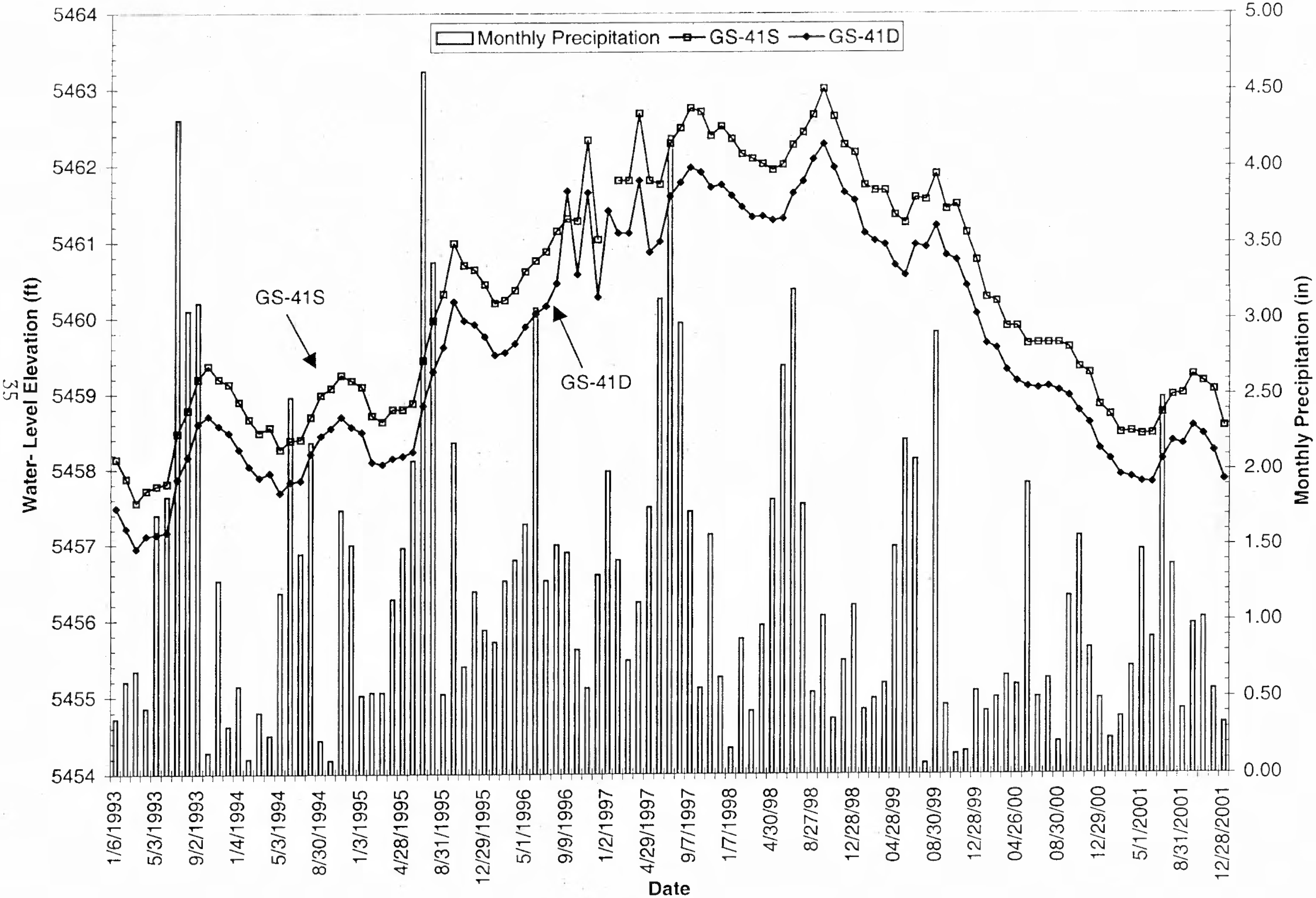


Figure 2-18. Water-level hydrographs for GS-41S and GS-41D wells.

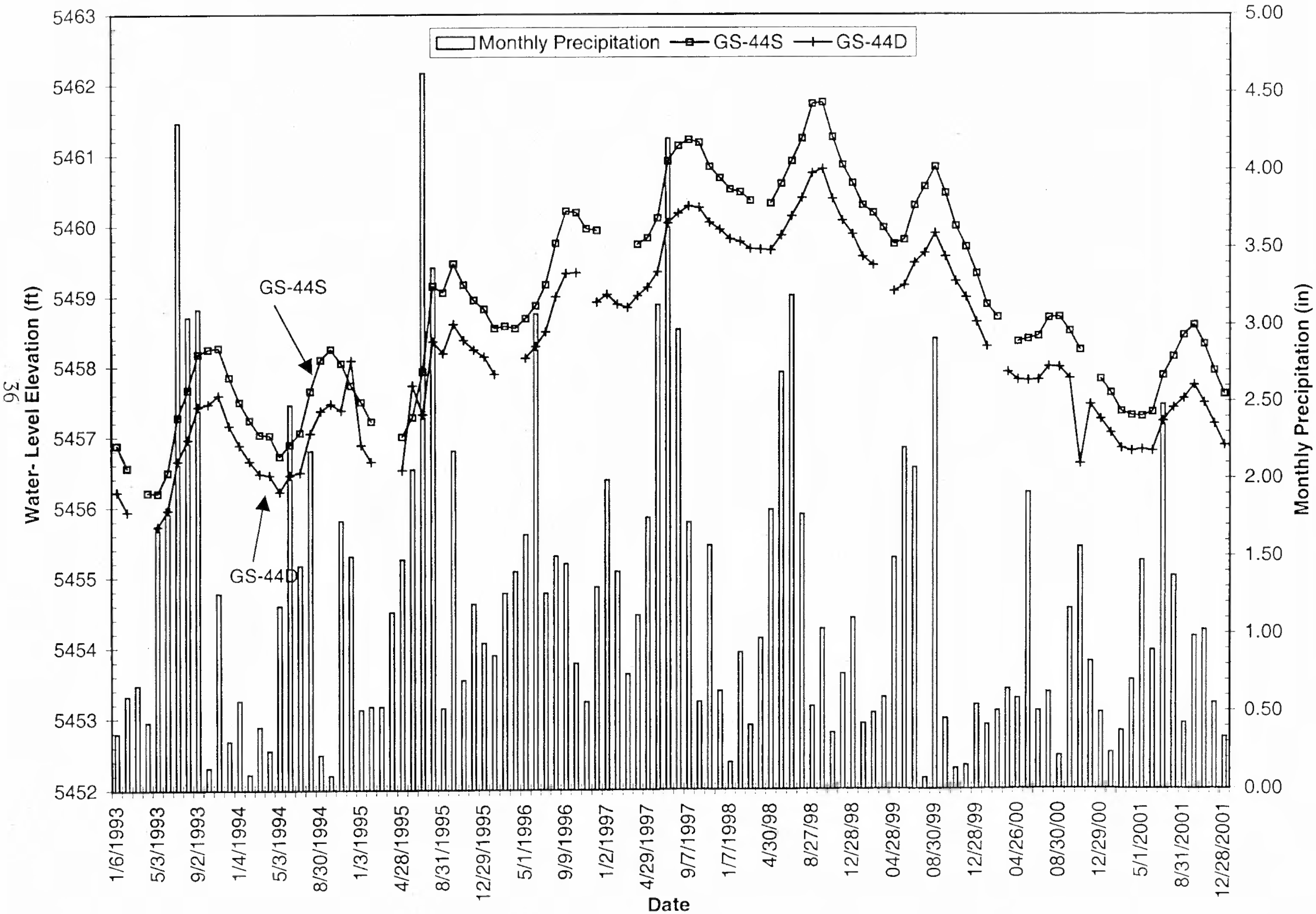


Figure 2-19. Water-level hydrographs for GS-44S and GS-44D wells.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

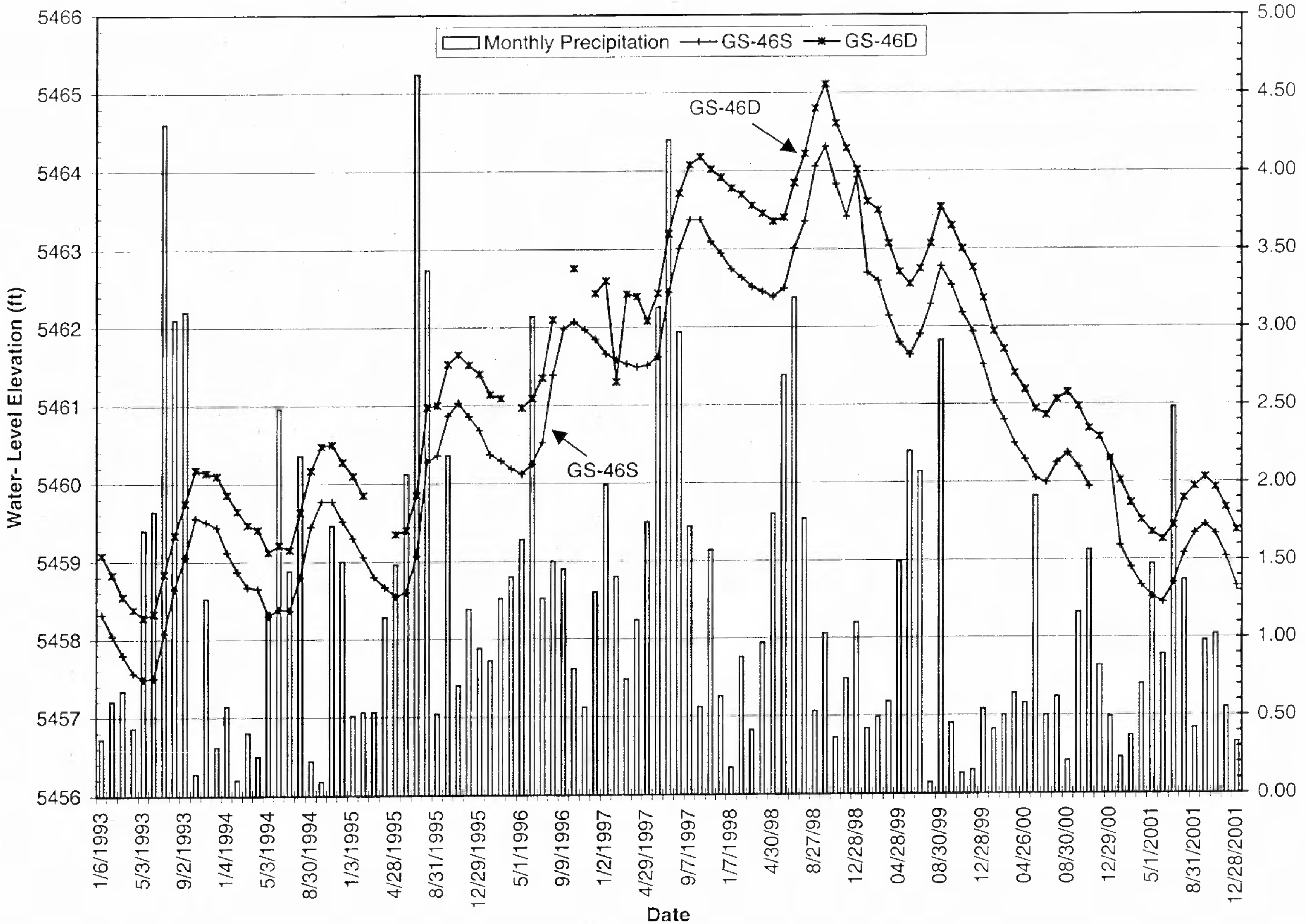


Figure 2-20. Water-level hydrographs for GS-46S and GS-46D wells.

Wells GS-44S and GS-44D had similar water-level changes throughout 2001 (figure 2-19). The rise and fall of seasonal water levels are similar to those described for wells GS-41S and 41D. The water levels also had less of an overall decline for the year, with the net 2001 change being less than 0.5 foot.

Overall, water-level trends were similar during 2001 in wells GS-46S and GS-46D (figure 2-20), and followed the trends discussed previously for wells GS-41 and GS-44. Water levels declined from 1.78 feet in well GS-46S to 0.92 feet in well GS-46D during 2001. These declines are substantially greater than those in the other two pair of wells. These wells are also the farthest away from the mine area, which might account for the greater change. Total water-level increases in these two wells since 1993 are less than 0.5 foot. The seasonal trends are the same as those in the other GS series wells.

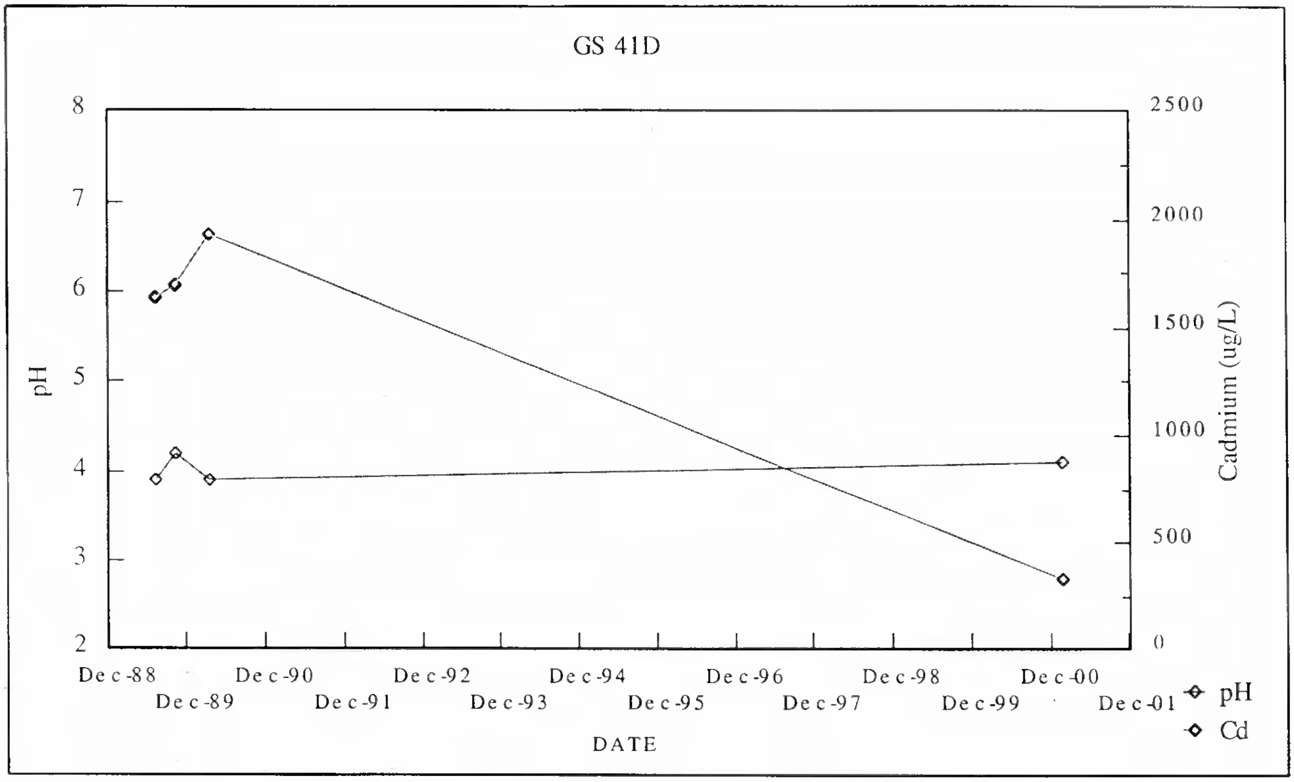
In both the GS-41 and GS-44 wells the water levels in the shallow wells are higher than those of the deeper wells, implying that there is a downward vertical gradient. That is, water in the upper part of the alluvial aquifer is moving down, providing recharge to the lower portions of the aquifer. Water levels in wells GS-46S and GS-46D show the opposite. The water level in well GS-46D is higher than the water level in GS-46S. This implies that water had the potential to move upwards in the aquifer and possibly discharge into a surface-water body, such as Silver Bow Creek.

Section 2.1.4.1 GS Series Wells Water Quality

No water-quality samples were collected from these wells as part of the BMFOU monitoring. However, samples were collected as part of sampling activities for another on-going project. The results of those samples are therefore discussed in comparison to historic trends.

The GS series wells were installed during the Silver Bow Creek Remedial Investigation (RI), Phases I and II in 1988 and 1989, and were discussed in the earlier report (Metesh and Duaime, 2000). Additional data were collected from some of the GS wells in 1997 through 1999 for the Butte Priority Soils Remedial Investigation, and still others were sampled by the MBMG as part of another investigation in 2001. A composite of the available data presents an opportunity to look at water quality over a 9- to 12-year period.

Throughout the period of record, both GS-41S and GS-41D exceeded MCLs and SMCLs for several dissolved constituents including aluminum, arsenic, copper, iron, zinc, sulfate, and cadmium. For example, copper concentrations in both wells are over 300,000 ug/L; similarly, zinc concentrations in both wells are consistently greater than 250,000 ug/L. The greatest change in concentrations has been that of cadmium in GS-41D and arsenic in GS-41S; both decreased, but remained well above their respective MCL (figure 2-21).



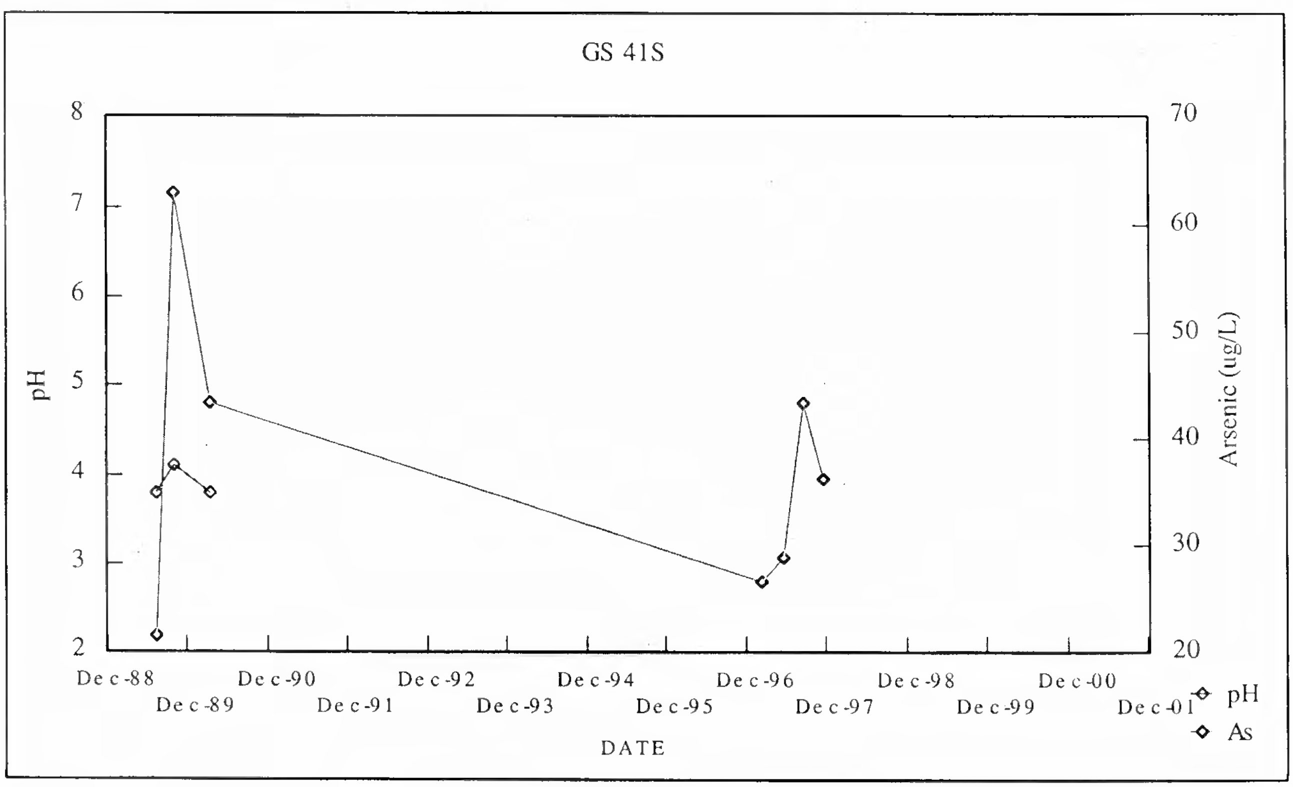


Figure 2-21. Cadmium trend for GS-41D and arsenic trend for GS-41S.

GS-44S and GS-44D are south of the Parrott Tailings area; these wells generally show better water quality compared to the GS-41 wells, but still exceed several MCLs and SMCLs. As with GS-41D, the greatest change in water quality has been the concentration of cadmium. Cadmium in GS-44S has decreased from about 100 ug/L to just over 50 ug/L (figure 2-22). GS-44D has exhibited large changes in cadmium concentrations, but the net change over the period of record is a decrease of about 2 ug/L.

GS-46S and GS-46D are nested wells about 2,500 feet southeast of the Metro Storm Drain - Parrott Tailings area. GS-46D exceeds MCLs and SMCLs for cadmium, aluminum, iron, and sulfate. Overall, concentrations of dissolved constituents have shown little change over the 12-year period of record. Copper, for example, varied from 11.8 to 16.8 to 10.6 μg/L from 1989 to 2001. The concentrations of dissolved constituents in GS-46S are consistently below MCLs and SMCLs; most notably, the concentration of cadmium has decreased from about 10 μg/L to less than 3 ug/L over the period of record (figure 2-23); the MCL for cadmium is 5 ug/L.

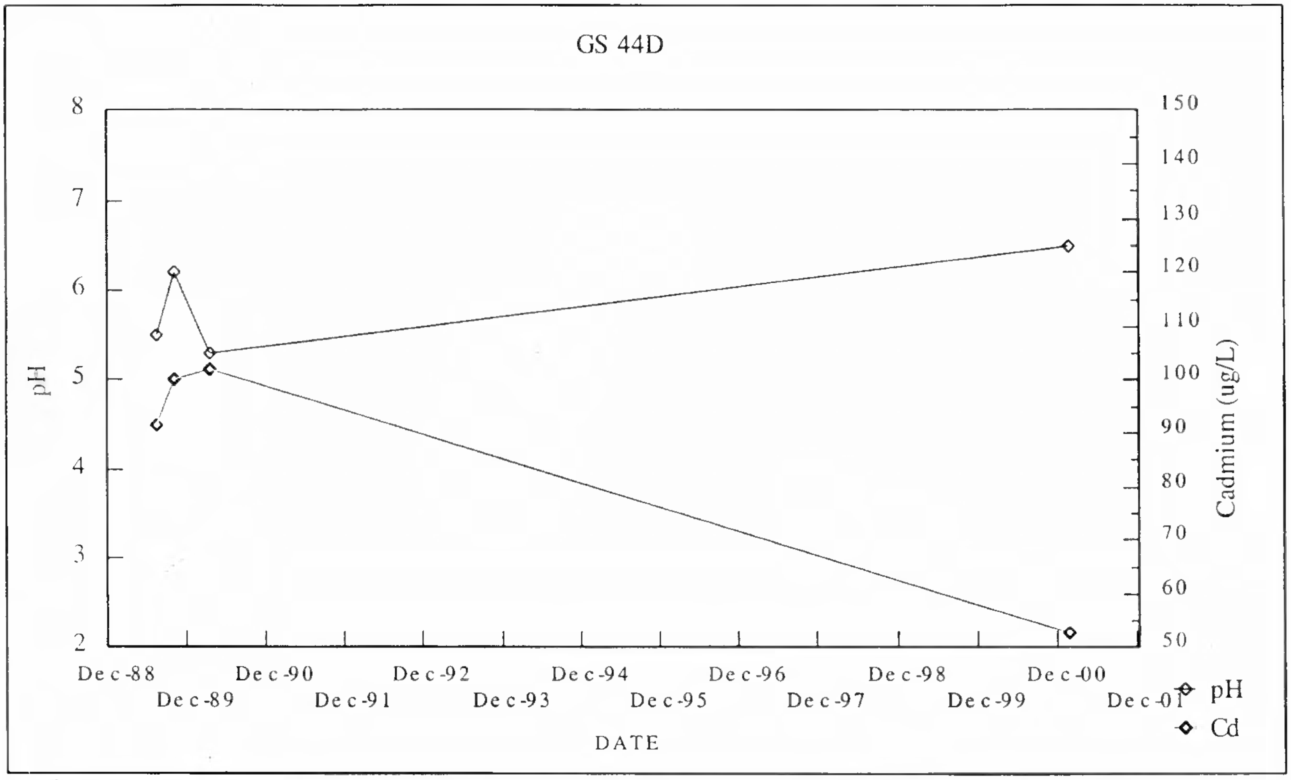
Other wells in the GS series show a wide range of concentrations and variable trends. Concentrations of dissolved constituents have changed with respect to MCLs and SMCLs in several wells. Selected data from all of the GS series wells are presented in the appendix.

Section 2.1.5 Domestic Well Monitoring

Monitoring continued in the 14 domestic wells for the fifth year. The locations of these wells are shown on figure 2-24. Table 2.1.5.1 contains summary water-level data for these wells.

Water-level changes were quite large in a number of wells, while others had changes less than one foot during 2001. Well 93-24 rose almost 19 feet, based upon year-end measurements in 2000 and 2001. However, the 2000-year-end measurement was taken when the pump was operating, or had recently operated. When that measurement is discarded the 2001 water-level change would have been a decline of almost two feet. All the wells east of Harrison Avenue exhibited the same large decrease in water levels for 2001. The size of the water-level drop is much greater than that seen in any of the previous years, however, the total water-level change in these wells since 1993 is minor. It is possible that these wells reflect the cyclical nature of water levels due to short-term climatic conditions. The Butte Basin had above-average precipitation between 1993 and 1998, which has been followed by a period of below-average precipitation.

Figures 2-25 and 2-26 are hydrographs of selected domestic monitoring wells east of Harrison Avenue. The effect of precipitation was less pronounced in wells 93-20, 93-22, 93-93-25, and 93-26 (figures 2-25 and 2-26) than in previous years. Water levels stopped their decline in the spring, one to two months after precipitation increased, before leveling off and falling during the winter. Water-level trends are very similar in each of these figures.



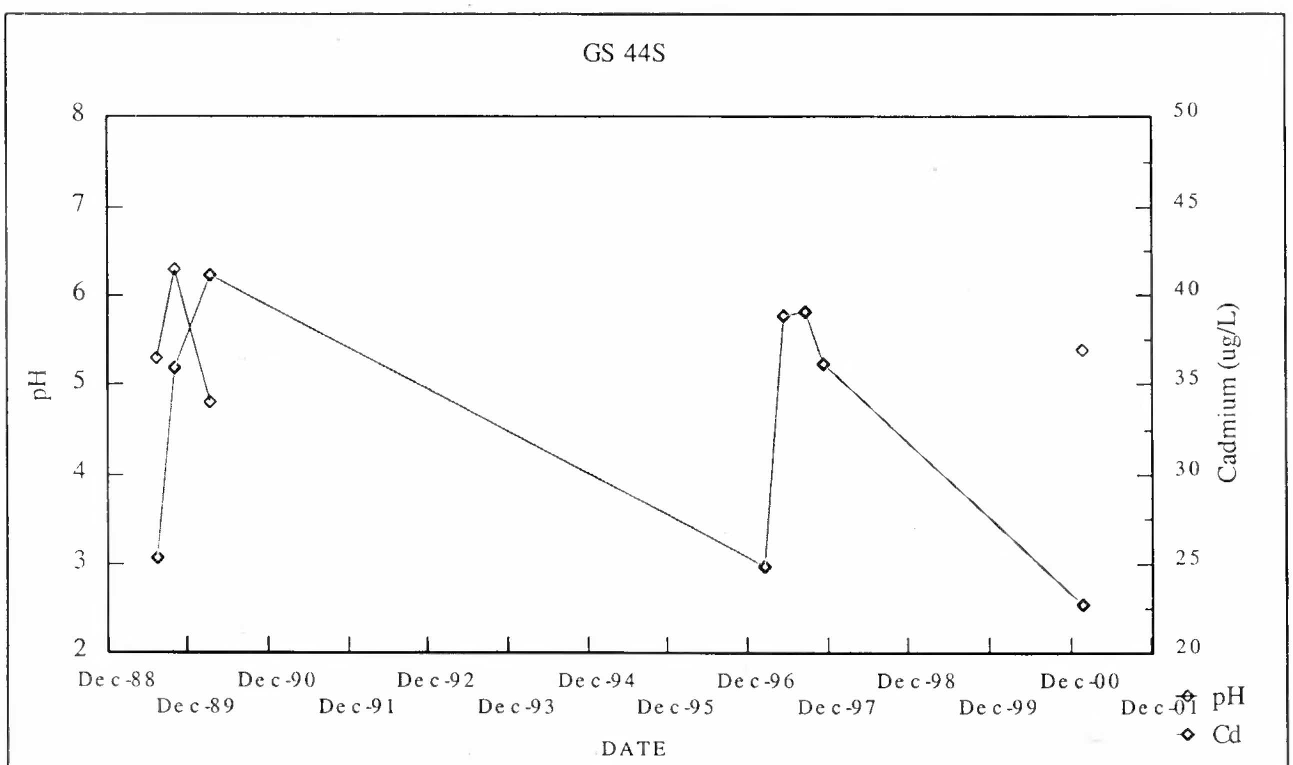
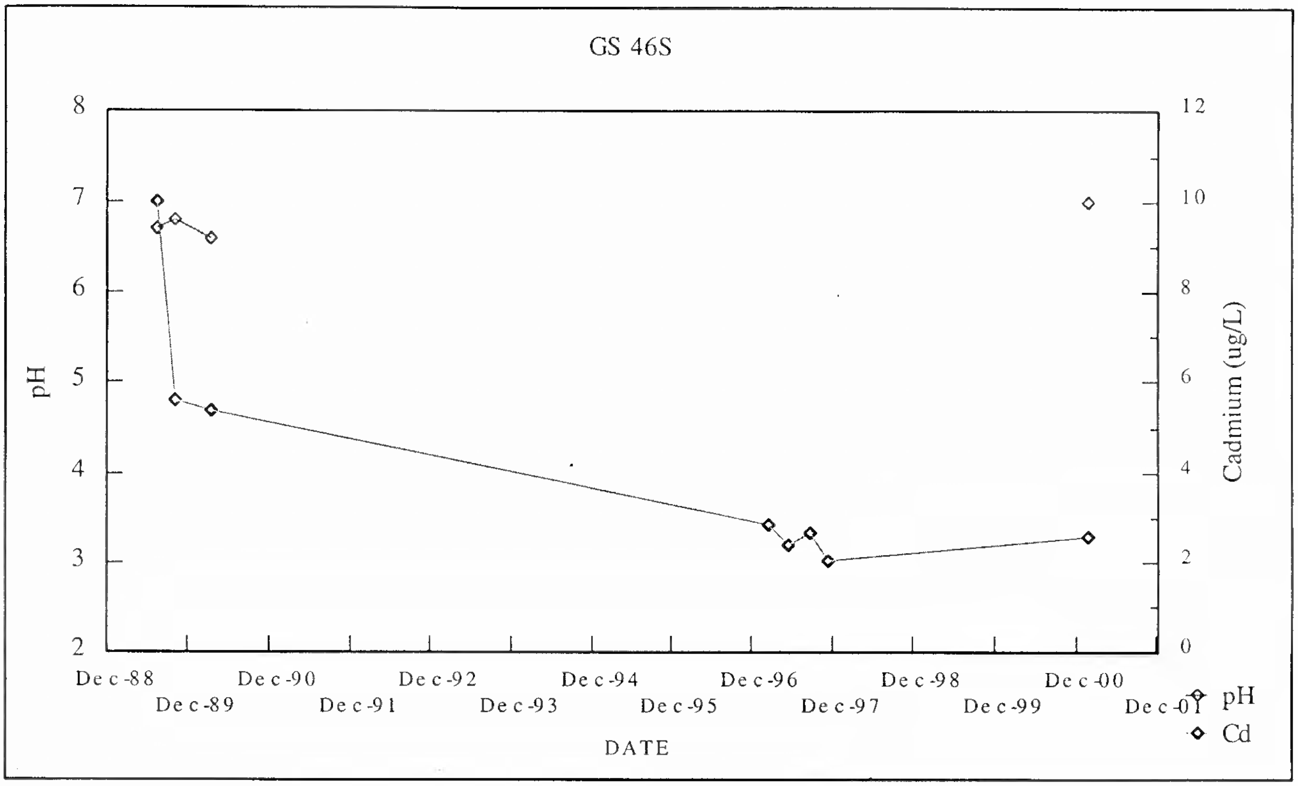


Figure 2-22. Cadmium concentrations and pH for GS-44D and GS-44S.



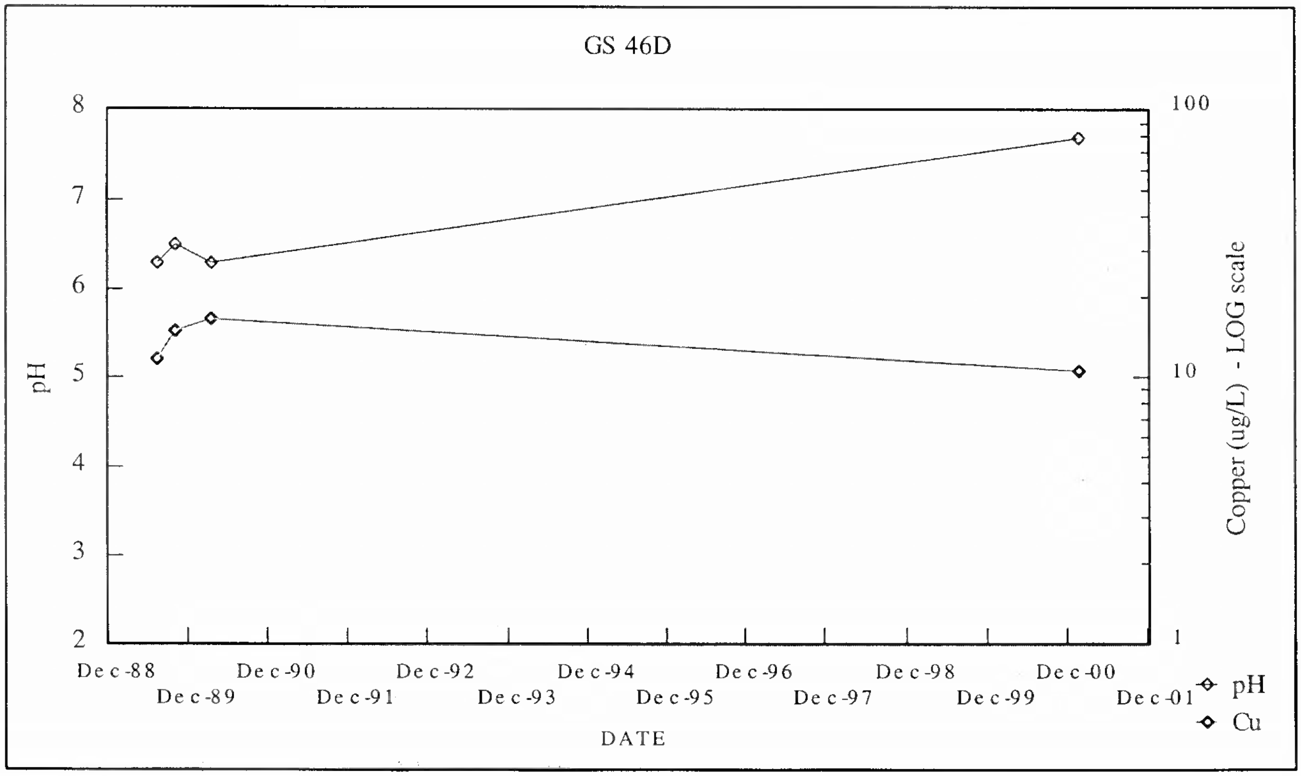


Figure 2-23. Cadmium concentrations for GS-46S and copper concentrations for GS-46S.

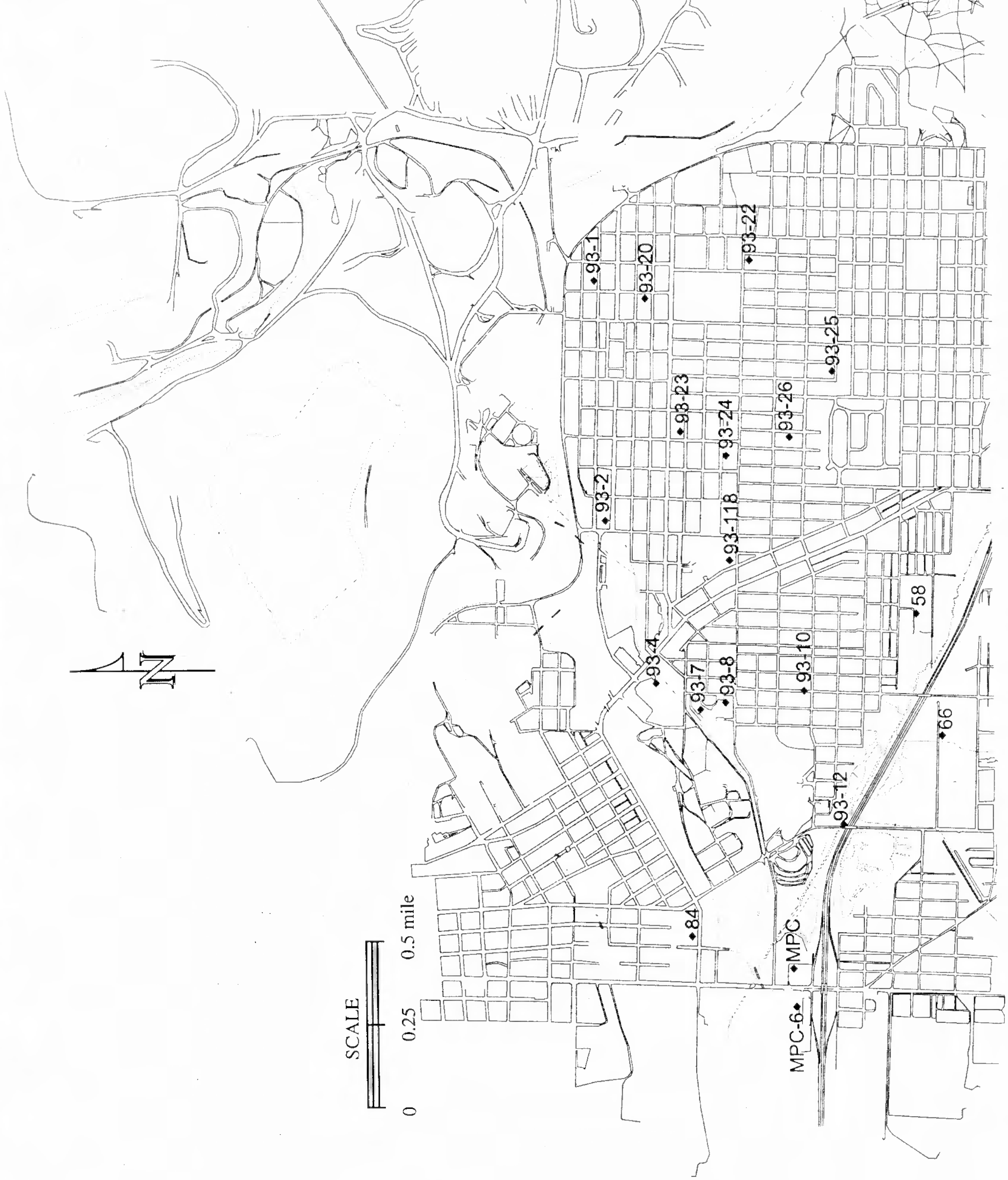


Figure 2-24. Domestic Well Location Map.

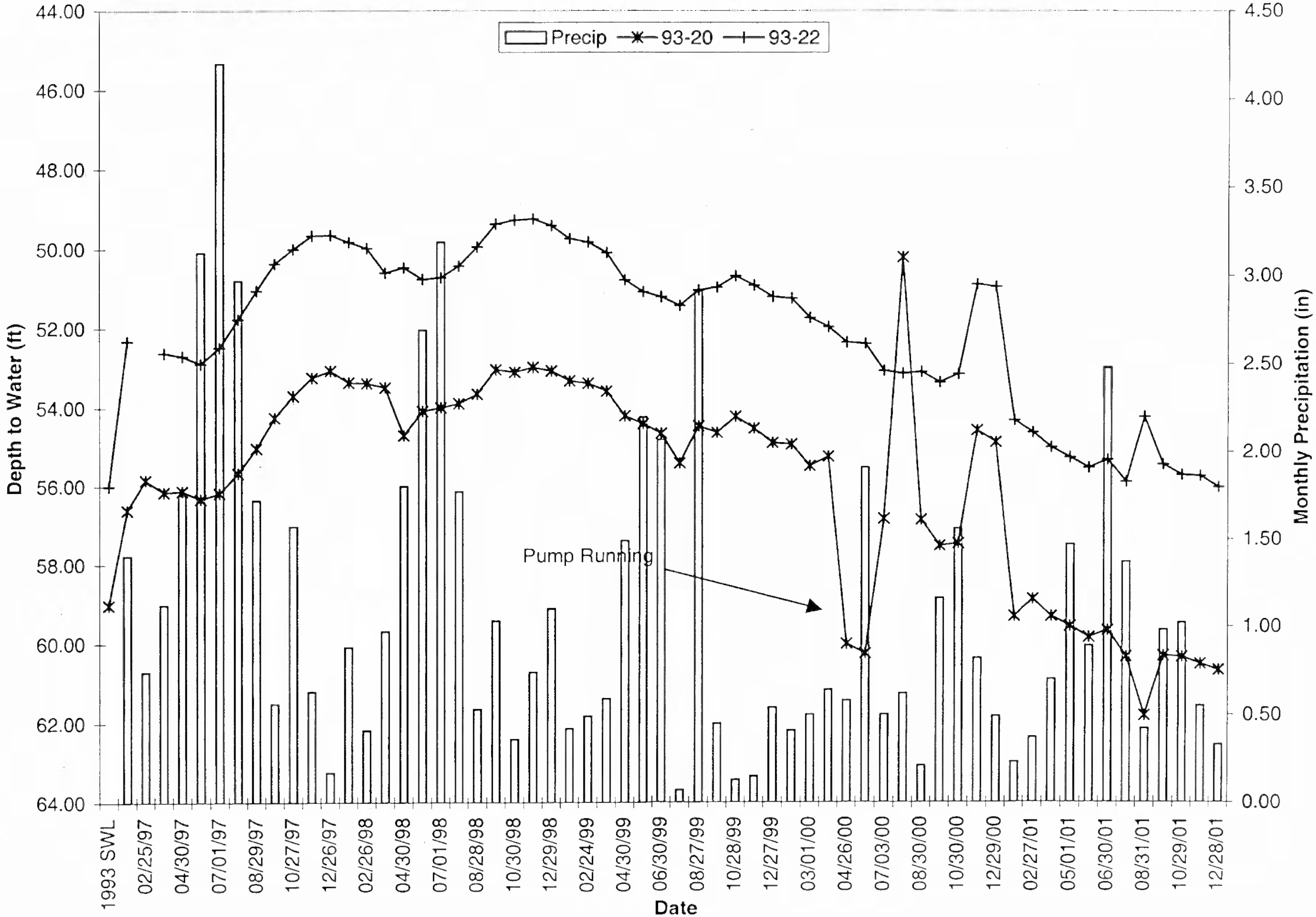


Figure 2-25. Water-level hydrographs for domestic wells 93-20 and 93-22.

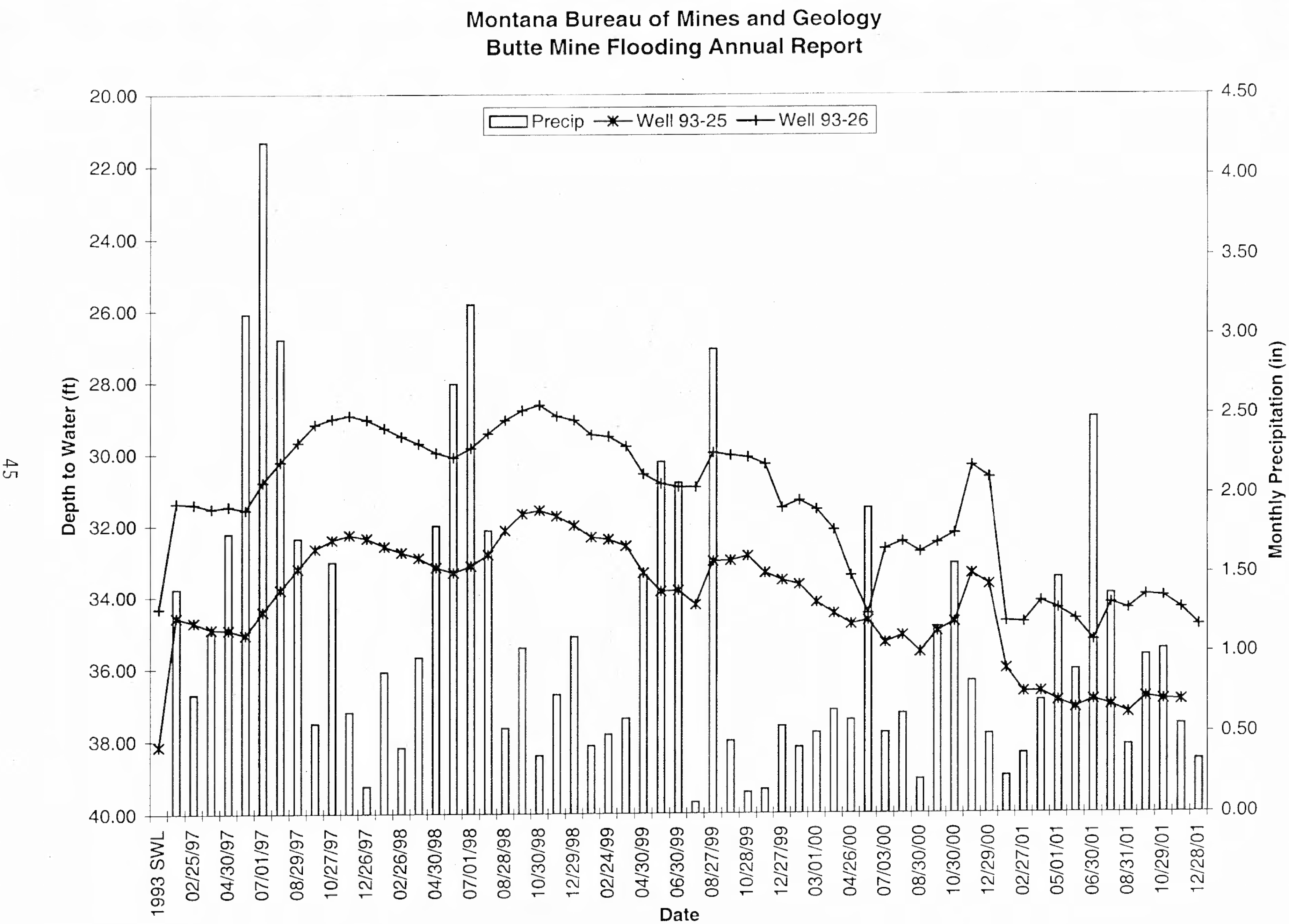


Figure 2-26. Water-level hydrographs for domestic wells 93-25 and 93-26.

Table 2.1.5.1 Annual Water-Level Changes and Net Changes for Domestic Wells

Map Well ID	WL Change (ft) 1993-12/1997	WL Change (ft) 1998	WL Change (ft) 1999	WL Change (ft) 2000	WL Change (ft) 2001	Total WL Change (ft)
93-20	5.95	0.00	-1.81	0.02	-5.80	-1.64
93-22	6.35	0.24	-1.79	0.26	-5.07	-0.01
93-25	5.80	0.36	-1.55	-0.12	-3.23	1.26
93-26	5.28	-0.01	-2.44	0.84	-4.14	-0.47
93-23	4.88	-0.06	-1.96	0.70	-4.65	-1.09
93-24	5.37	0.04	-1.65	-22.56*	18.99	0.19
93-2	3.45	1.14	-2.43	-0.04	-2.07	0.05
93-118	1.66	---	---	---		1.66
93-4	0.58	0.01	-0.03	-0.01	-0.62	-0.07
93-7	-0.04	-0.11	-0.41	-0.46	-0.25	-1.27
93-8	-0.35	-0.05	-0.43	-0.49	-0.14	-1.46
93-9	-1.08	-0.03	-0.34	0.17	-0.73	-2.01
93-10	-0.21	0.04	-0.48	0.37	-0.31	-1.33
93-12	1.58	-5.02	4.74	-0.06	-0.08	-2.00
MPC-6	-0.07	0.14	-0.13	-0.04	-0.14	-0.24

* December water level measured while pump was operating.

Figures 2-27 and 2-28 are hydrographs of selected domestic monitoring wells (93-4, 93-7, 93-8, 93-10, and 93-12) west of Harrison Avenue. The seasonal trends are similar to the other alluvial water levels. The water-level rise seen in well 93-9 during 2000 reversed during 2001, with the trend being similar to previous years.

Total water-level changes range from a decline of 2.01 feet to a rise of 1.26 feet, at wells 93-9 and 93-25, respectively. In previous years, water levels had a net increase in wells east of Harrison Avenue; however, water levels had a net decline in 2001. Water levels continued to decrease in areas west of Harrison Avenue, as seen in previous years. The seasonal water-level changes are remarkably similar to those seen in other alluvial monitoring wells. Minimum water levels occur in early spring and maximum water levels occur in the late summer or early fall. No effects of the September 1998 Berkeley Pit landslide were seen in any of the domestic wells.

Based upon the 6 years of data there are several things apparent from these figures. There is a delay (lag) period between precipitation increases and well responses south of the pit and east of Harrison Avenue. This is similar to trends seen in the GS series wells. Water-level response to increased precipitation in wells west of Harrison Avenue is nearly immediate. Increases in water levels are seen in the month precipitation levels increase, or the following

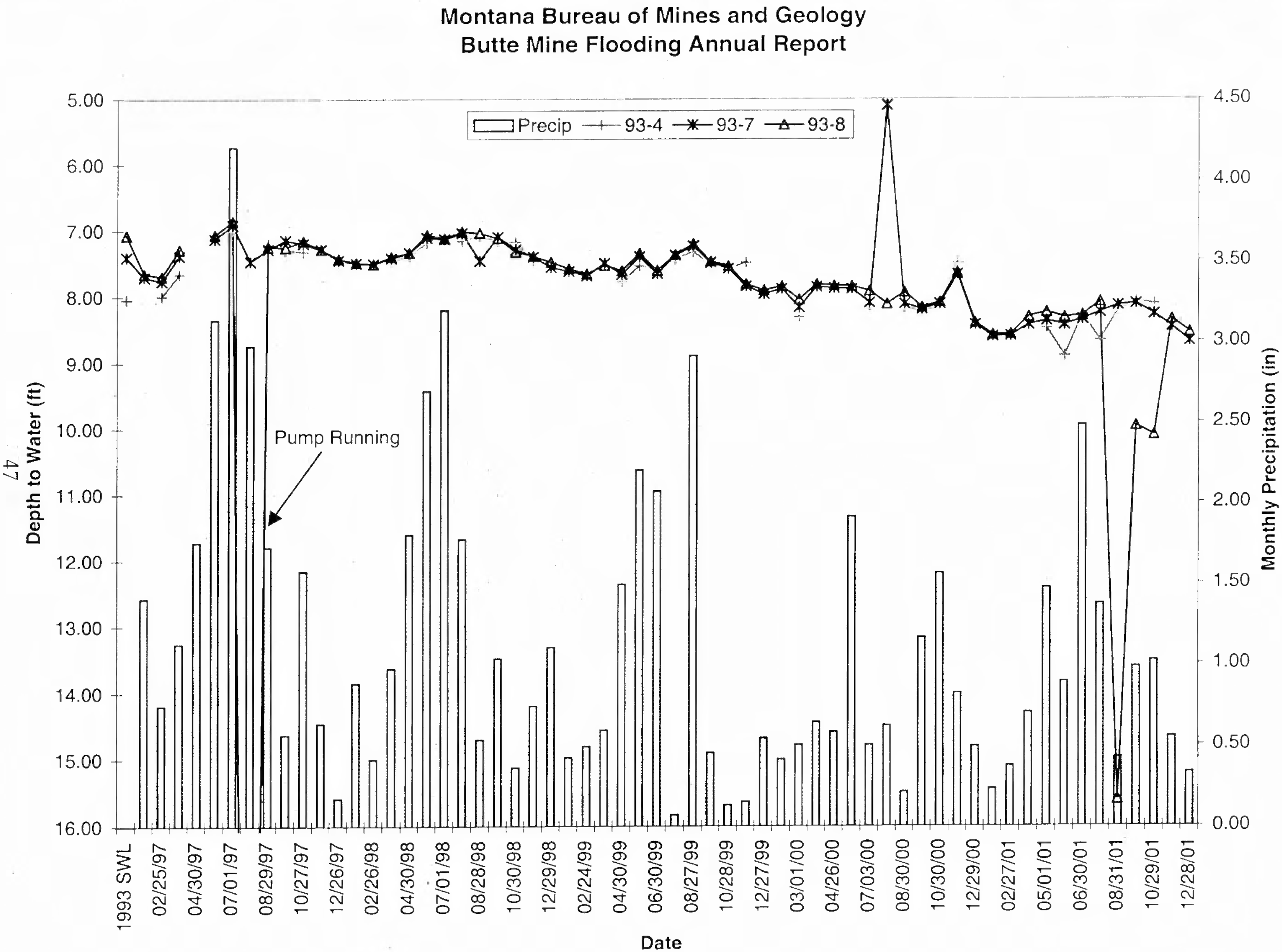


Figure 2-27. Water-level hydrographs for domestic wells 93-4, 93-7 and 93-8.

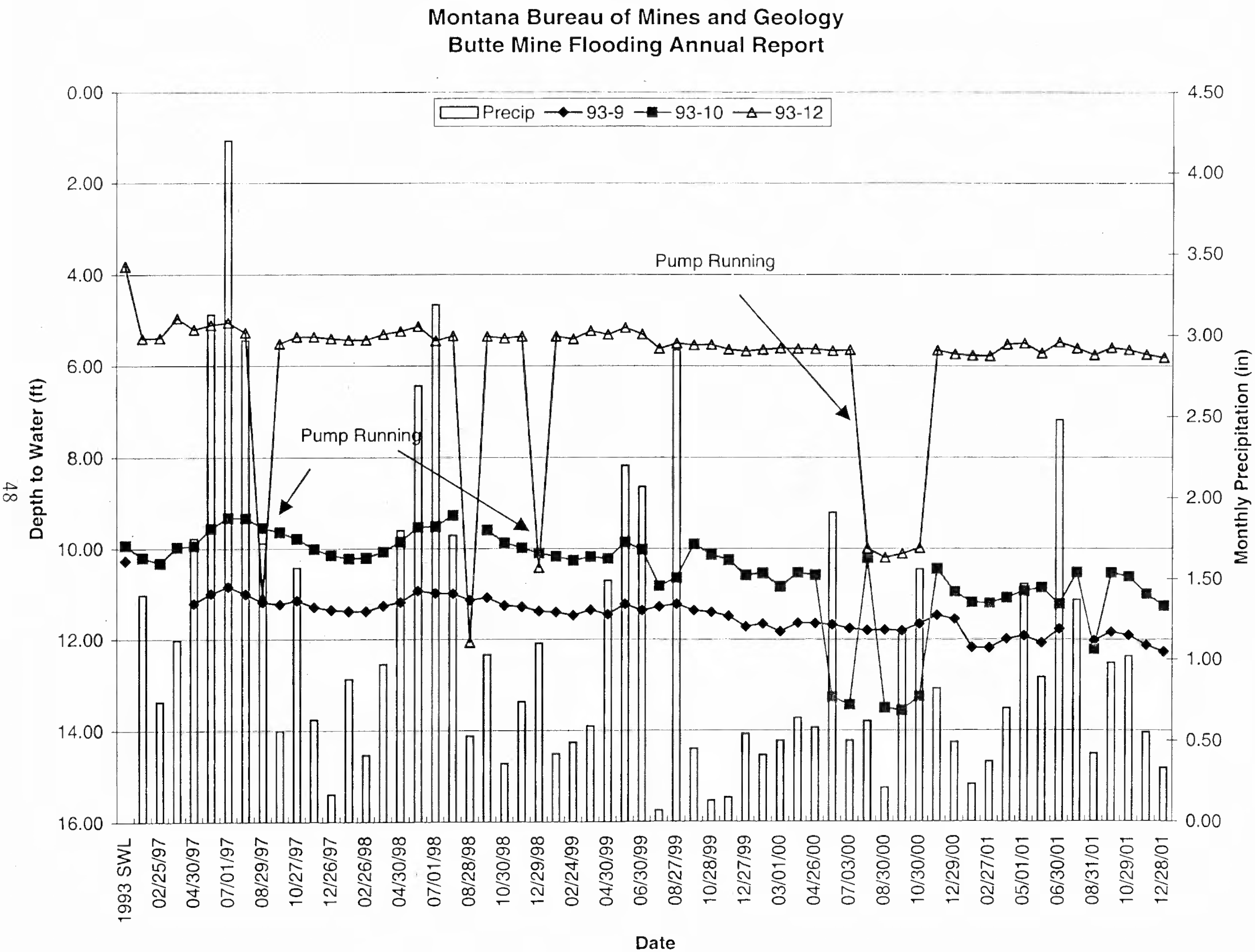


Figure 2-28. Water-level hydrographs for domestic wells 93-9, 93-10, and 93-12.

month, and are short lived, with levels dropping the next month if precipitation levels decrease. These responses are similar to those noted earlier for wells AMC-23 and AMC-24.

No water quality samples were collected from these wells during 2001. These wells were used solely for water-level monitoring.

Section 2.2 East Camp Underground Mines

Monitoring of water levels in the 7 East Camp underground mines continued. Their locations are shown on figure 2-29. During the year 2001, water levels rose between 16 and 18 feet in the mines, with the exception of the Kelley Mine, where the water level rose 11.77 feet. The Berkeley Pit water level rose 17.97 feet (Table 2.2.1). Figure 2-30 shows the annual water-level changes graphically for five of the mines.

Table 2.2.1 Annual Water-Level Changes in East Camp Mines

Year	Berkeley	Anselmo	Kelley	Belmont	Steward	Granite	Lexington	Pilot
1982			1,304.00	117.00	85.00			
1983			877.00	1,054.00	1,070.00			
1984			262.00	269.00	274.00			
1985			122.00	121.00	123.00			
1986		56.00	96.00	102.00	101.00			
1987		77.00	84.00	77.00	79.00	67.00		
1988		53.00	56.00	53.00	52.00	57.00	8.10	
1989		29.00	31.00	31.00	29.00	31.00		
1990		32.00	33.00	34.00	33.00	34.00		
1991	12.00	29.00	33.00	30.00	29.00	31.00		
Total	*12*	*276*	*2898*	*1888*	*1875*	*220*	*8.10*	
1992	25.00	22.00	24.00	24.00	23.00	25.00		
1993	26.00	24.00	25.00	26.00	25.00	26.00		
1994	27.00	25.00	26.00	25.00	25.00	27.00		
1995	29.00	28.00	27.00	18.00	28.00	30.00		
1996	18.00	16.00	19.00	4.15	18.00	18.00	1.19	3.07
1997	12.00	13.58	16.09	15.62	14.80	15.68	12.79	18.12
1998	17.08	13.23	14.73	13.89	14.33	14.24	13.71	11.26
1999	12.53	11.07	11.52	12.15	11.82	11.89	10.65	11.61
2000	16.97	14.48	14.55	15.66	14.60	15.09	14.01	14.11
2001	17.97	16.43	11.77	16.96	16.48	16.35	15.95	16.59
*Grand Total Change**	*213.74*	*459.05*	*3,086.11*	*2,058.14*	*2,066.17*	*419.12*	*76.4*	*74.76*

(*) Total change is the measured change in water level. Access or obstructions have prevented continuous water-level measurements at some sites.

Figure 2-31 is a hydrograph based upon water levels for the Anselmo Mine and Kelley Mine. There are no obvious variations in water levels on this figure; however, when water levels are plotted from 1995 through 2001, several changes are noticeable (figure 2-32). The stoppage of HSB drainage water from entering the pit in 1996 resulted in a flattening of the line, while the

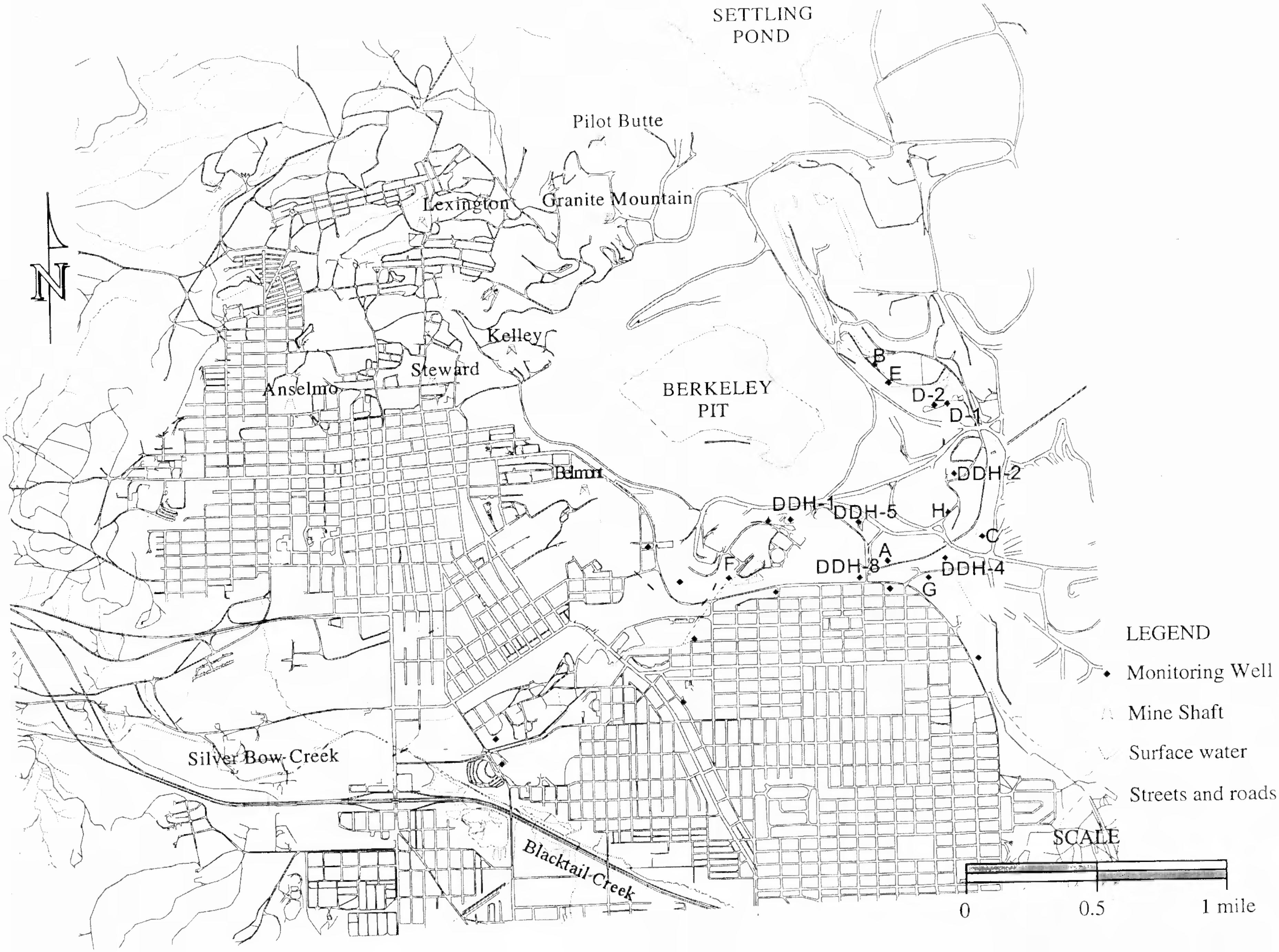


Figure 2-29. East Camp Mines and Bedrock Wells Location Map

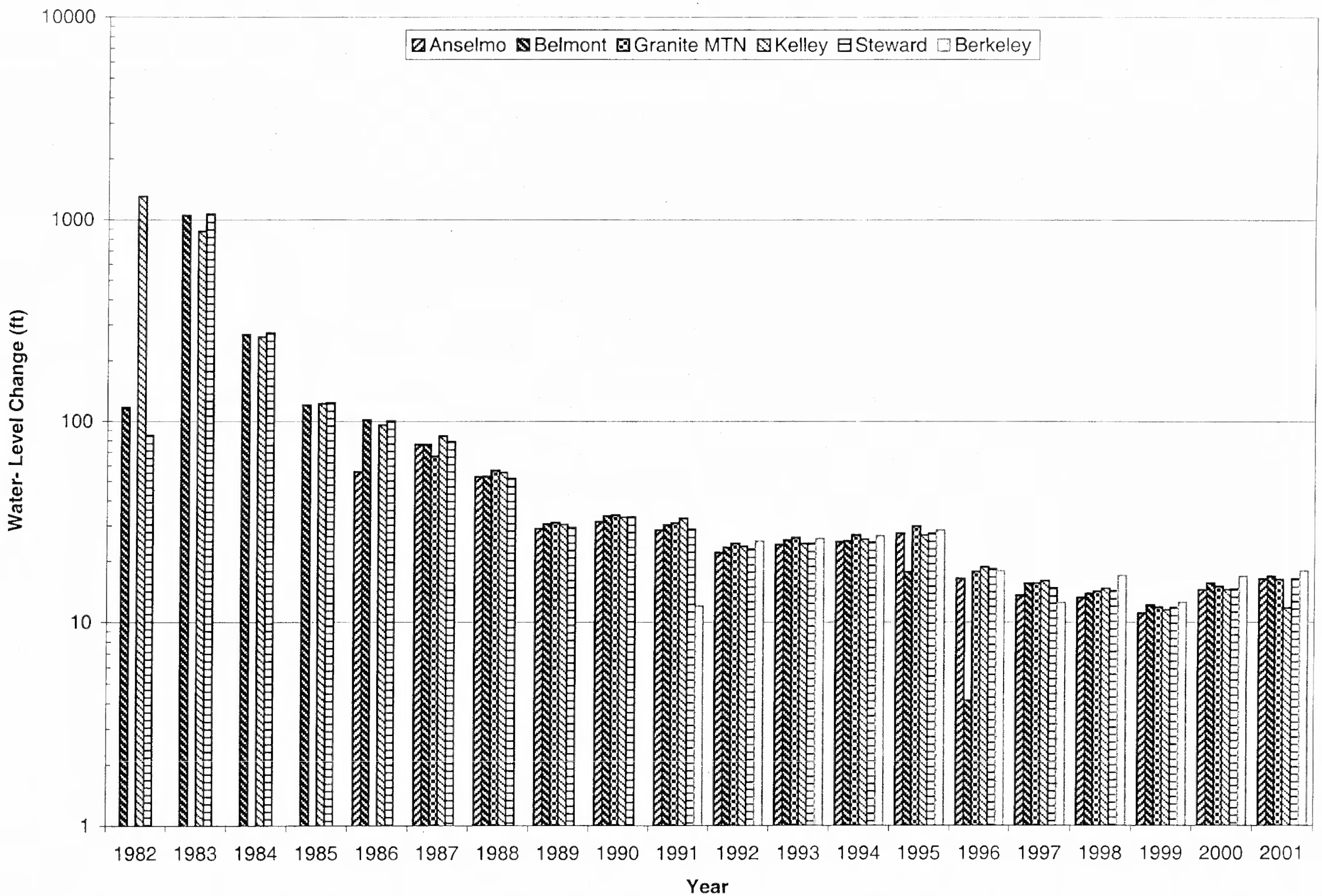


Figure 2-30. East Camp mines annual water-level changes.

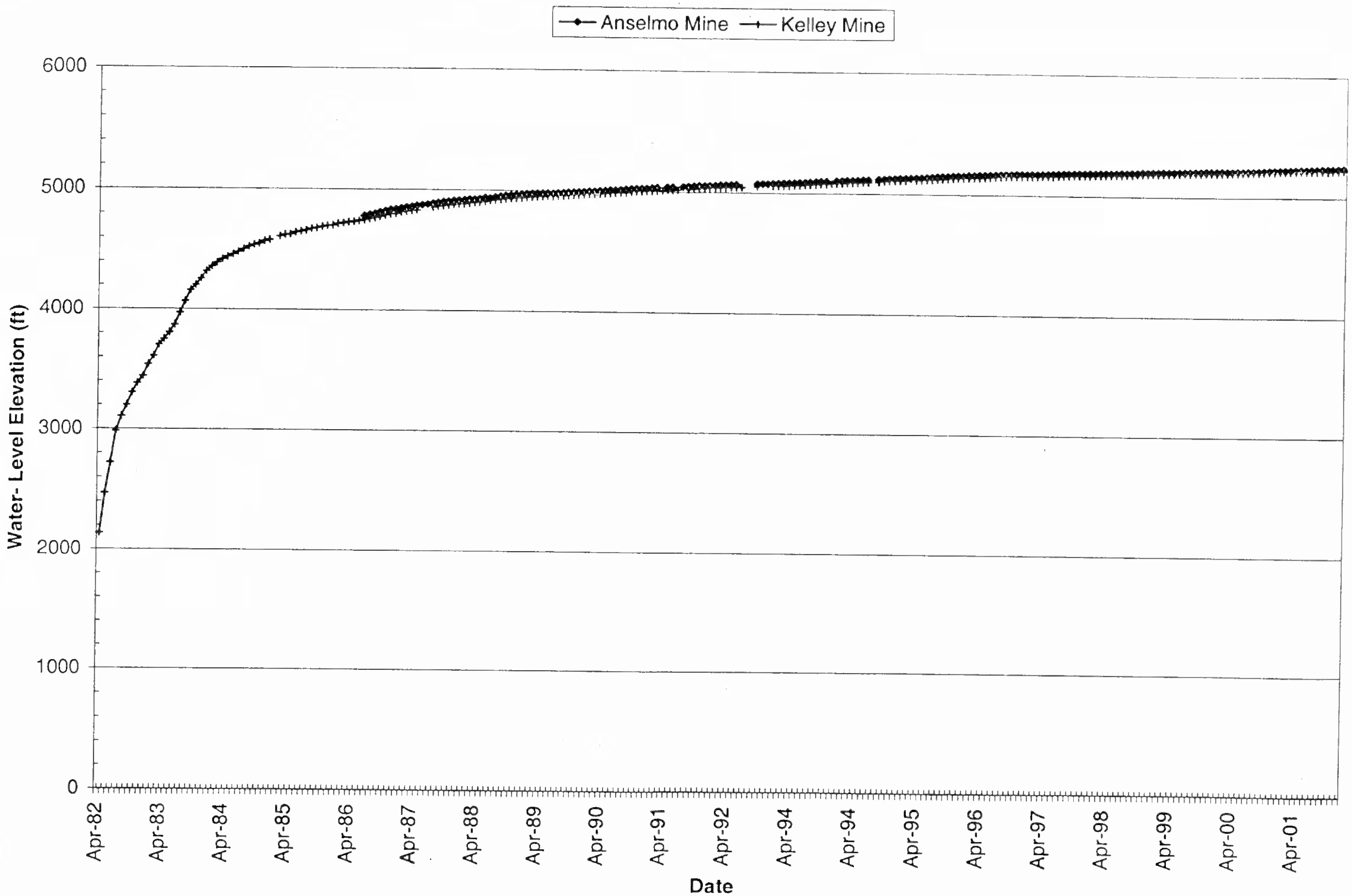


Figure 2-31. Water-level hydrographs for the Anselmo Mine and Kelley Mine.

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Butte mine Flooding Annual Report

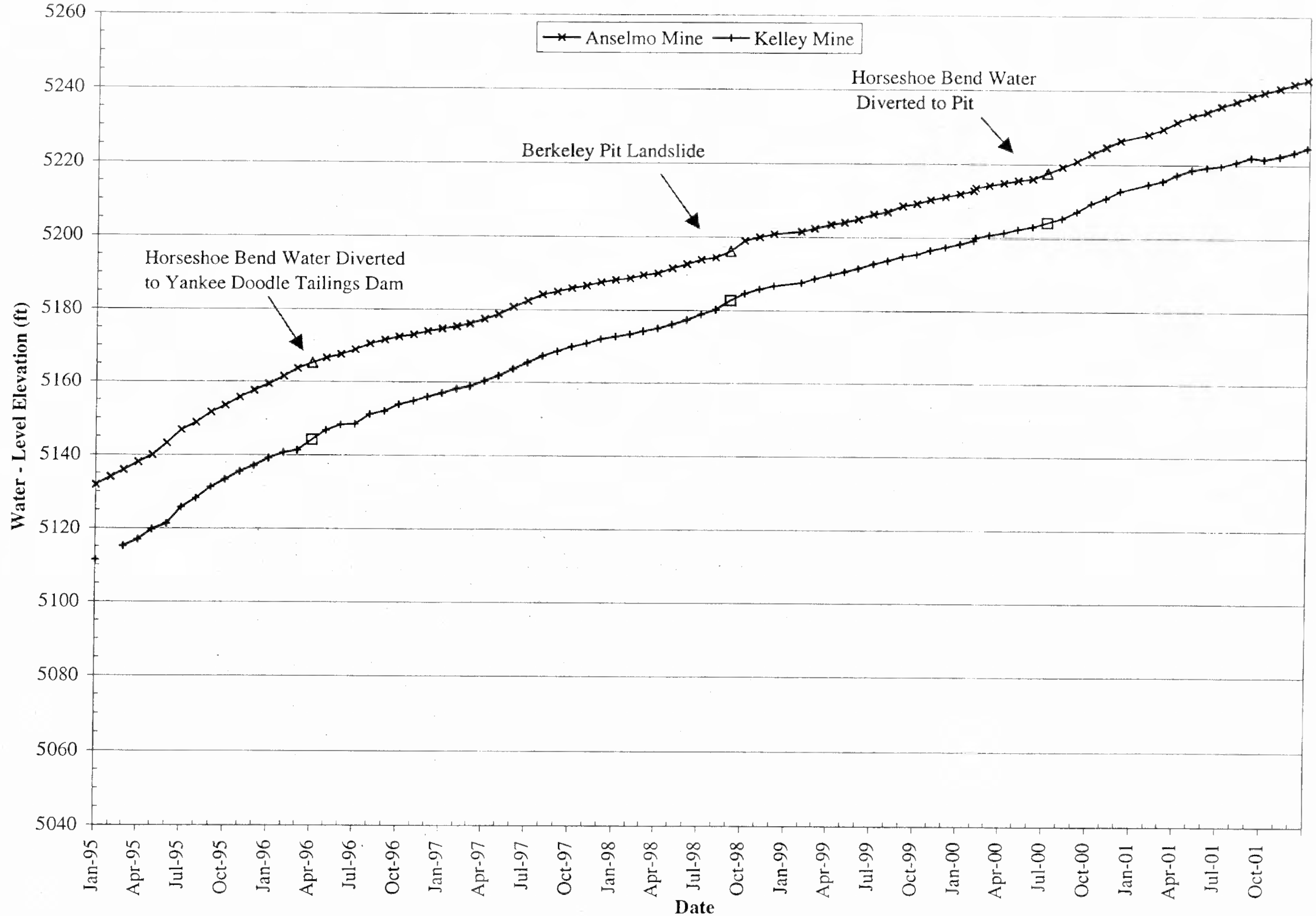


Figure 2-32. Water-level hydrographs, 1995-2001, Anselmo Mine and Kelley Mine.

2000 addition of this same water resulted in an increased slope of the line. The large water-level change (rise) following the 1998 Berkeley Pit landslide is very noticeable.

Figure 2-33 shows monthly water-level changes in the Berkeley Pit through 2001. The continued addition of HSB drainage water into the pit is responsible for the increased rate of rise. Water-level changes seen over the last 6 months of 2000, following the addition of Horseshoe Bend drainage water, continued through 2001. A similar trend was seen in all the East Camp underground mines. Water levels remain the highest in the sites farthest from the Berkeley Pit. This continues to confirm that water is flowing towards the pit, thus keeping the pit the low point in this system.

One interesting trend was seen in the Kelley Mine water levels during 2001. The monthly and annual water-level rise was considerably less than that of the other mines. The annual rise was about five feet less than the other East Camp mines. The cause is uncertain, but it maybe the result of the close proximity between the mine and Berkeley Pit, and the potentially greater level of interconnection between the two sites. Based upon the volume estimates of the underground mines and water-level elevations, over 90 percent of the underground mine workings are flooded.

Figure 2-34 is a plot of selected mine-shaft water levels versus precipitation. There is no apparent influence on water levels in the underground mines from monthly precipitation. It is obvious that the rise in water levels is a function of historic mine-dewatering activities and the void areas in the underground mines and Berkeley Pit, and is not a function of precipitation.

Section 2.2.0.1 Water Quality

As noted in earlier reports, water quality in the East Camp mines has been steady or slightly improving over the last few years. Data collected in 2001 indicated only slight changes over the past 12 months.

The Kelley Mine, for example, has exhibited high concentrations and large variations of arsenic over the period of record. The most recent samples suggest a trend toward increasing concentrations of arsenic and a trend toward decreasing concentrations of copper (figure 2-35). The last sample from the Kelley had one of the lowest concentrations of copper thus far. Water quality in the Granite Mountain shaft has shown the most consistent trends; arsenic and copper concentrations have generally increased throughout the period of record (figure 2-36). Water quality in the Anselmo Mine shows only a slight change in concentrations of dissolved constituents (figure 2-37). Selected chemistry for the East Camp mines including the Steward, Missoula, and Lexington mines, which have not been sampled in recent years, are presented in the appendix. A summary of selected analytes for the East Camp monitoring sites is presented in table 2.2.0.1.

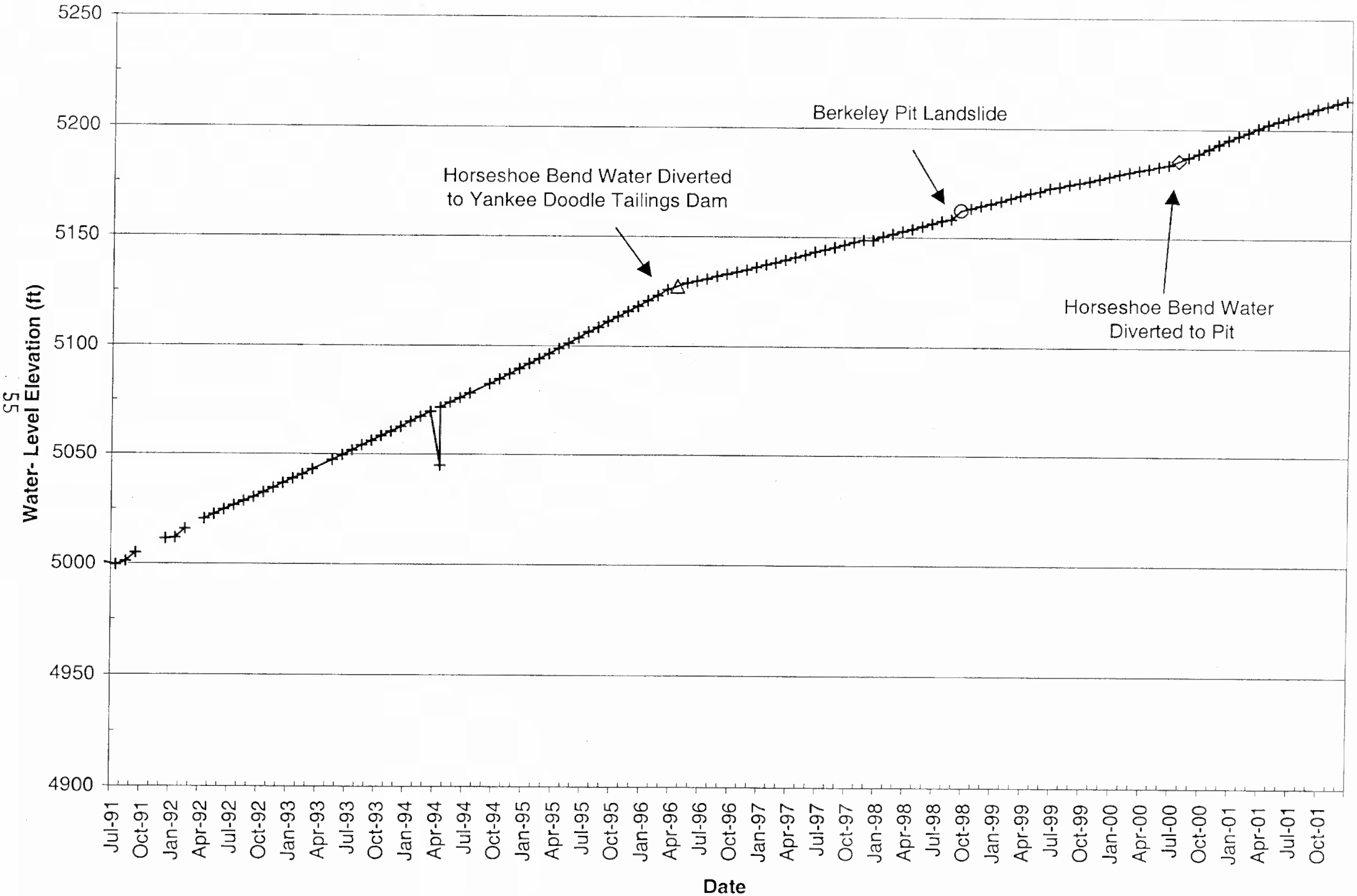


Figure 2-33. Water-level hydrograph for the Berkeley Pit.

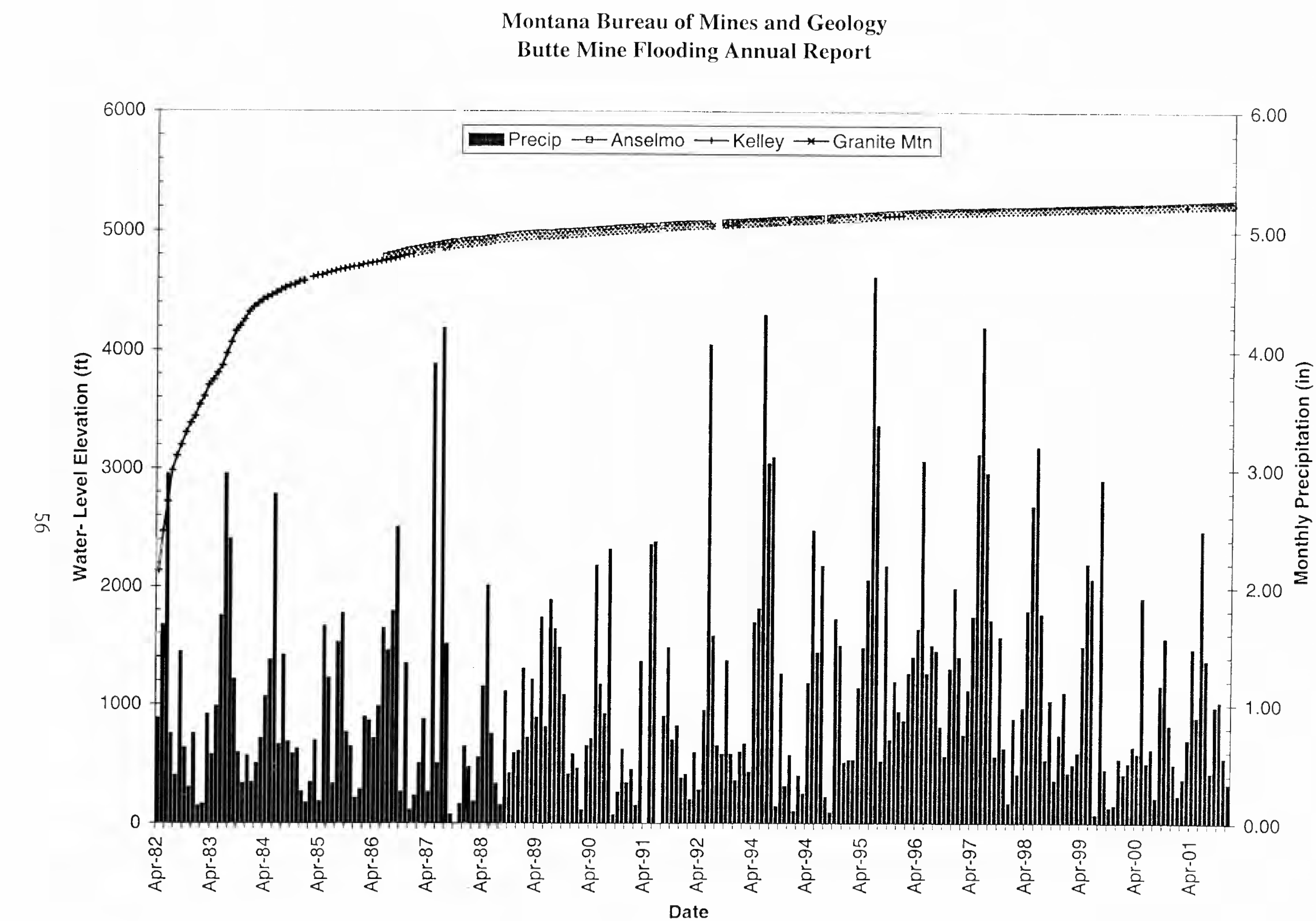
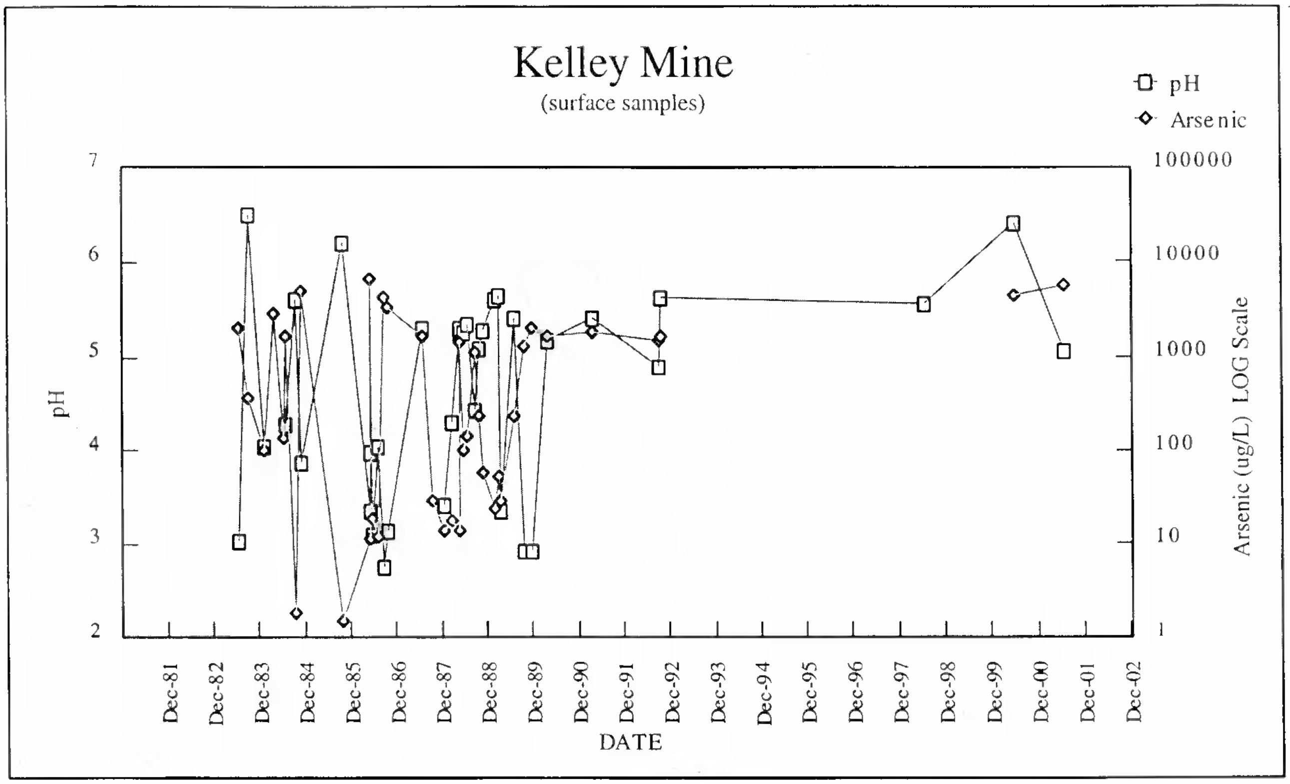


Figure 2-34. Water-level hydrographs for selected East Camp Mines, with monthly precipitation.



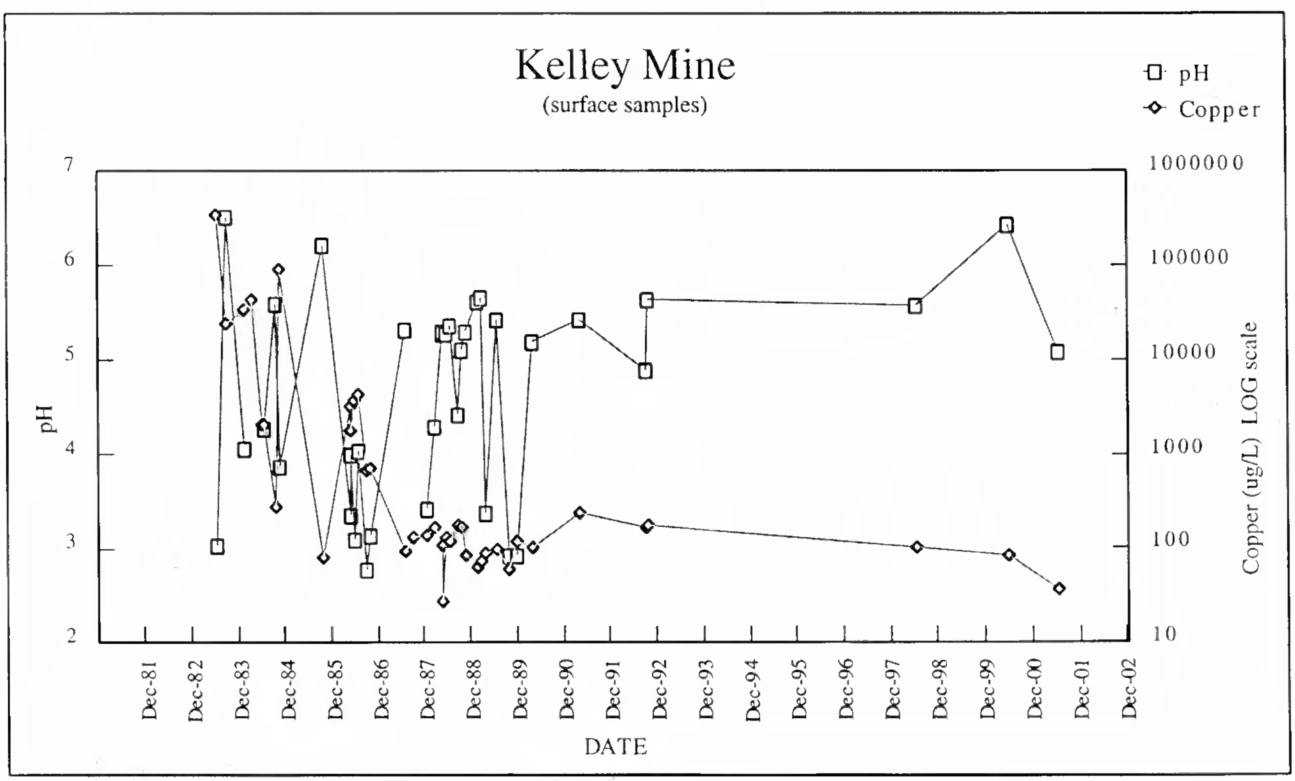
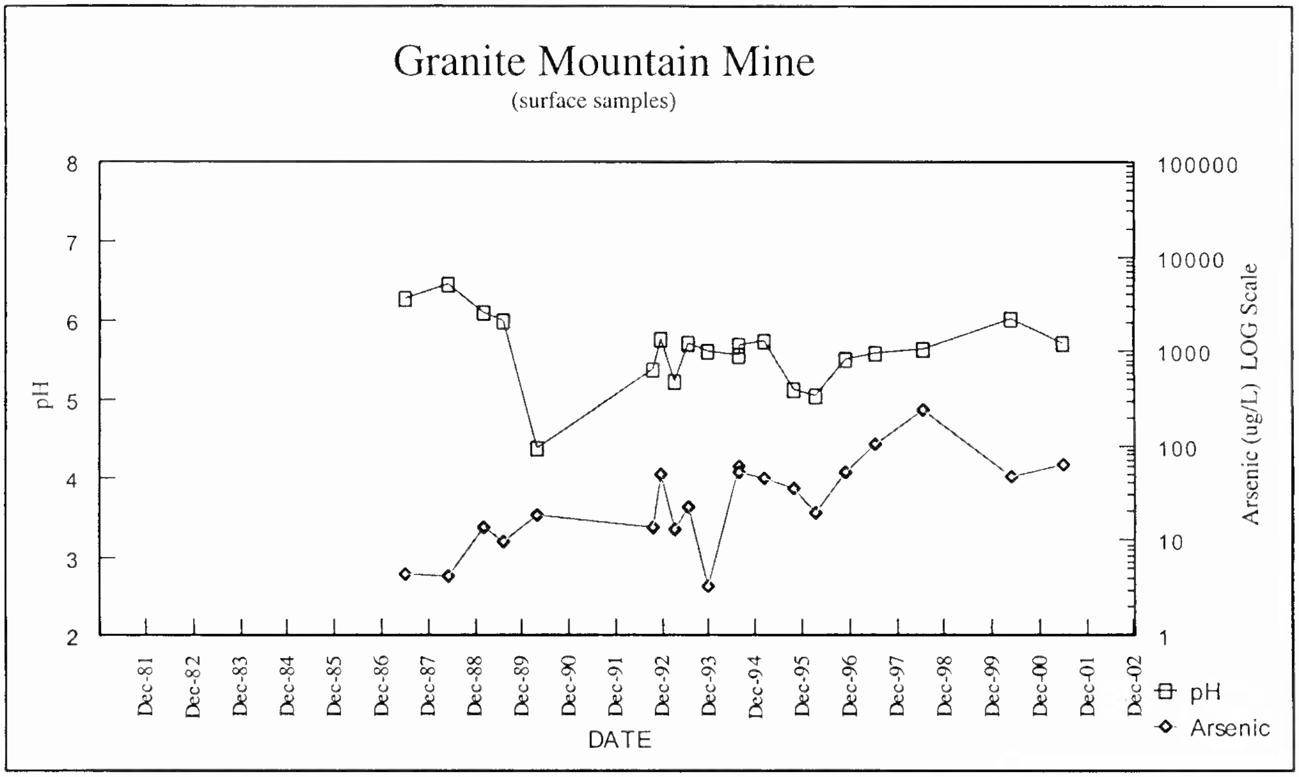


Figure 2-35. Arsenic and copper concentrations for the Kelley shaft (surface samples).



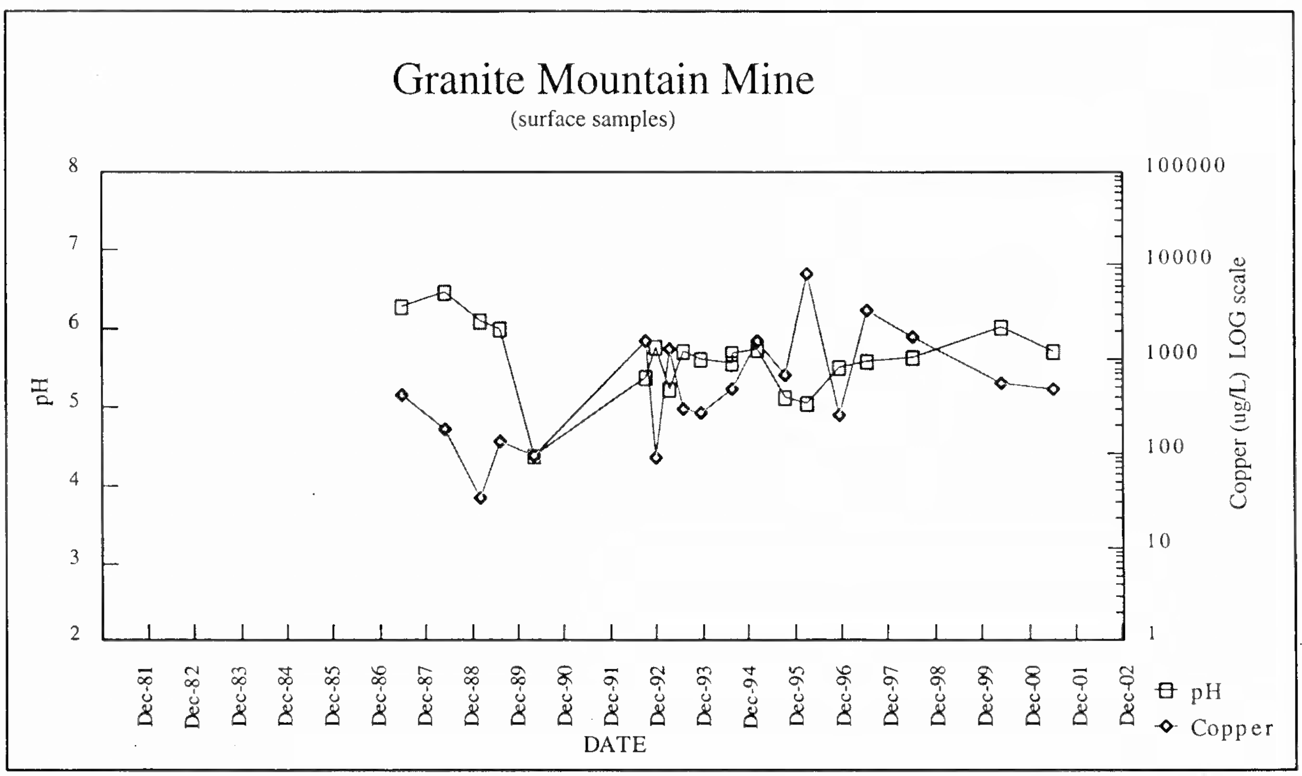
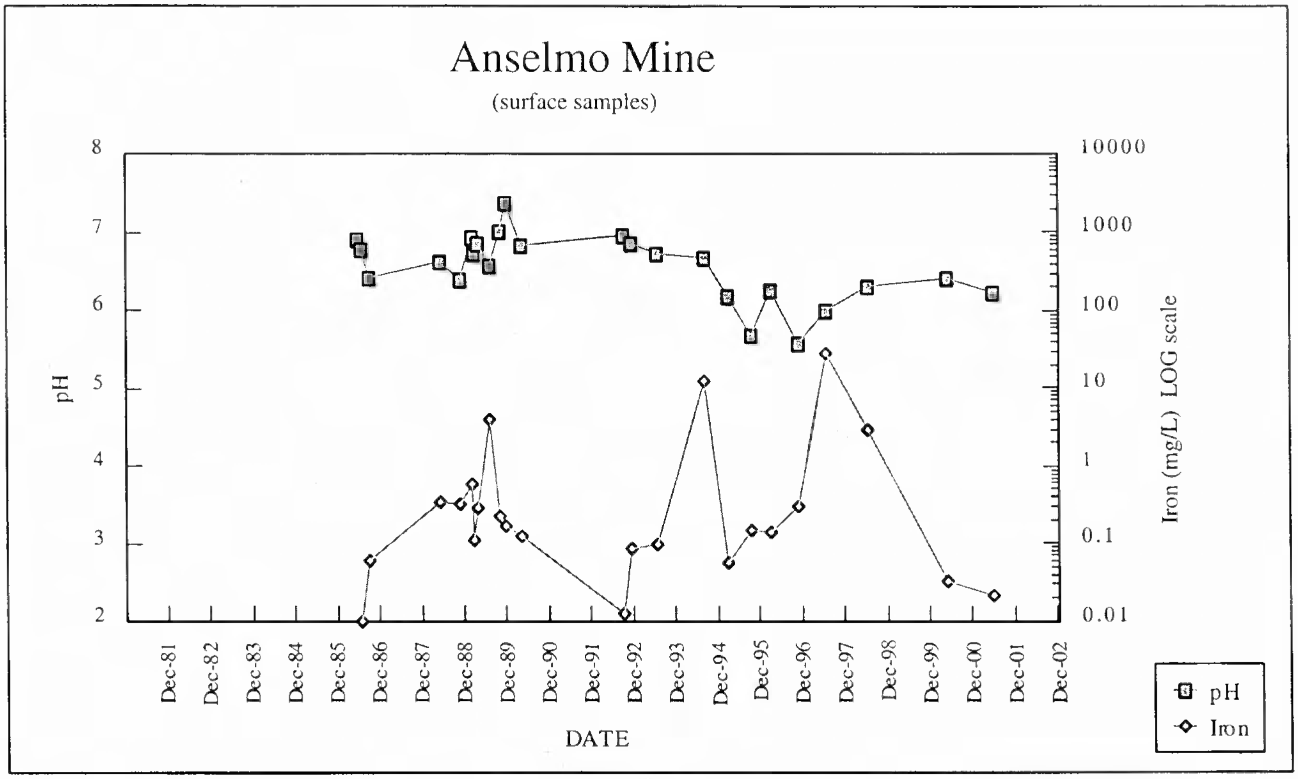


Figure 2-36. Arsenic and copper concentrations for the Granite Mountain shaft (surface samples).



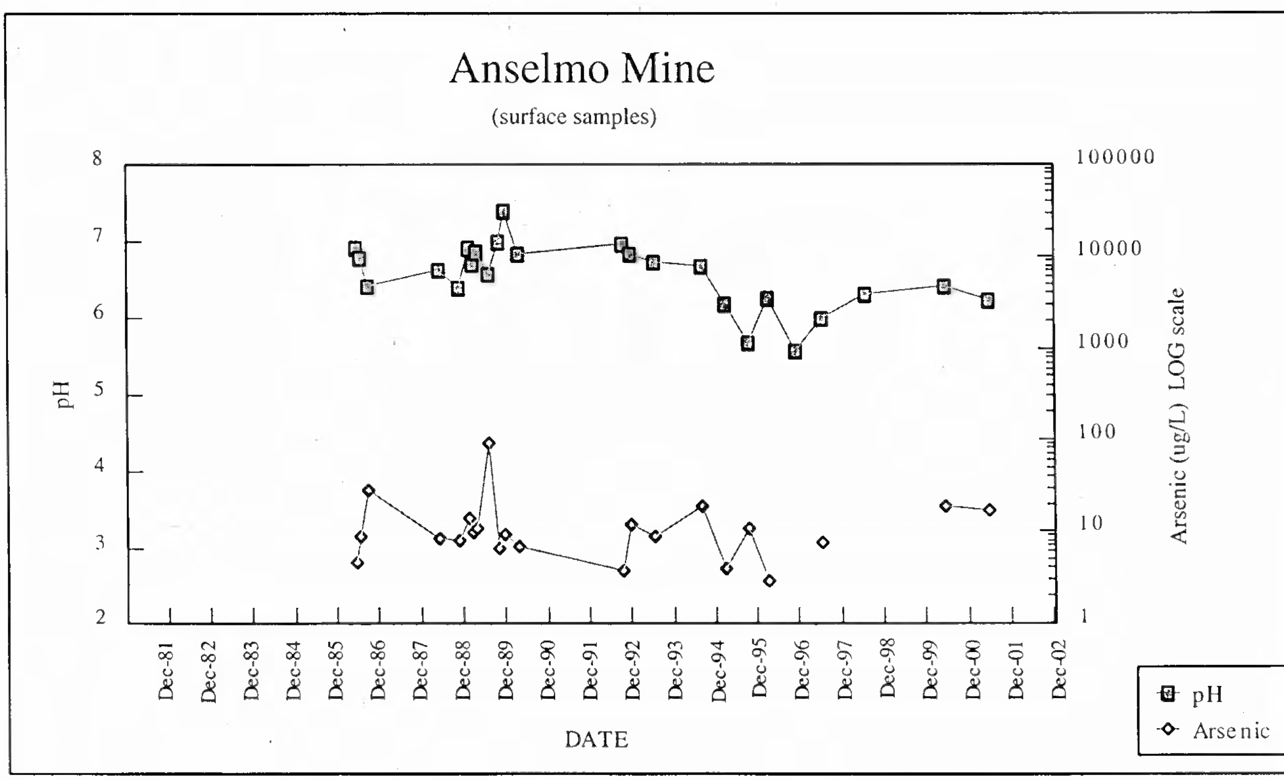


Figure 2-37. Iron and arsenic concentrations for the Anselmo shaft (surface samples)

Table 2.2.0.1. Selected Chemistry from East Camp Shafts, 2001 Data

Mine	Sample Date	pH (S.U.)	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	SO_4 (mg/L)	Zn (µg/L)
Kelley	7/18/01	5.08	2,730	36	5.17	2,780	159,000
Anselmo	6/25/01	6.25	<20	21.5	<1	982	25,200
Granite Mountain	7/12/01	5.71	423	501	2.02	2,263	22,800

Section 2.2.1 RI/FS Bedrock Monitoring Wells

Monitoring of the 9 RI/FS and ROD-installed bedrock wells continued. Monitoring well locations are shown on figure 2-29. Water levels continue to rise in wells A, C, D-1, D-2, G, and J at levels similar to those in the East Camp Mine system. Water levels in wells E and F continue to follow patterns identified in earlier reports. Table 2.2.1.1 contains yearly water-level changes and figure 2-38 shows those changes graphically.

As mentioned earlier, water-level trends in wells A, C, D-1, D-2, G, and J followed those identified in last year's report. Figures 2-39 and 2-40 are hydrographs for wells A, D-1 and D-2. The continued and steady rise in water levels is very apparent. Precipitation is also shown on these figures to compare water-level changes to precipitation. Unlike a number of the shallow alluvial wells, no variations in water levels are noted either seasonally or yearly as a result of precipitation. Water-level changes in the bedrock aquifer, which had been affected by historic underground mine dewatering, are responding to the cessation of pumping and show no apparent relationship to precipitation from 1982 through 2001. Instead, physical changes that affect the flow of water into the Berkeley Pit and underground mines, e.g. the 1996 HSB water diversion and the 2000 addition of the HSB drainage flow, are very apparent and are the major influences on water-level increases (figure 2-41). The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

Water levels measured in well J since its completion in 1999 have been in the same range as those in other surrounding bedrock wells and are shown on figure 2-42. Historic water levels for well H are shown on this figure with a linear projection of water levels included. Water levels for well J plot very close to those projected for well H, verifying that well J was completed in the same bedrock zone as well H.

The water-level change in well B continues to increase at about one-half the rate of those of the above bedrock wells over the past two years. Since 1992, the rate of water-level rise in this well is about 46 percent that of the Berkeley Pit. Figure 2-43 is hydrographs for wells A and B,

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Butte Mine Flooding Annual Report

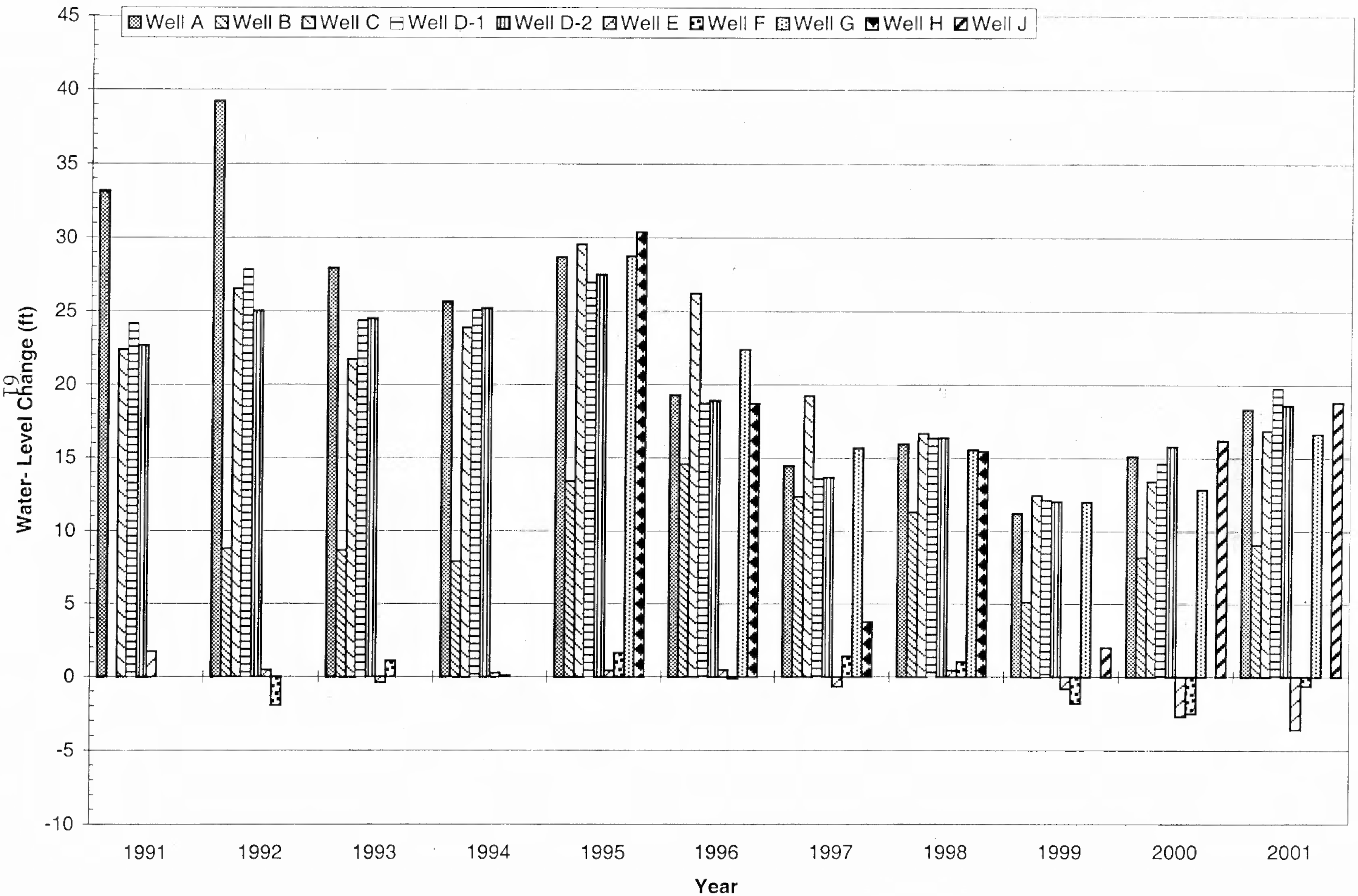

Figure 2-38. RI/FS bedrock wells annual water-level change.

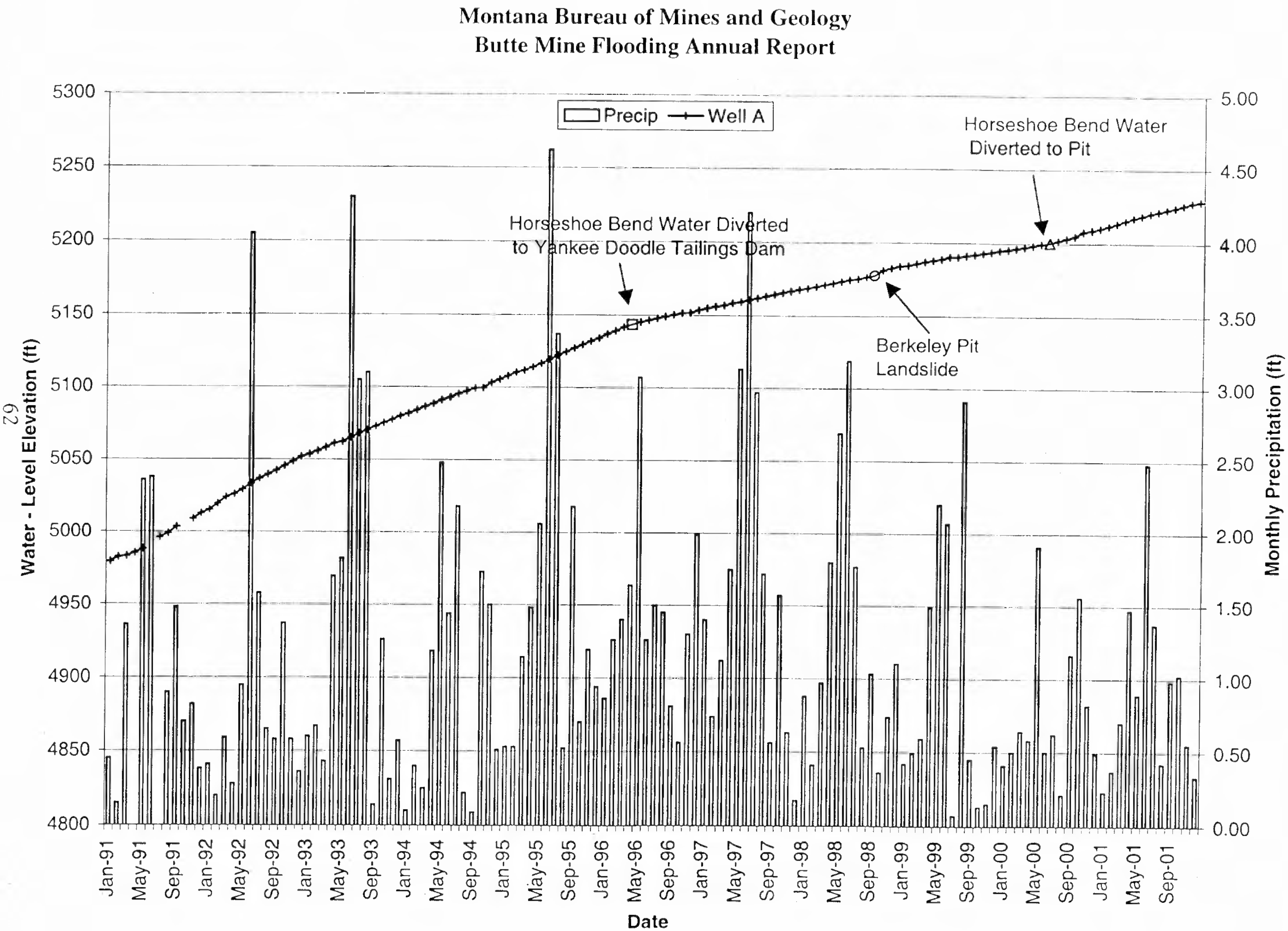

Figure 2-39. Water-level hydrograph for bedrock well A.

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Butte Mine Flooding Annual Report

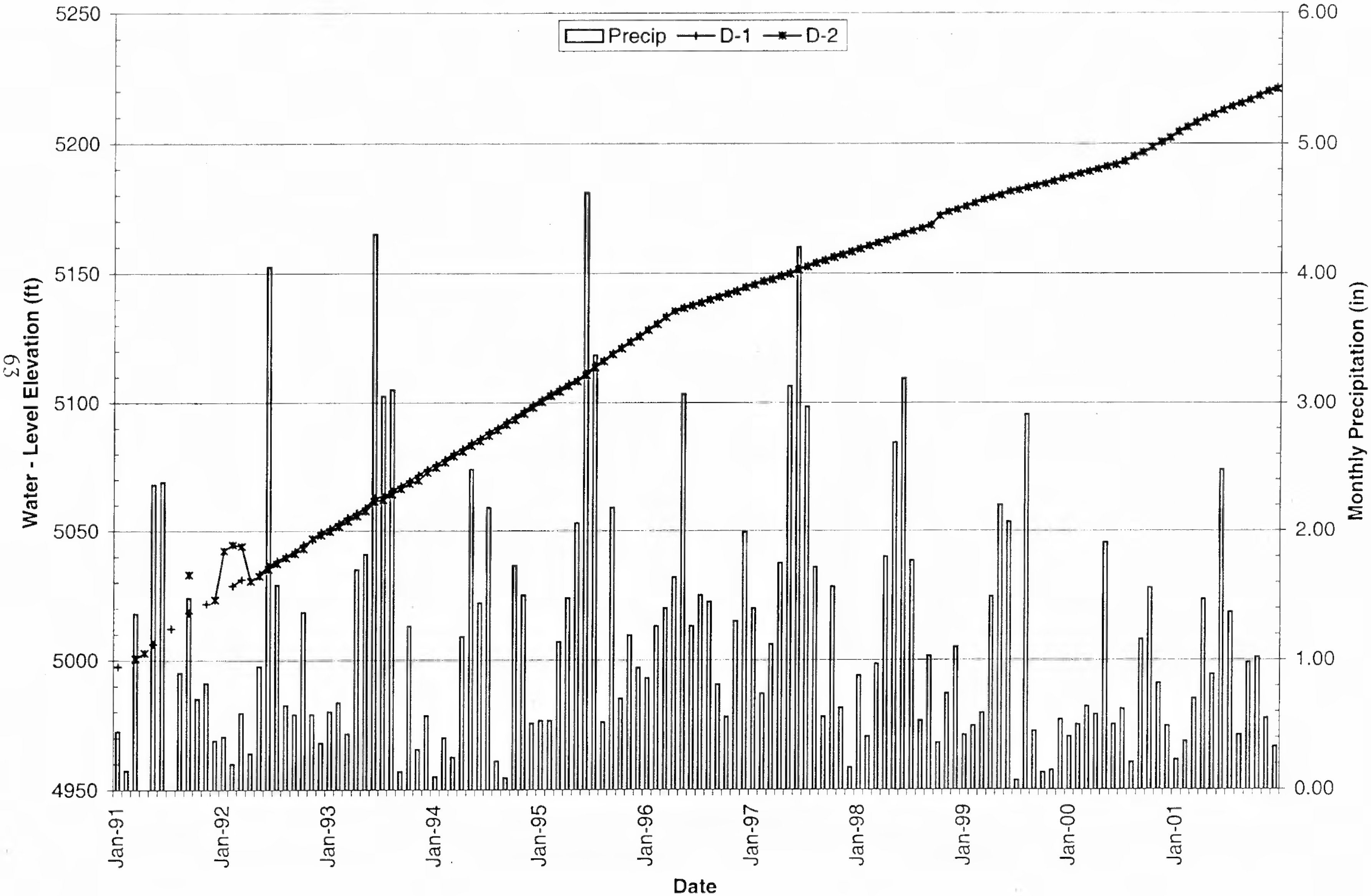

Figure 2-40. Water-level hydrographs for bedrock wells D-1 and D-2.

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Butte Mine Flooding Annual Report

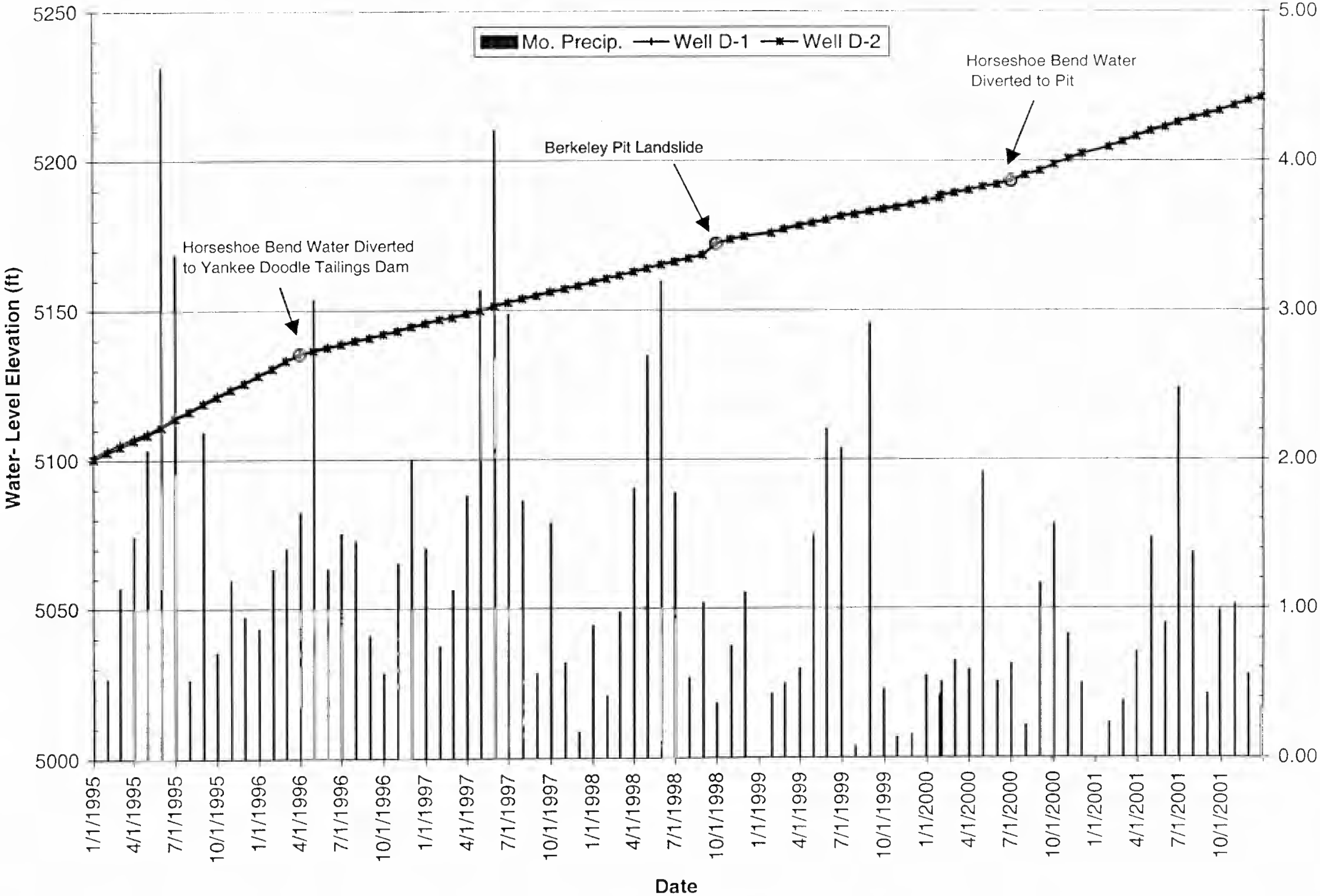

Figure 2-41. Water-level hydrographs, 1995-2001, wells D-1 and D-2.

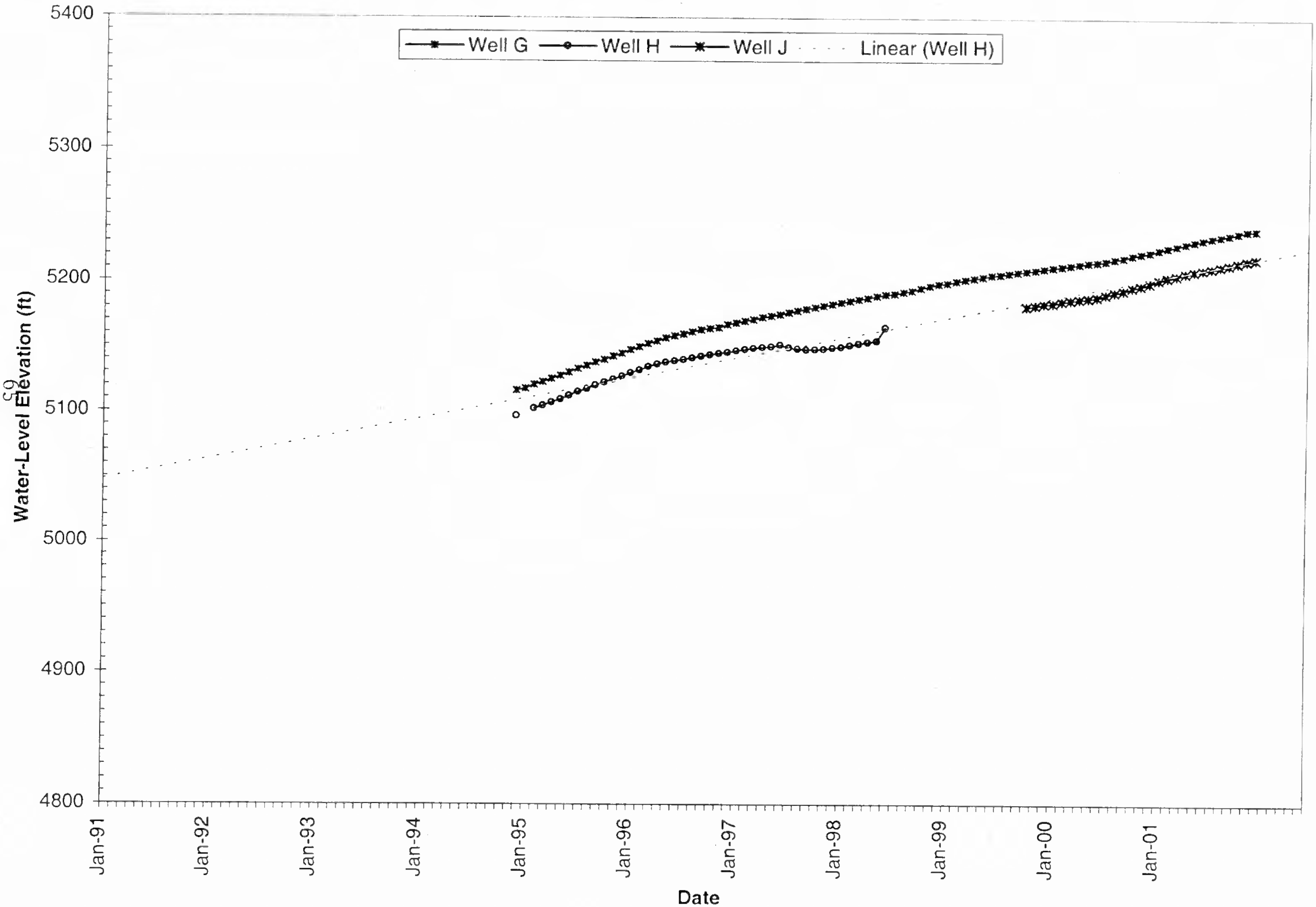

Figure 2-42. Water-level hydrographs for bedrock wells G, H, and J.

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Butte Mine Flooding Annual Report

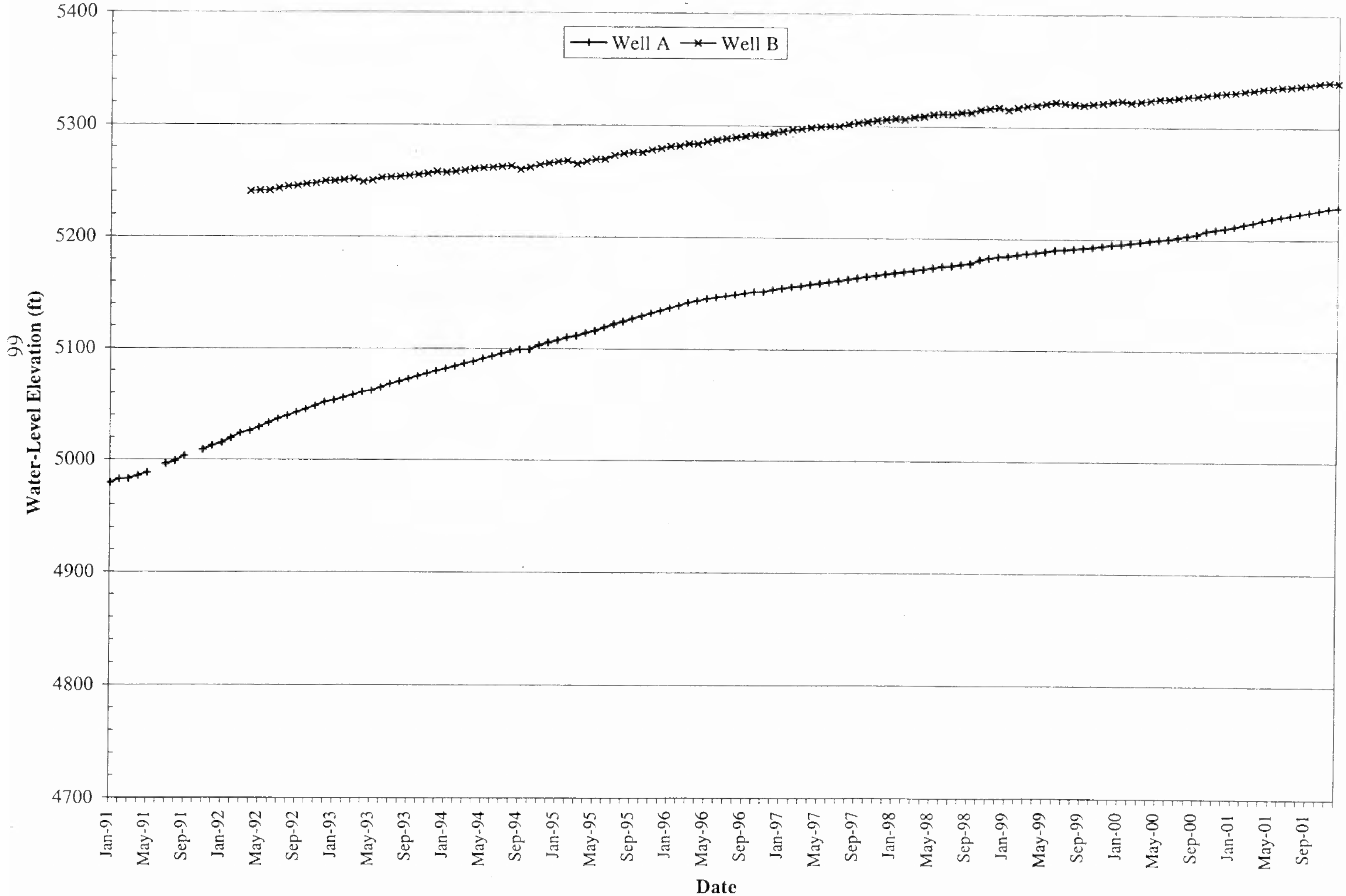


Figure 2-43. Water-level hydrographs for bedrock wells A and B.

showing monthly water-level elevations. From this figure it is apparent that the water-level trend in well B is following those of the other bedrock wells (A, C, D-1, D-2, G, and J).

Table 2.2.1.1 RI/FS Bedrock Well Annual Water-Level Change

Year	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H	Well J
1989										
1990										
1991	33.18		22.38	24.20	22.68	1.73				
1992	39.22	8.78	26.53	27.89	25.04	0.47	-1.92			
1993	27.95	8.68	21.72	24.41	24.51	-0.37	1.09			
1994	25.65	7.90	23.88	25.12	25.21	0.27	0.11			
1995	28.69	13.41	29.55	26.99	27.50	0.44	1.65	28.74	30.37	
1996	19.31	14.56	26.22	18.77	18.92	0.48	-0.11	22.40	18.72	
1997	14.44	12.35	19.25	13.62	13.68	-0.64	1.41	15.67	3.76	
1998	15.96	11.30	16.68	16.41	16.39	0.44	1.03	15.56	15.44	
*Total 10-Year Change**	*204.4*	*76.98*	*186.21*	*177.41*	*173.93*	*2.82*	*3.26*	*82.37*	*68.29*	
1999	11.21	5.11	12.44	12.18	12.03	-0.78	-1.80	12.00	P&A	1.99
2000	15.12	8.20	13.39	14.66	15.79	-2.68	-2.49	12.84	P&A	16.19
2001	18.33	9.08	16.86	19.81	18.61	-3.58	-0.61	16.56	P&A	18.81
*Total Change**	*249.06*	*99.37*	*228.90*	*224.06*	*220.36*	*-4.22*	*-1.64*	*123.86*	*68.29*	*36.99*

Year	DDH-1	DDH-2	DDH-4	DDH-5	DDH-8
1989	29.53			34.83	30.48
1990	36.24	30.99	5.44	27.61	35.96
1991	27.03	28.20	39.81	27.01	28.96
1992	28.25	26.09	37.66	31.07	26.16
1993	24.33	24.16	26.88	24.40	24.46
1994	25.00	25.65	28.34	19.78	15.97
1995	27.66	28.74	28.80	26.10	--
1996	18.53	18.97	20.24	12.41	55.68
1997	13.33	14.09	14.32	15.89	13.38
1998	15.03	16.20	16.25	16.50	16.50
**Total 10 Year Change*	*244.93*	*213.09*	*217.74*	*235.6*	*247.55*
1999	11.66	12.00	11.88	4.82	15.50
2000	14.64	16.11	14.77	P&A	10.42
2001	18.14	18.78	18.52	P&A	18.93
*Total Change**	*289.37*	*259.98*	*262.91*	*240.42*	*292.40*

(*) Total change is the measured change. Access or obstructions prevented continuous water-level measurements at some sites. P&A - well plugged and abandoned due to integrity problems. Well J was drilled as a replacement for well H.

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (figure 2-44). They are considerably higher than those in the other bedrock wells, indicating a lack of dewatering from historic mining activities.

Water-level monitoring continues to confirm that the flow of water in the affected bedrock aquifer is towards the Berkeley Pit. Figure 2-45 is a potentiometric-surface map for the East Camp bedrock aquifer showing the flow of water from all directions towards the pit.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

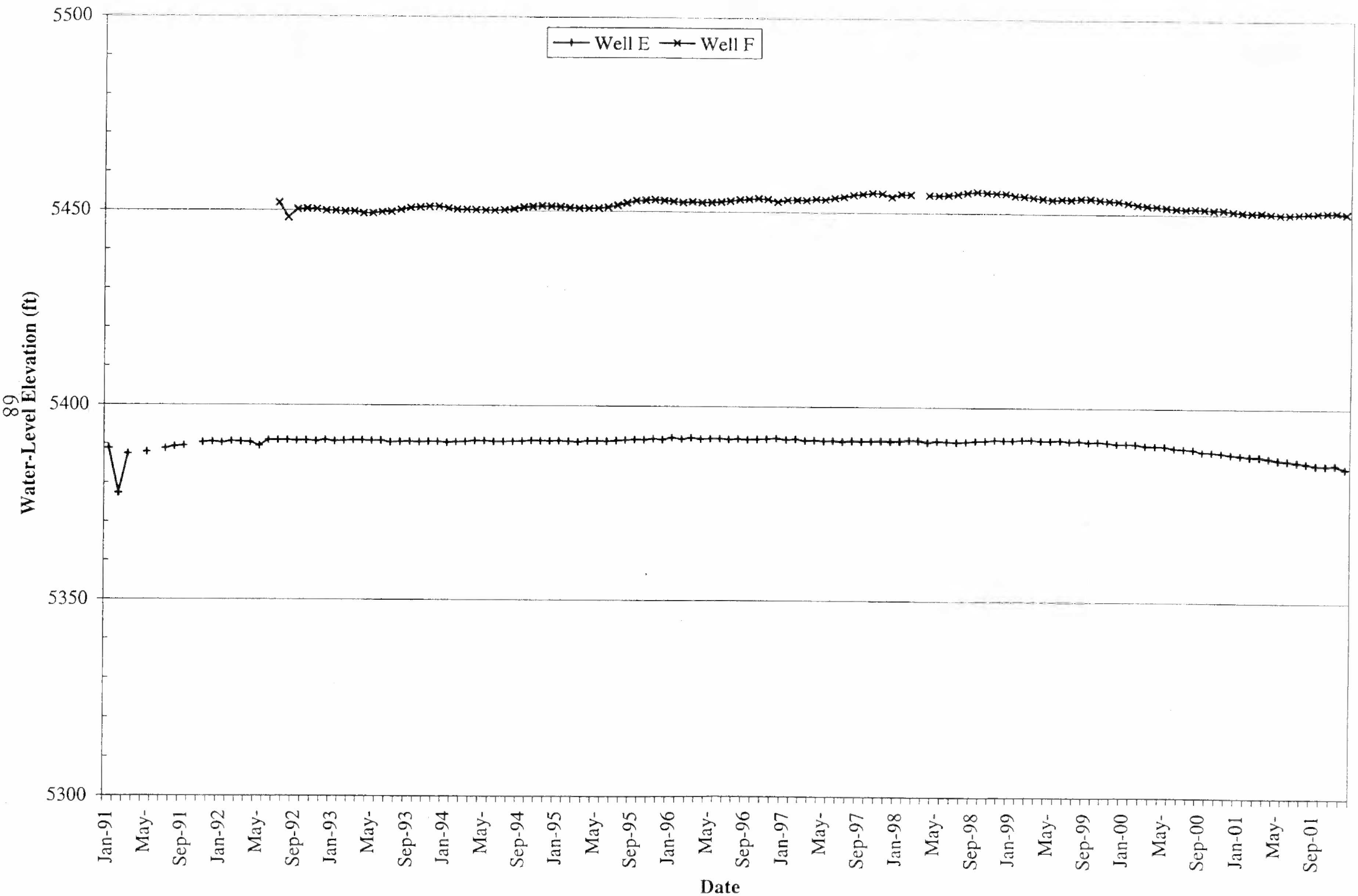


Figure 2-44. Water-level hydrographs for bedrock wells E and F.

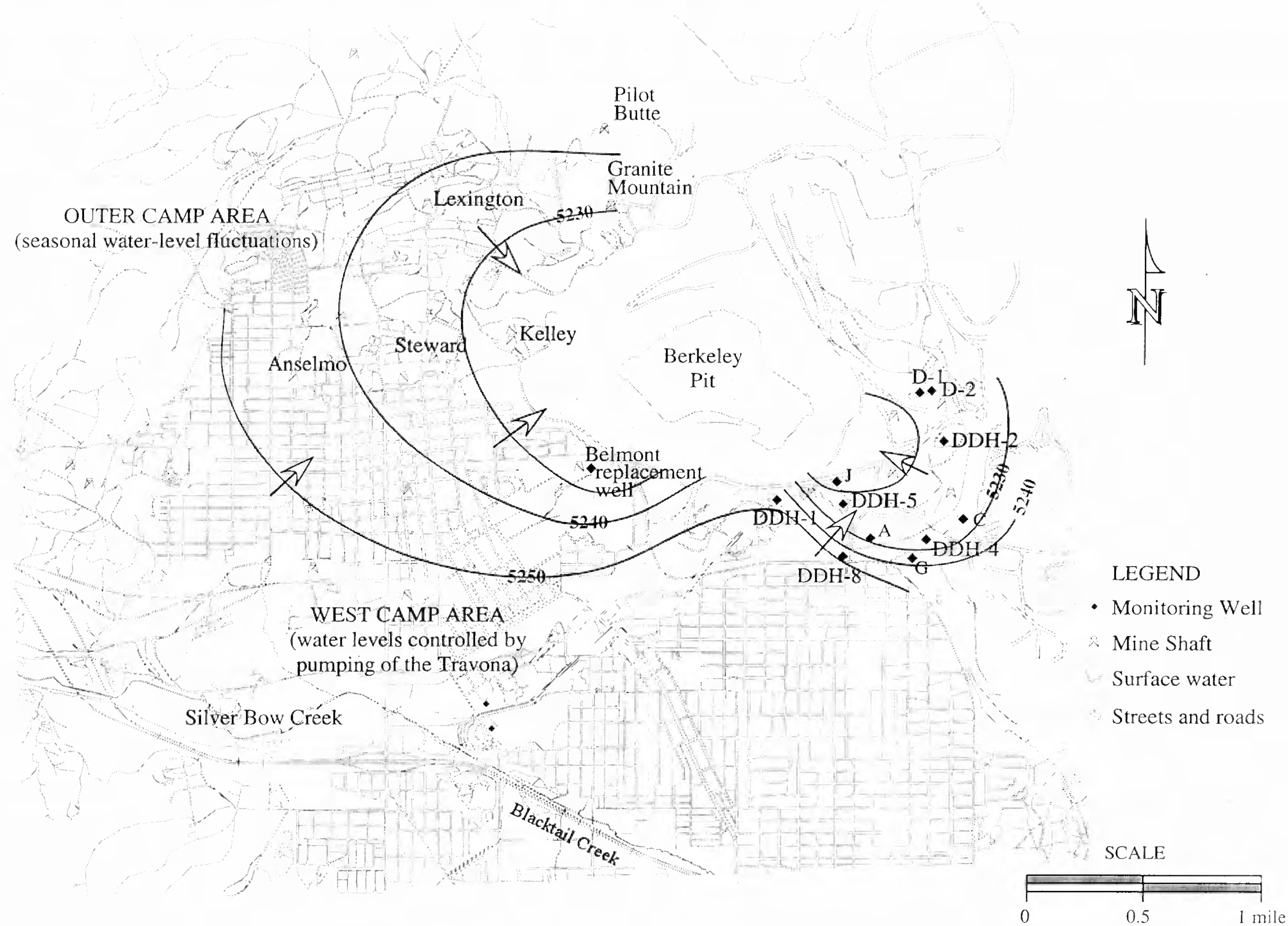


Figure 2-45. East Camp Bedrock Aquifer Potentiometric Map, December 2001 Water Levels; arrows indicate direction of ground-water flow (contour interval is 10 feet)

Section 2.2.1.1 RI/FS Bedrock Well Water Quality

Water quality varies widely between the RI/FS- and ROD-bedrock wells; sulfate concentrations range from about 300 mg/L in well D1 to nearly 2,500 mg/L in well F. Similarly, arsenic ranges from about 1,000 µg/L in well J to less than 2 µg/L in well C. The concentration of dissolved metals likewise has a wide range. Water-quality trends are generally continued from recent years; several wells, such as well A, show upward trends for some constituents (in this case zinc) and no trend for others (sulfate). Table 2.2.1.1.1 summarizes the water-quality trends over the period of record though 2001. Graphs of selected chemistry are presented in the appendix.

Section 2.2.2 DDH Series Wells

Water-level monitoring of the DDH series wells continued. Water levels have continued to rise in these wells, following previous trends. The water-level rise in wells DDH-1, DDH-2, DDH-4, and DDH-8 ranged from 18.14 to 18.93 feet in 2001. The rates of rise are consistent with those of the other bedrock wells and East Camp mine shafts. Figure 2-46 is hydrographs for wells DDH-2 and DDH-4 showing water-level increases. Once again precipitation does not show any affect on water-level rise.

No water-quality samples were collected from these wells, as they are used for water-level monitoring only.

Section 2.2.3 Berkeley Pit, Continental Pit and Horseshoe Bend Drainage

Berkeley Pit water-level elevations were surveyed monthly to coincide with monthly water-level monitoring in wells. Figure 2-47 is a hydrograph showing its water-level rise over time. The overall trend is similar to that of previous years. There are three noticeable changes on this figure. The first change represents a slow decrease in the filling rate when the HSB drainage diversion occurred in April of 1996, the second notes an increased filling rate from the

Table 2.2.1.1.1. Exceedences and Trends for East Camp Bedrock Wells (1989 to 2001)

Well Name	Exceedences (± 1)*	Concentration Trend	Remarks
A	Y	Variable	Arsenic (MCL), sulfate (SMCL)
B	N	Variable	Sulfate (SMCL)
C	N	None	Sulfate (SMCL)
D-1	N	Variable	Sulfate (SMCL)
D-2	Y	Increase	Arsenic (MCL); sulfate (SMCL)
E	Y	Variable	Sulfate (SMCL); arsenic (MCL)
F	Y	None	Arsenic (MCL), sulfate (SMCL)
G	N	Decrease	Sulfate (SMCL)
J	Y	Variable	Very poor quality water

(*) excludes sulfate

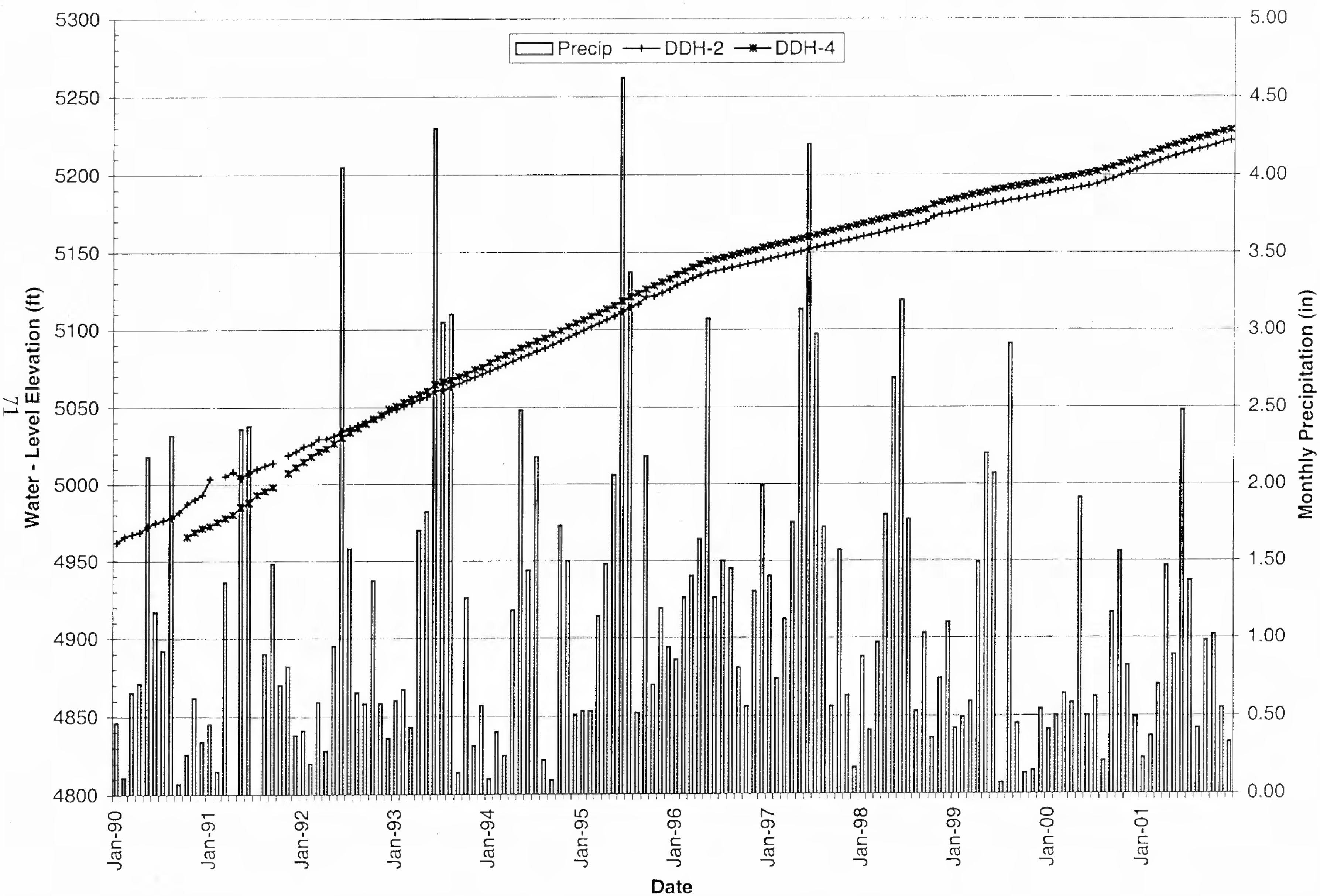


Figure 2-46. Water-level hydrographs for bedrock wells DDH-2 and DDH-4.

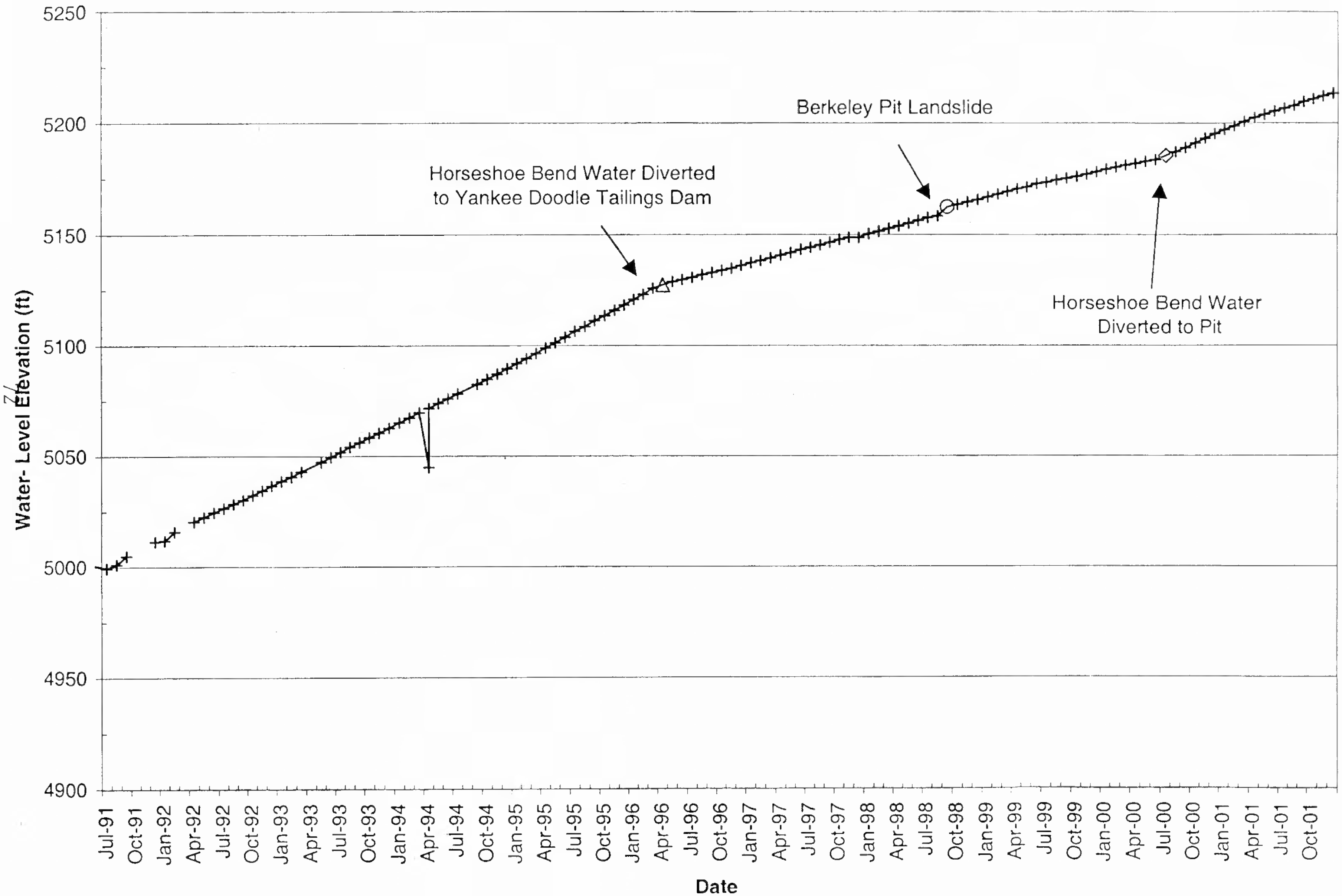


Figure 2-47. Water-level hydrograph for the Berkeley Pit.

September 1998 landslide, and the third depicts an increased filling rate following the June 2000 suspension of mining by MR and the subsequent inflow of water from the HSB drainage to the pit. From April 1996 through June 2000, water from the HSB drainage was diverted and incorporated in the mining and milling process. Following MR's June 2000 suspension of mining, water from the HSB drainage was again allowed to flow into the Berkeley Pit. The volume of water allowed to enter the pit exceeded 1.8 billion gallons from July 2000 through December 2001 (figure 2-48). This represents an average flow of almost 2,300 gallons per minute. The overall Berkeley Pit water-level rise for 2001 was 17.97 feet.

The Continental Pit water level was measured by monitoring the water level in the Sarsfield dewatering well. The pump in the dewatering well operated through January 2001. A total of 9.8 million gallons of water were pumped during that time. The water level in this well rose over 16 feet during 2001, resulting in about 14 feet of standing water in the pit bottom.

A 90° V-notch weir was installed during the first part of July 2001 in the HSB for improved flow monitoring. As discussed in last year's report, a problem was identified with the Parshall Flume that was used for measuring the flow rate of water into the Berkeley Pit. In order to more accurately measure the flow rate, it was decided that a V-notch weir would provide the best information. Therefore a weir was installed the first week of July 2001.

Section 2.2.3.1 Berkeley Pit, Continental Pit and Horseshoe Bend Drainage Water Quality

Water-quality trends in the shallow and deep Berkeley Pit have been generally the same since 1999. Probably the greatest influence on water quality has been activities related to HSB and the leach pads. From 1996 to 2000, these waters were diverted from the pit; with the suspension of mining activities in mid-2000, waters from HSB and the leach pads have been flowing into the pit. The pH of the pit water has increased from about 2.2 to 2.9, nearly equal to the pH of the water in 1984 (figure 2-49). In many cases, the same is true for the concentrations of dissolved metals (figures 2-50a, 2-50b); concentrations are near their lowest since 1984. Sulfate concentrations have decreased in waters at the surface, but appear to be increasing in the deeper water (100 to 400 feet below surface).

Both flow and water quality of the Horseshoe Bend drainage are probably related to the nearby leach pad operation. This is particularly evident in the response in copper concentrations in the Horseshoe Bend waters since the shut down of the leach pads. There has been a general decrease in concentration of several other constituents since 1994, but the shut down of the leach pads affected a greater rate of decrease (figure 2-51).

Water quality of the Horseshoe Bend outflow continues to be slightly better than that of the Berkeley Pit (table 2.2.3.1). This has been the case throughout the period of record and

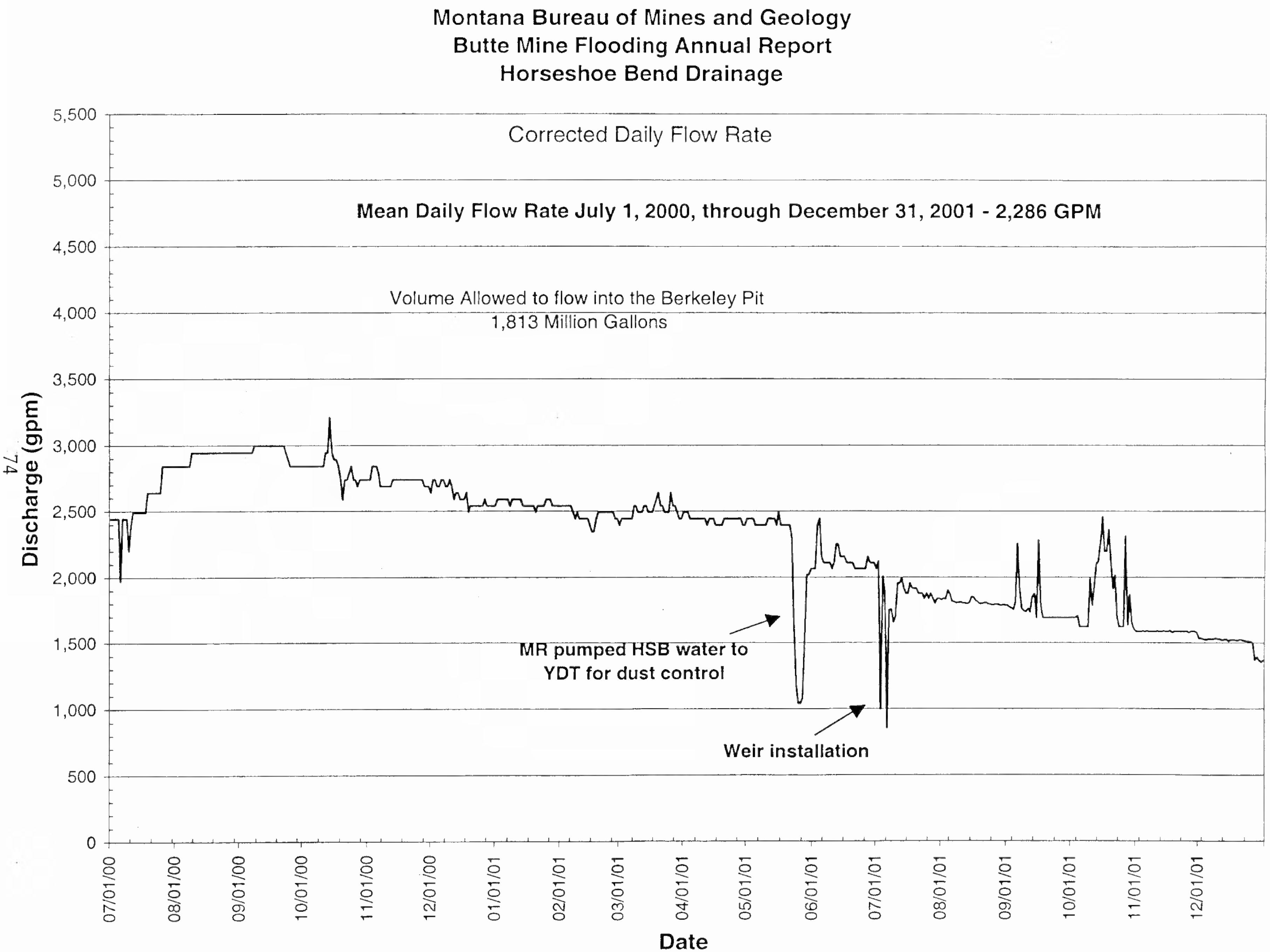


Figure 2-48. Horseshoe Bend Drainage daily average flow rate, July 1, 2000, through December 31, 2001.

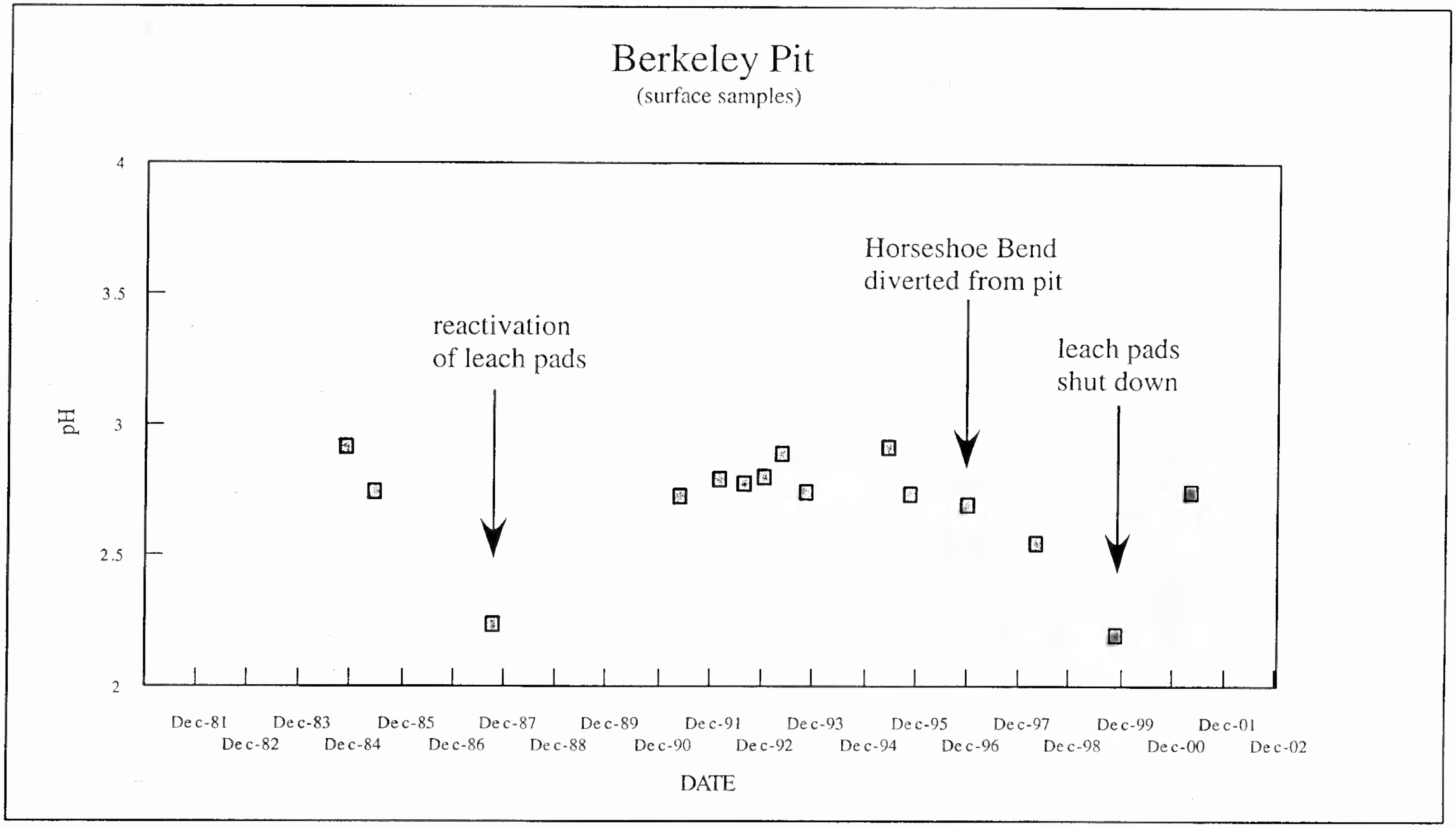


Figure 2-49. Berkeley Pit pH values (surface samples) through the period of record.

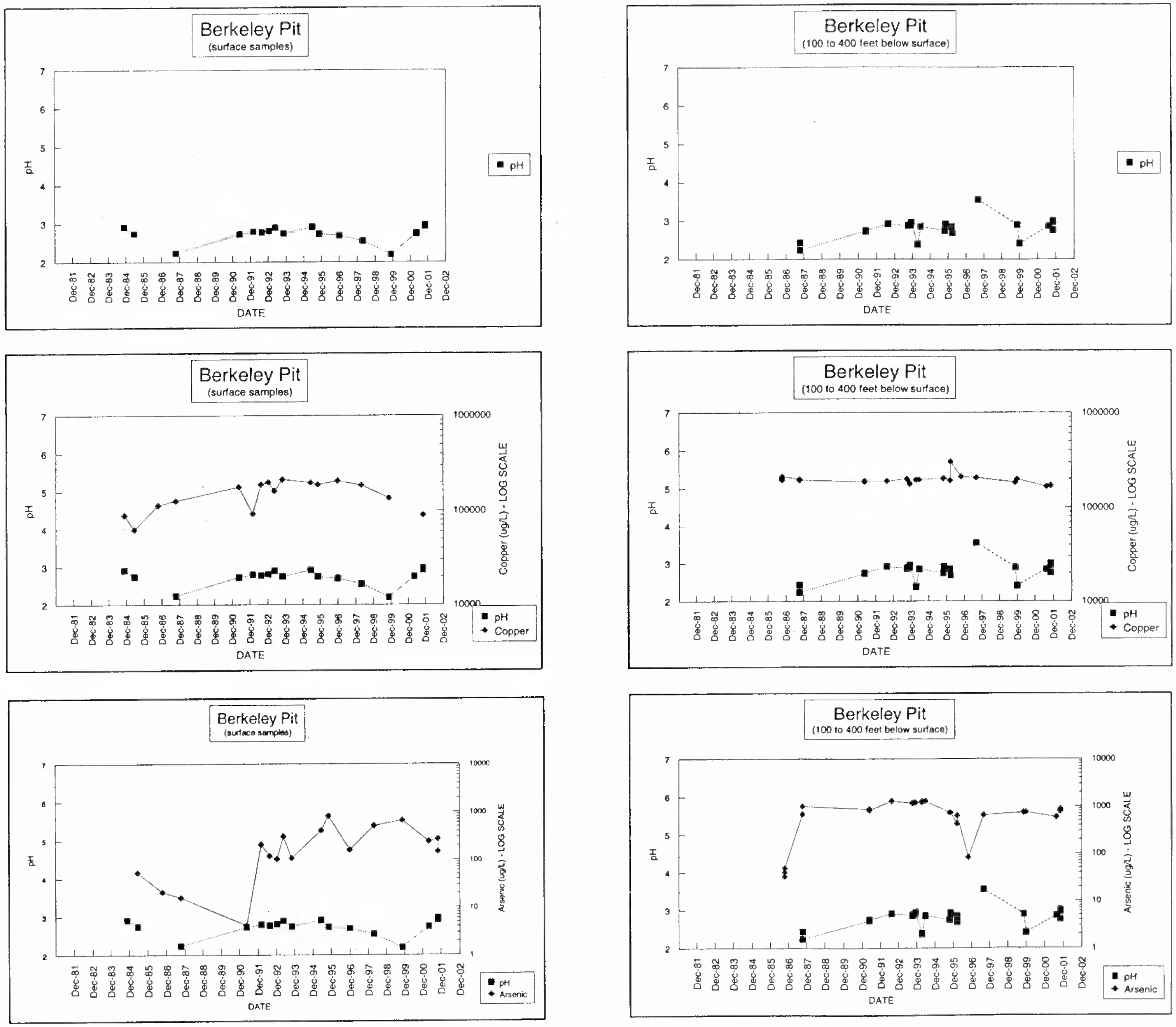


Figure 2-50a. Selected chemistry for the Berkeley Pit (surface samples)

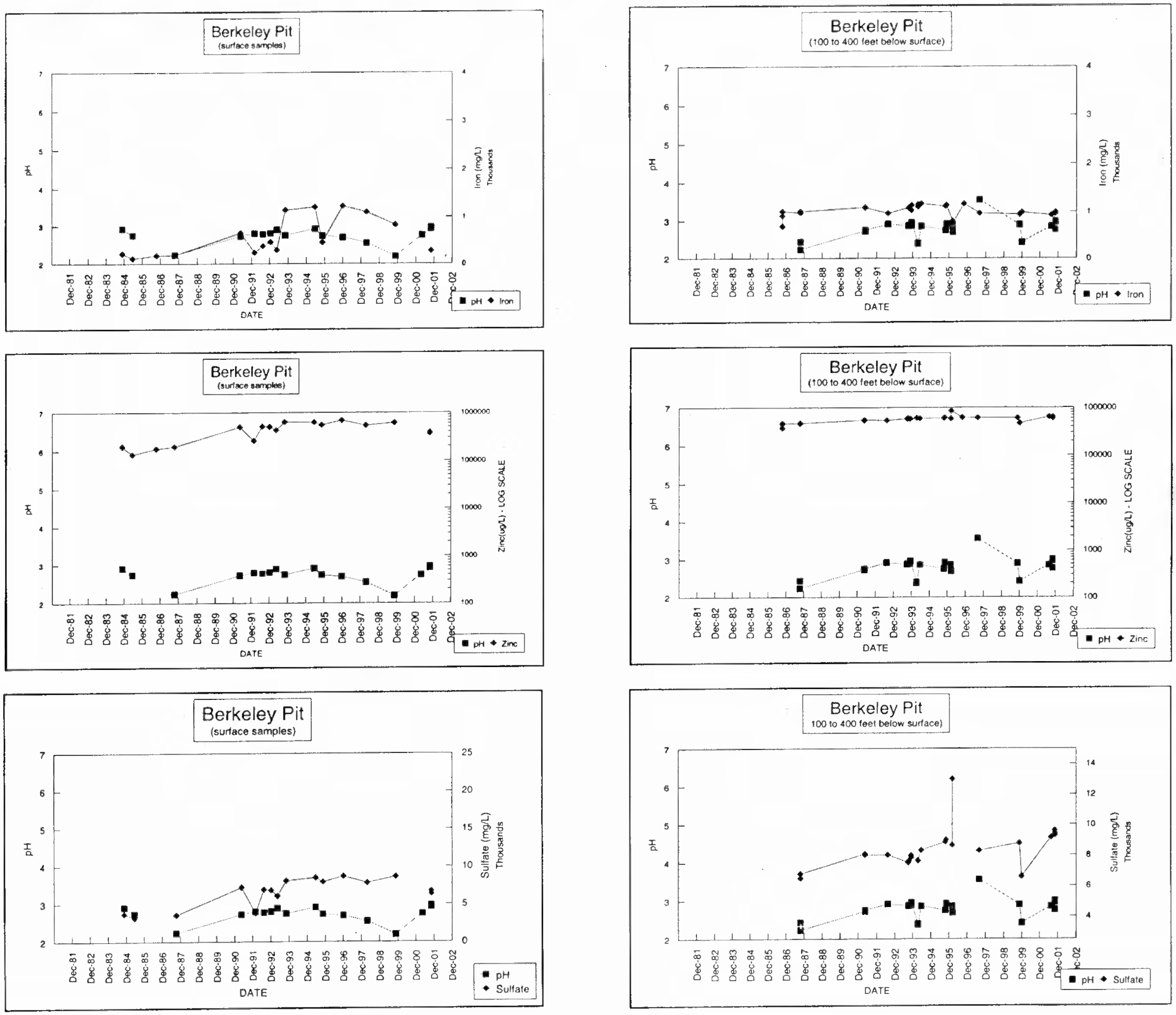


Figure 2-50b. Selected chemistry for the Berkeley Pit (surface samples)

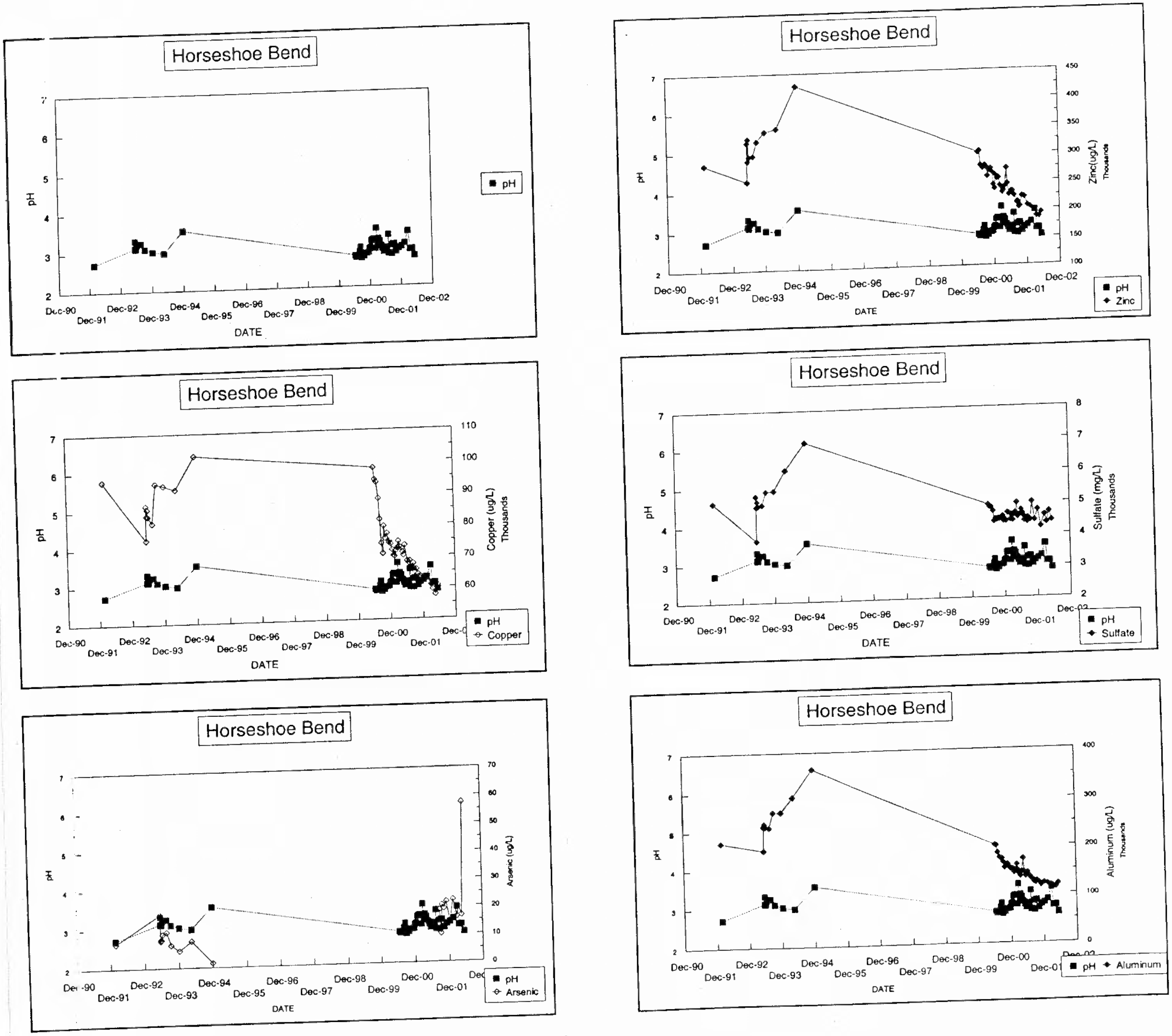


Figure 2-51. Selected chemistry for the Horseshoe Bend discharge.

reflects the sustained geochemical processes within the pit.

Table 2.2.3.1. Selected Chemistry from the Berkeley Pit and the Horseshoe Bend Sampling Site, 2001 Data

Location	Sample	pH (S.U.)	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	SO_4 (mg/L)	Zn (µg/L)
Berkeley	11/6/01	2.68	178,000	90,600	33.7	6,753	393,000
HSB	12/5/01	2.80	117,000	63,500	<20	4,431	221,000

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring was continued during 2001 in the mine shafts and 6 monitoring wells (figures 3-1). ARCO installed additional monitoring systems at the West Camp pump station. These systems include the continuous monitoring of hydrogen sulfide ambient air concentrations, continuous water level monitoring of well BFM96-1D, and the ability to acquire water level information via phone dial-up.

Section 3.1 West Camp Underground Mines

Water levels in the West Camp Mine system continue to be controlled by pumping facilities located at the BMF-96-1D and BMF-96-1S site. ARCO had a special well drilled for dewatering (pumping) purposes in the fall of 1997. This well is referred to as the West Camp Pumping Well (WCP). Pumping activities were transferred from the Travona Mine to this site on October 23, 1998. However, the pump and pipeline were left intact at the Travona Mine enabling the Travona Mine to serve as a backup pumping system.

The West Camp pumping system operated almost continuously during 2001, with the exception of several short periods caused by power outages and short periods for maintenance. However, the pumping rates were less than those of recent years. A total of 260 acre-feet of water was pumped in 2001, compared to 326 acre-feet in 1999, and 270 acre-feet in 2000. Table 3.1.1 shows the annual amount of water pumped in acre-feet on a yearly basis, percent change from the previous year, and the percent change from 1996 (the first full year of continuous pumping). Figure 3-2 shows the annual amount of water pumped and the percent of average annual precipitation since 1982.

Water-level changes in the West Camp mines reflect changes in pumping rates in the WCP. The 2001 pumping rate resulted in a net water-level decline of over 1.5 feet in the West Camp mines for 2001 (table 3.1.2). Figure 3-3 shows annual water-level changes for the West Camp sites. Water levels are more than 12 feet below the West Camp action level of 5,435 feet stipulated in the 1994 ROD.

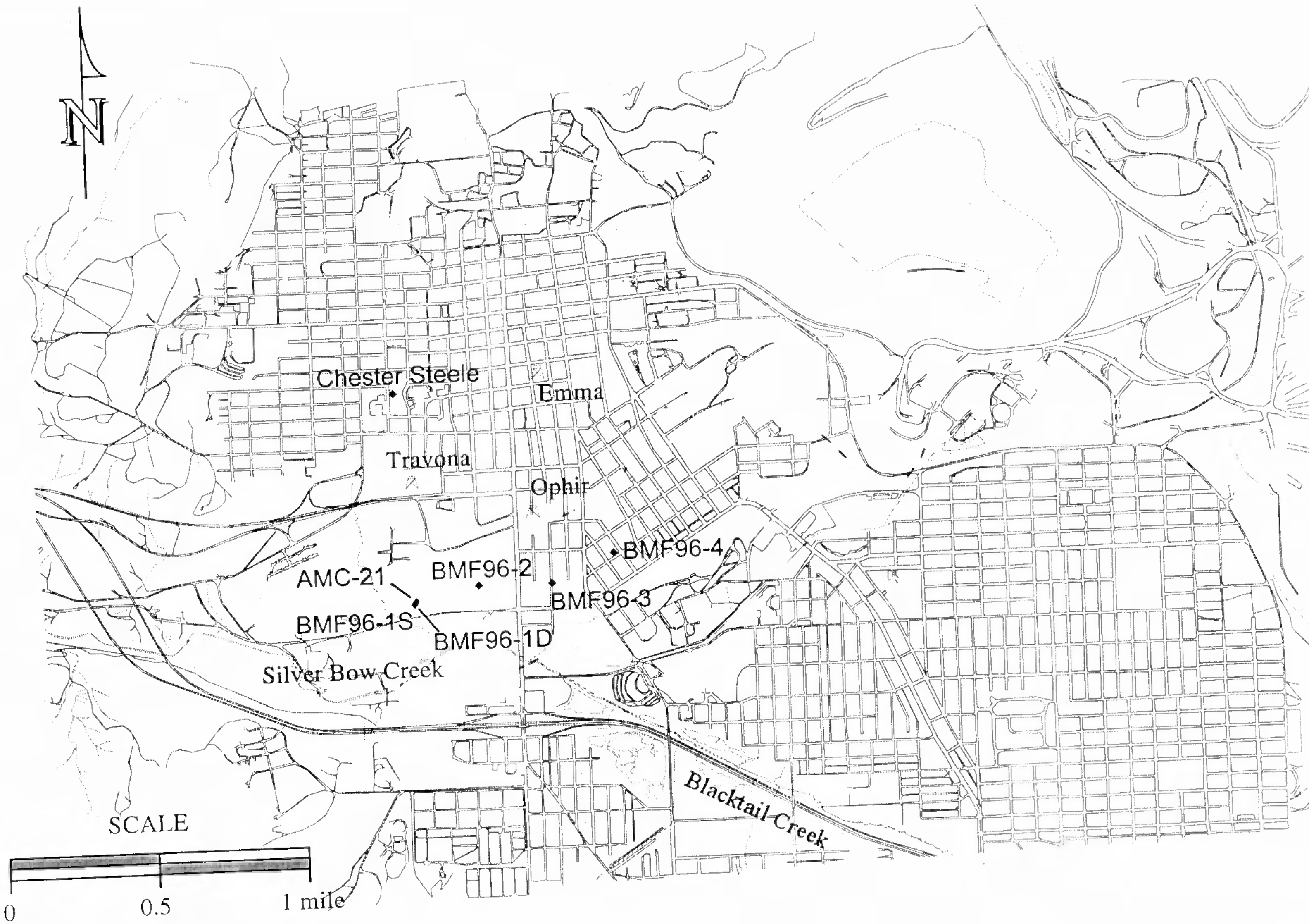


Figure 3-1. West Camp Monitoring Sites Location Map.

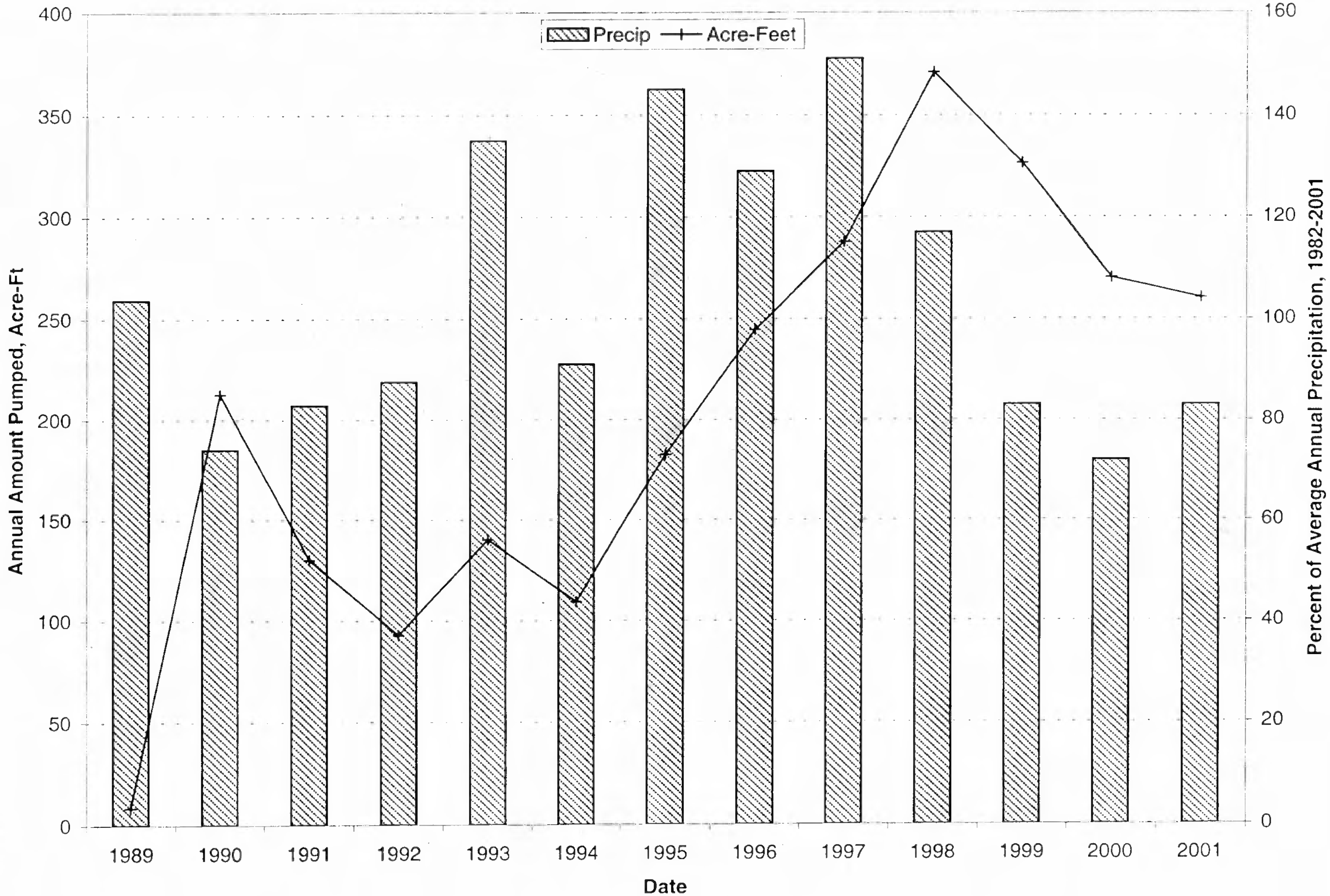


Figure 3-2. Annual amount of water pumped from the West Camp system.

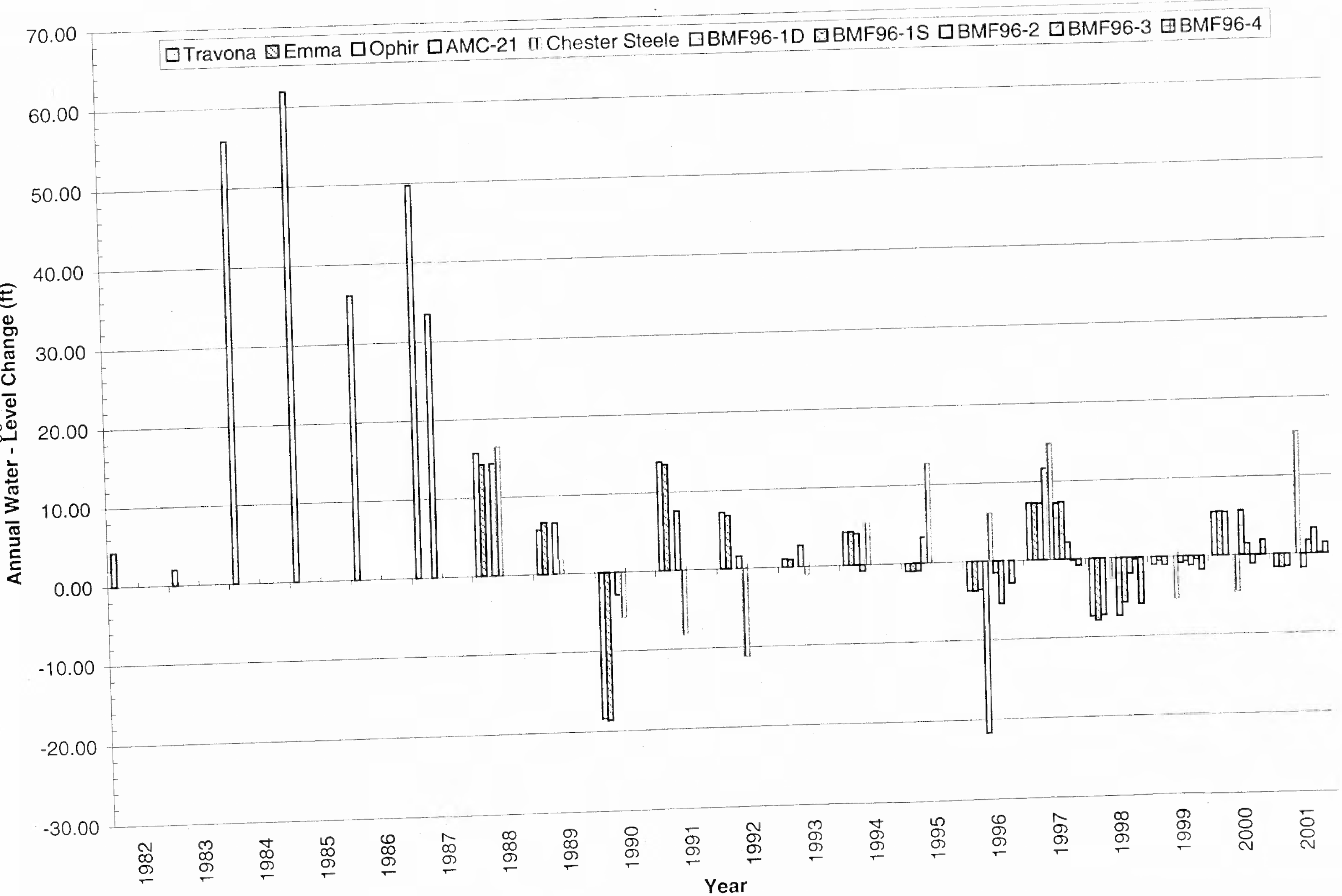


Figure 3-3. West Camp sites annual water-level change.

Monthly water-level elevations for the three West Camp mines are shown on figure 3-4. Water levels in these mines are almost identical and continue to follow the trends of previous years. Pumping rates and the amount of water pumped are the most important controls on water levels.

Table 3.1.1 Annual Quantity of Water Pumped from the West Camp in Acre-Feet

Year	Total Amount Pumped	Percent Change From Prior Year	Percent Change from 1996
1989	8.50		
1990	212.54	25.00	
1991	130.16	0.61	
1992	92.82	0.71	
1993	140.18	1.51	
1994	109.31	0.78	
1995	182.54	1.67	
1996	244.56	1.34	
1997	287.70	1.18	1.18
1998	370.72	1.29	1.52
1999	326.56	0.88	1.34
2000	270.20	0.83	1.10
2001	260.37	0.96	1.06

Section 3.2 West Camp Monitoring Wells

Water levels rose in four of the five BMF96 West Camp wells during 2001, the exception being BFM96-1D. Well BMF96-1D, which is completed into the Travona Mine workings, had water-level changes similar to the three West Camp mines, declining over 1.7 feet. The water levels in wells BMF96-1S and BMF96-4 rose 1.7 feet and 1.4 feet, respectively. These changes are shown in Table 3.1 and on figure 3-3.

Figure 3-5 is water-level hydrographs for wells BMF96-1D, BMF96-1S and BMF96-4. Water levels in wells BMF96-1D and BMF96-4 respond similarly to one another, reflecting the influence pumping has on the system. This is an important trend since well BMF96-4 was not completed into mine workings. It is, however, in the area of the historic 1960's flooding problems that led the Anaconda Company to install well AMC-21 for control of water levels in the West Camp. (See MBMG 1998 Open-File Report 376 for a greater discussion of historic flooding problems in the West Camp System). While water levels had a net decline in well BMF96-1D, and a net rise in BMF96-4 in 2001, the overall trends in these wells were still the same. There is a lag time between the responses seen in these two wells, which is most likely because well BMF96-4 was not completed into mine workings. During periods of continued water-level change in wells BMF96-1D and BMF96-4, there does appear to be a similarity in

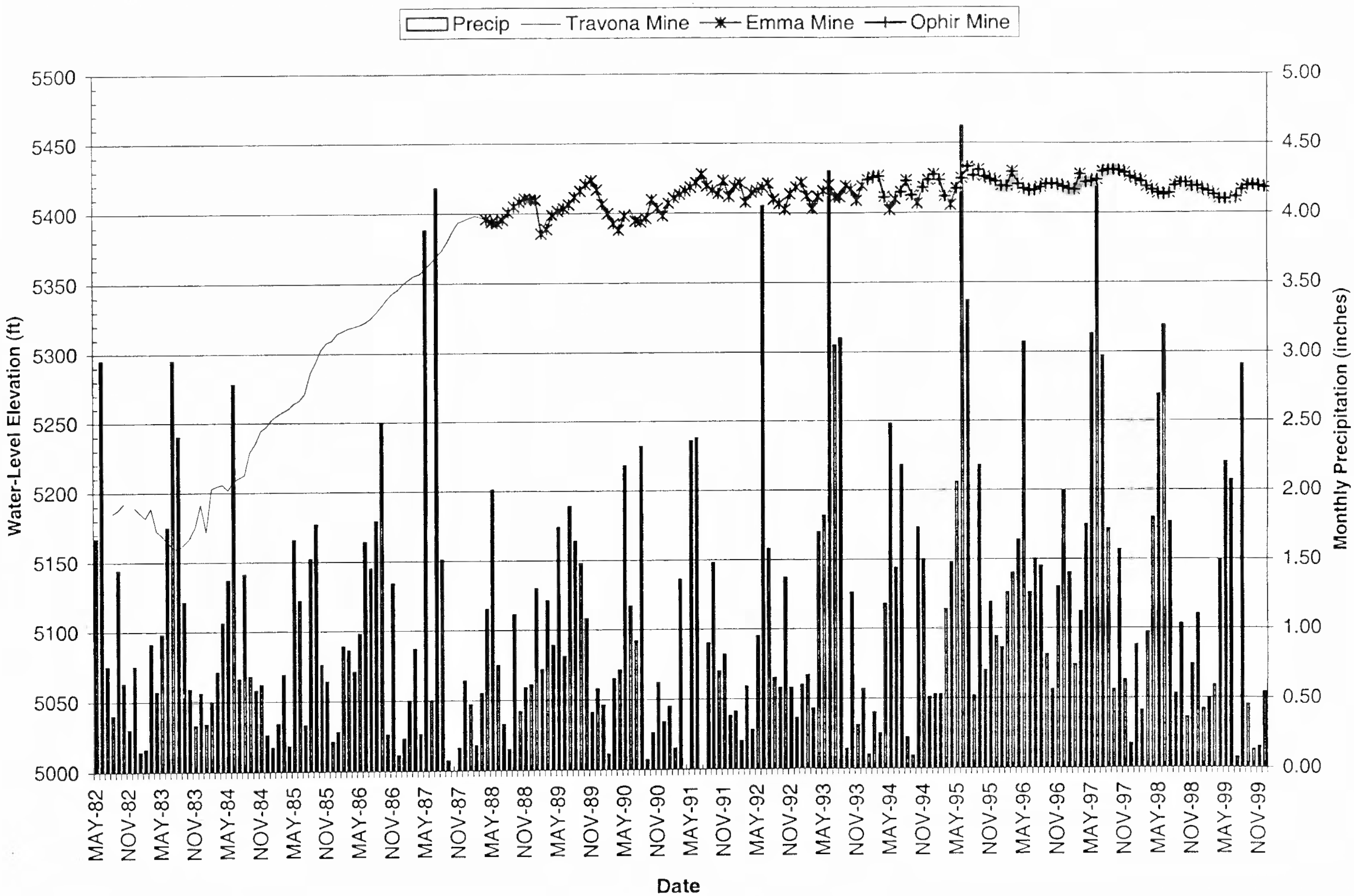


Figure 3-4. West Camp water-level hydrographs and total amount of water pumped monthly.

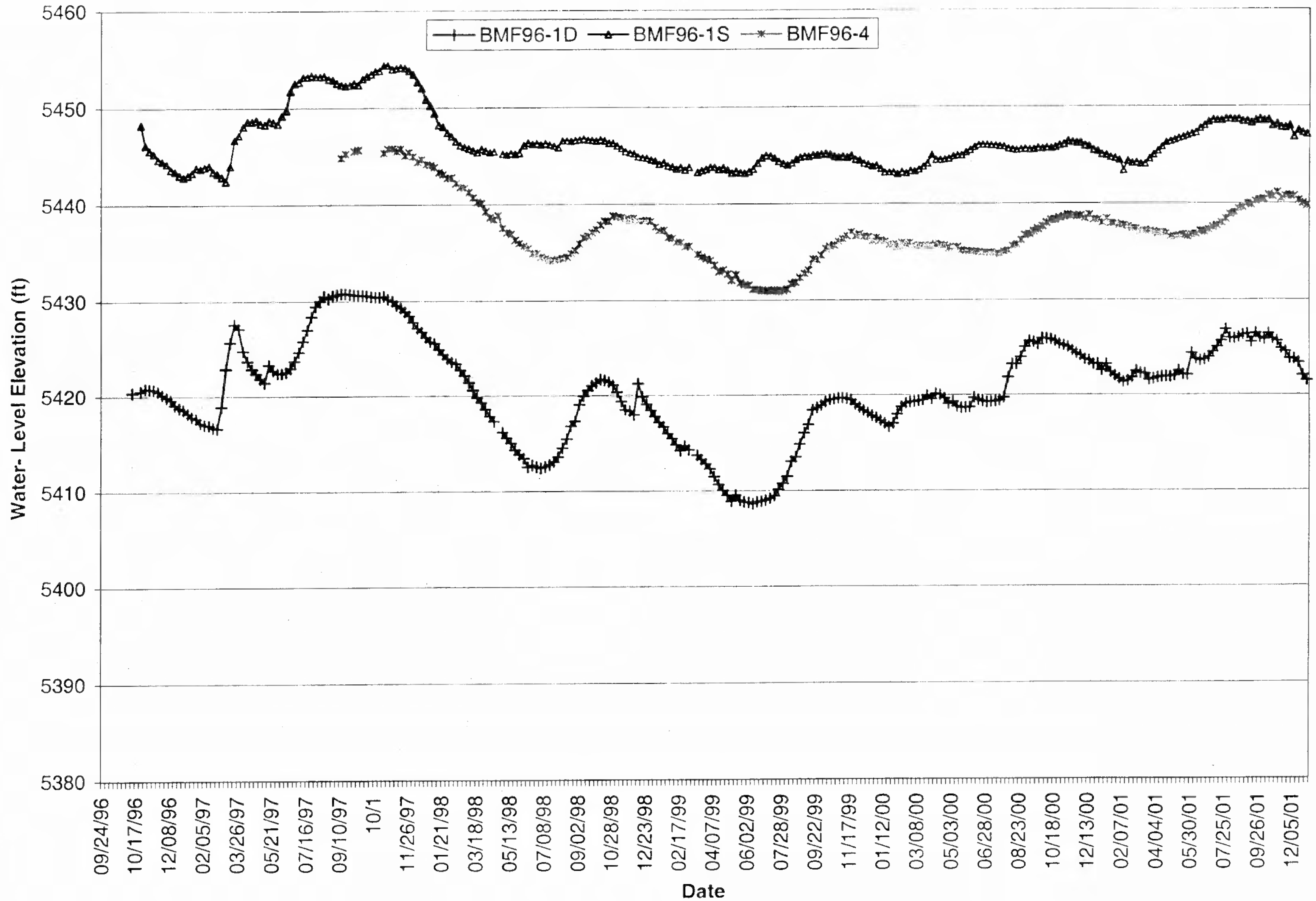


Figure 3-5. Water-level hydrographs for West Camp BMF96-1D, BMF96-1S, and BMF96-4 wells.

Table 3.1.2 Annual Water Level Changes for the West Camp Sites

Year	Travona	Emma	Ophir	AMC-21	Chester Steele	BMF 96-1D	BMF 96-1S	BMF 96-2	BMF 96-3	BMF 96-4
1982	4.30									
1983	2.00									
1984	55.90									
1985	61.90									
1986	36.10									
1987	49.70			33.48						
1988	15.69	14.20		14.32	16.42					
1989	5.67	6.60		6.52	1.79					
1990	-18.42	-18.66		-2.84	-5.77					
1991	13.88	13.52		7.57	-8.28					
*Total 10 Year Change**	*226.72*	*15.66*		*59.05*	*4.16*					
1992	7.21	6.79		1.55	-11.20					
1993	1.01	0.93		2.71	-1.11					
1994	4.24	4.26	4.00	-0.78	5.36					
1995	-0.98	-1.00	-0.96	3.32	12.72					
1996	-3.72	-3.76	-3.56	-21.69	6.14	-1.50	-5.41	0.00	-2.85	
1997	7.29	7.28	7.22	11.66	14.82	7.20	7.36	2.13	-0.19	-0.80
1998	-7.31	-7.88	-7.20	NA	-2.51	-7.35	-5.63	-2.00	-0.26	-5.88
1999	-0.97	-0.47	-1.03	NA	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	NA	-4.64	5.70	1.45	-1.13	-0.07	1.86
2001	-1.65	-1.70	-1.52	NA	15.61	-1.78	1.70	3.23	0.10	1.40
*Total Change**	*237.40*	*25.72*	*2.48*	*55.82*	*33.98*	*1.45*	*-1.14*	*1.08*	*-3.65*	*-5.18*

(*) Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

water-level change in well BMF96-1S. Well BMF96-1S is located adjacent to well BMF96-1D, but was completed at a shallower depth, in the weathered bedrock of the Missoula Gulch drainage. This well shows a response to pumping in the WCP. There was no change in longer-term trends in any of these wells from those described in the 1998 and 2000 reports.

Water levels in wells BMF96-2 and BMF96-3 are 20 to 50 feet higher than those in wells BMF96-1D and BMF96-4, and when plotted with the other BMF96 wells, appear to show very little change (figure 3-6). However, when these wells are plotted separately (figure 3-7), there is considerable variation in monthly water levels, and water levels in both wells respond similarly. Monthly precipitation is shown on these figures and water levels are seen to respond very quickly to precipitation events. Although these wells are completed at depths of 175 feet below ground surface, their water levels are less than 20 feet below ground surface. Water-level trends during 2001 in these wells for the most part were similar to those seen in previous years. During the last half of 2001 an unexplained water-level increase of several feet occurred

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

Figure 3-6. Water-level hydrographs for BMF96 series wells.

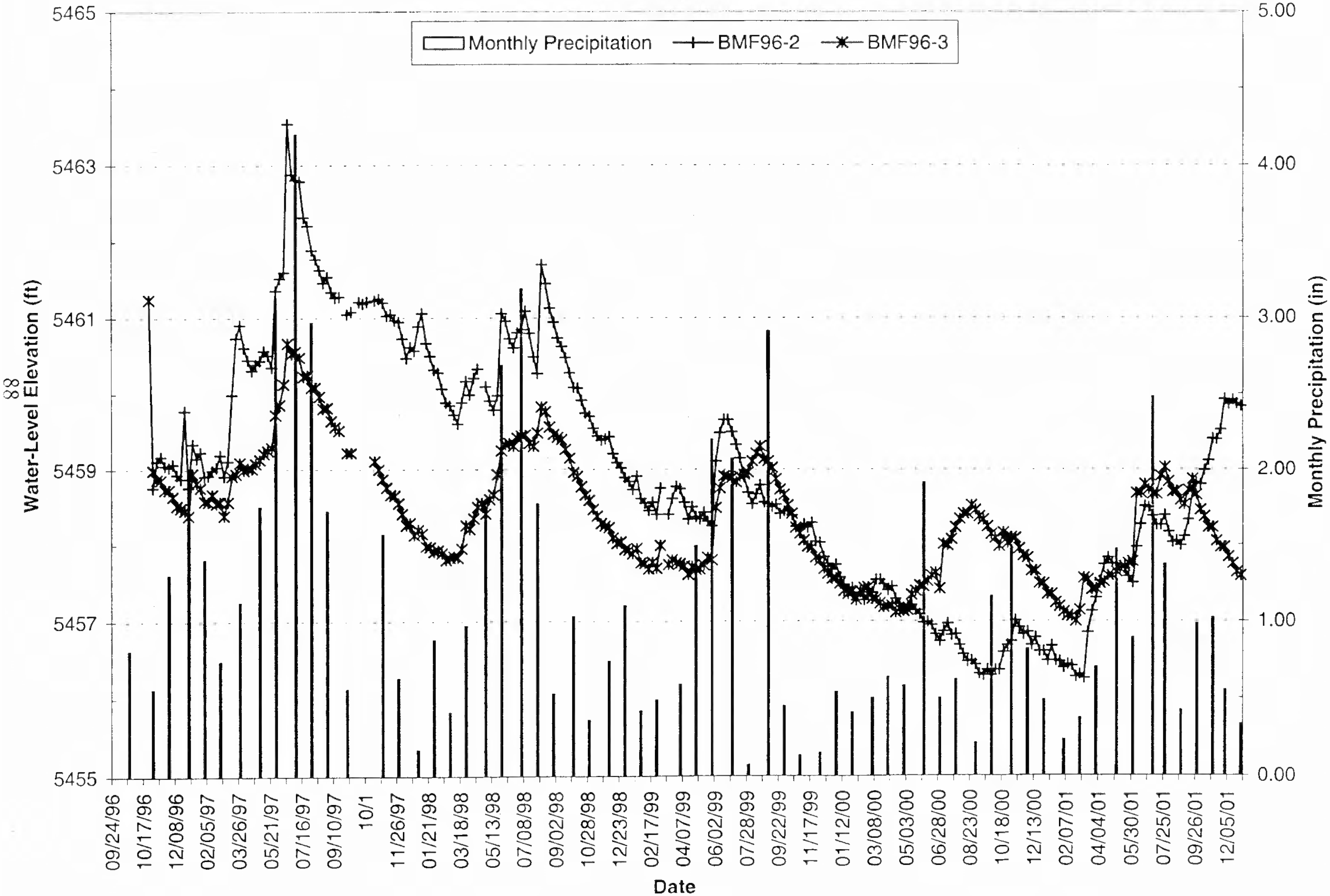


Figure 3-7. Water-level hydrographs for BMF96-2 and BMF96-3 wells.

in well BMF96-2; this was not seen in other wells.

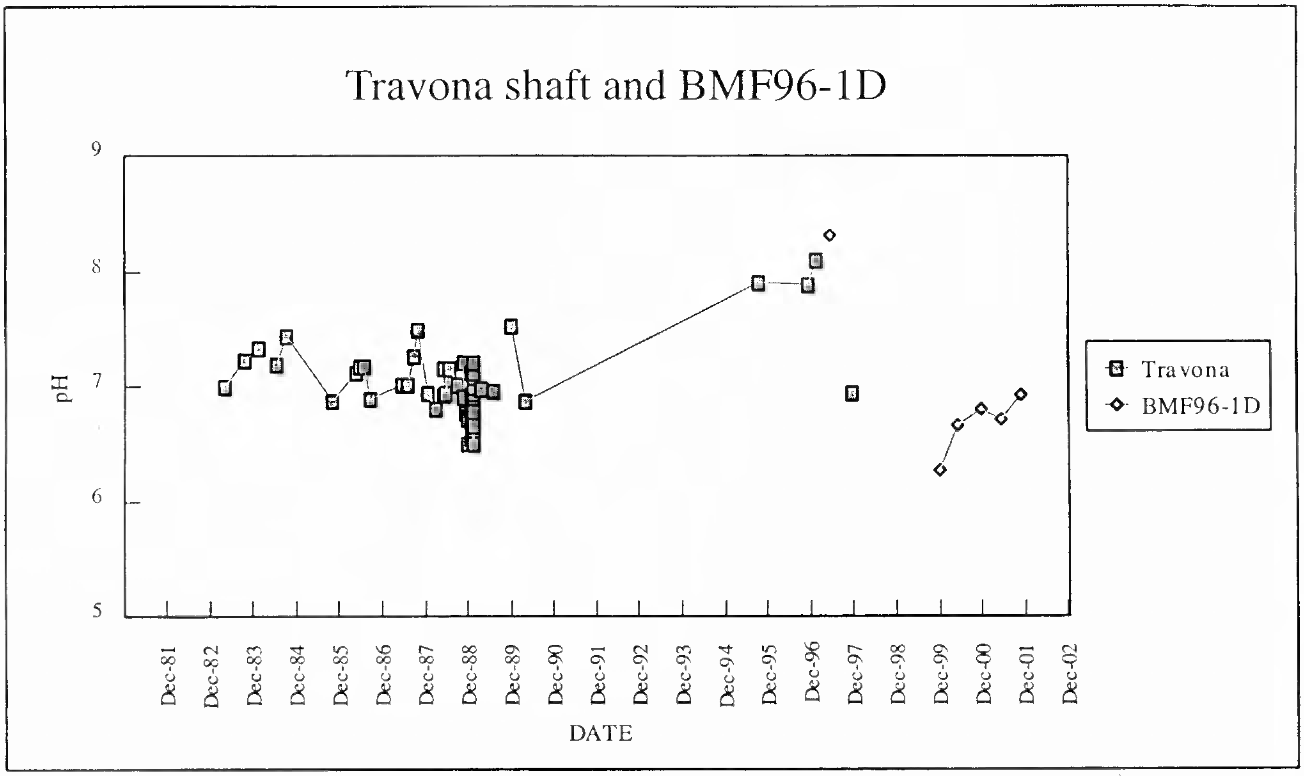
Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

The pH of the Travona shaft water was near neutral or slightly above neutral throughout the period of record until the last measurement (figure 3-8); this coincides with the change from pumping of the shaft to pumping of the replacement well. The replacement well, BMF96-1D (plotted with the shaft in figure 3-8), had a similar pH trend when installed, but indicated a pH decline of nearly one standard unit when pumping was initiated. Recent data for the replacement well indicate an upward trend back toward neutrality. Similarly, manganese concentrations dropped by about 7 mg/L at the time of initial pumping, but have recently followed the trend suggested by earlier data (figure 3-8).

As noted in earlier reports, arsenic concentrations in the replacement well have indicated an increase of 100 µg/L or more since pumping from the well began. The most recent sampling indicates the higher concentrations are sustained; however, there does appear to be a slight downward trend (figure 3-9) similar to that of the shaft before the change of pumping locations. Sulfate concentrations in the replacement well have also shown a trend similar to that of the shaft (figure 3-9).

The concentration of dissolved metals in the Ophir Mine water has remained relatively low and consistent throughout the period of record (1994 to present), especially compared to the Travona and Emma Mines. Arsenic and sulfate concentrations, however, have fluctuated and indicate change. The concentration of arsenic has decreased from about 40 µg/L to less than 10 µg/L; most recent data indicate a slight increase to about 15 µg/L (figure 3-10). Sulfate concentrations have ranged from 400 to 600 mg/L; the most recent data indicate a decrease to about 200 mg/L (figure 3-10).

Water-quality trends in the three West Camp monitoring wells are difficult to discern due to wide variations in concentrations. Simple trend analyses for temperature and arsenic are presented in figure 3-11. A best-fit linear analysis suggests an upward trend in temperature for BMF96-2 and BMF96-4, and no trend for BMF96-1S. Correlation coefficients for the line fit are about 0.3 for these data. A linear fit of arsenic data for the same three wells suggests a trend toward increasing concentrations in all three wells (figure 3-11). Correlation coefficients for these data are about 0.25 over the period of record. Although the concentrations of dissolved metals are generally lower than MCLs, they vary by as much as 200 percent. Sulfate concentrations exceed 250 mg/L in BMF96-1S and BMF96-2; recent data suggests a slight upward trend in both wells (figure 3-12). BMF96-4 has shown a variation of about 50 mg/L but no discernable trend (figure 3-12).



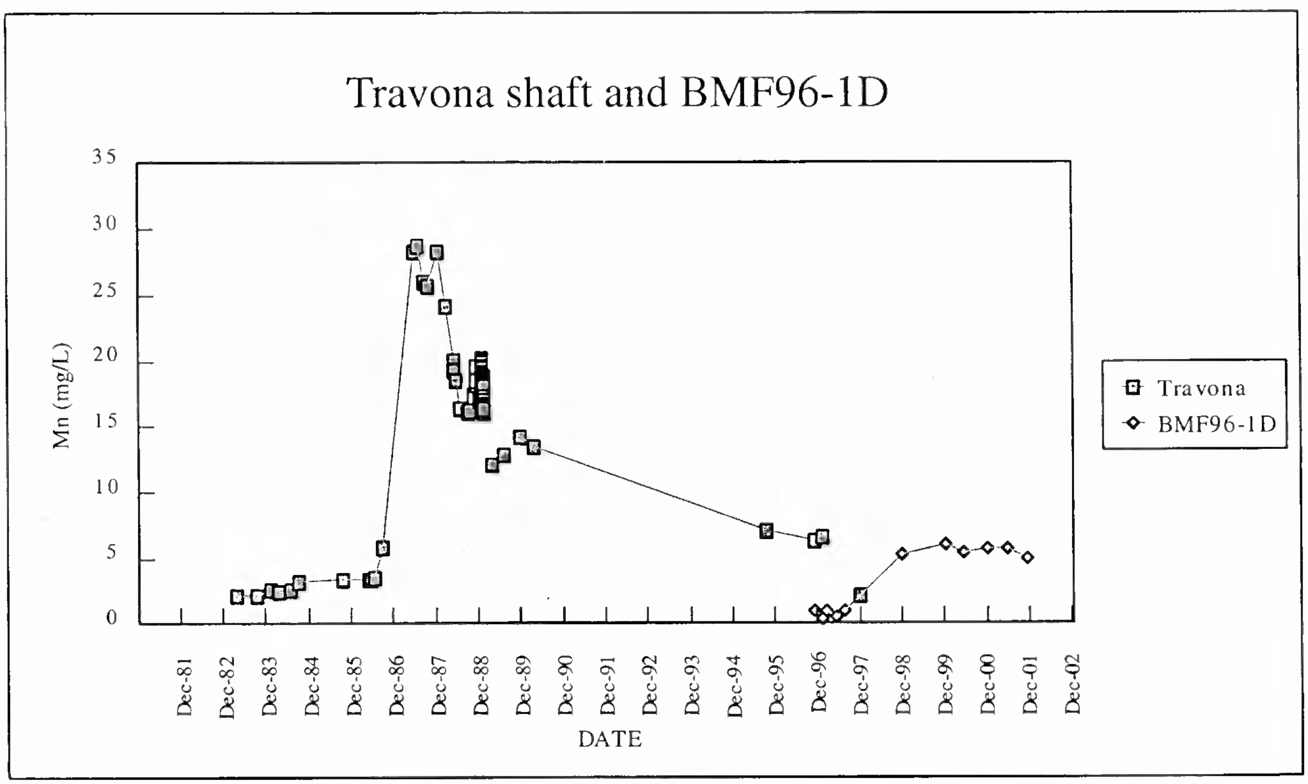
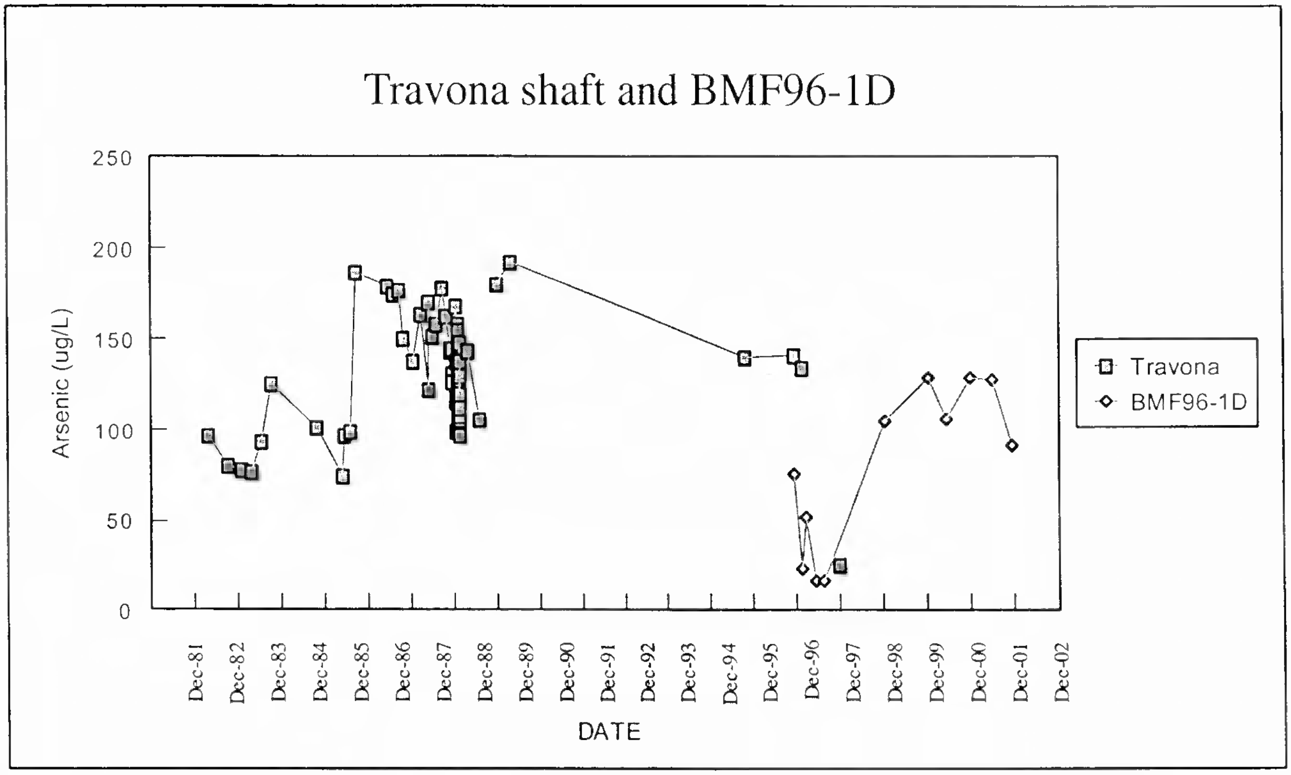


Figure 3-8. pH and manganese trends for the Travona Shaft and the replacement well, BMF96-1D



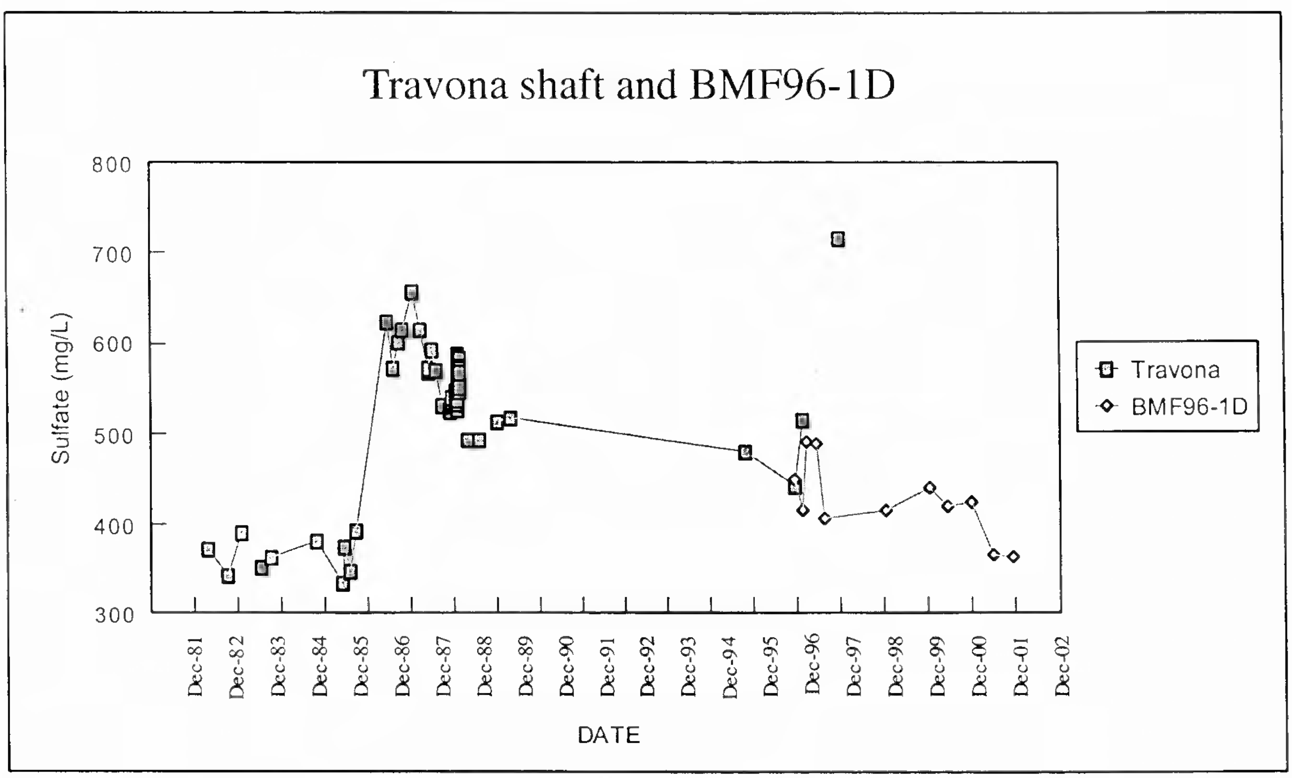
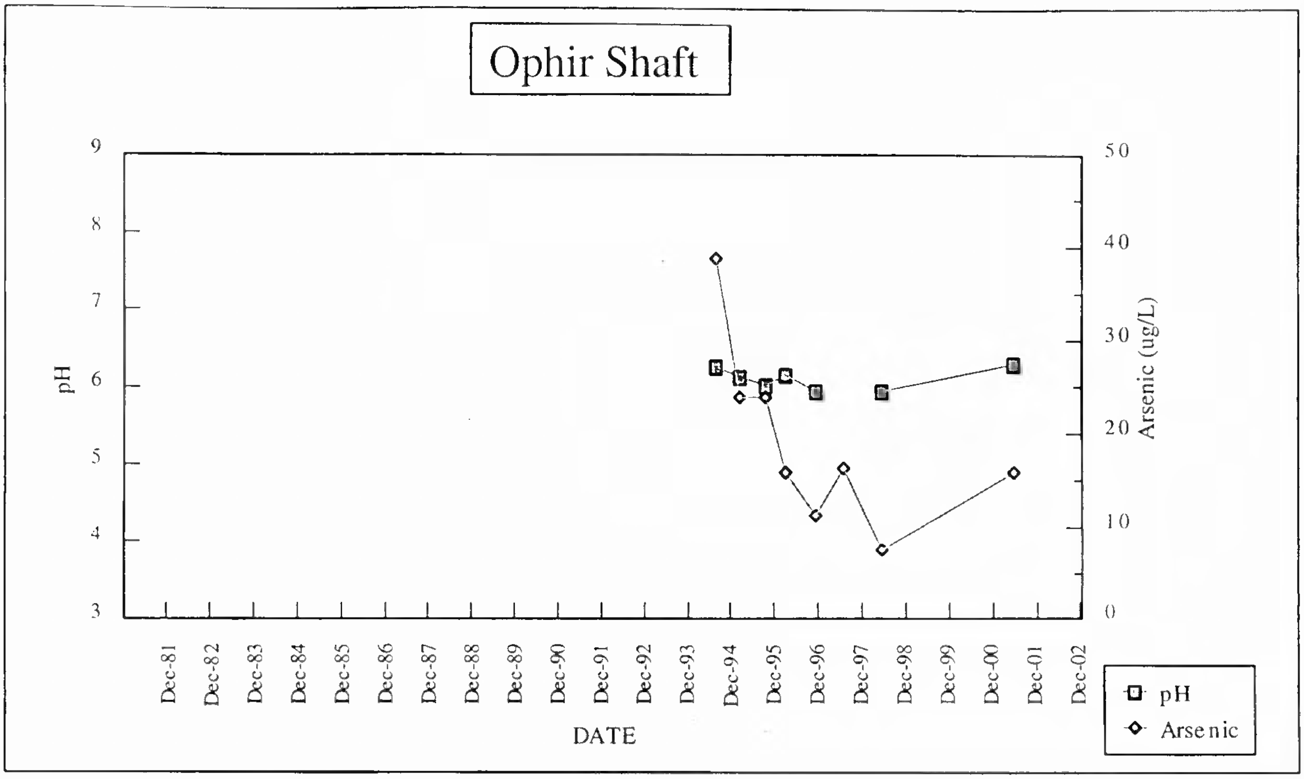


Figure 3-9. Arsenic and sulfate trends for the Travona Shaft and the replacement well, BMF96-1D



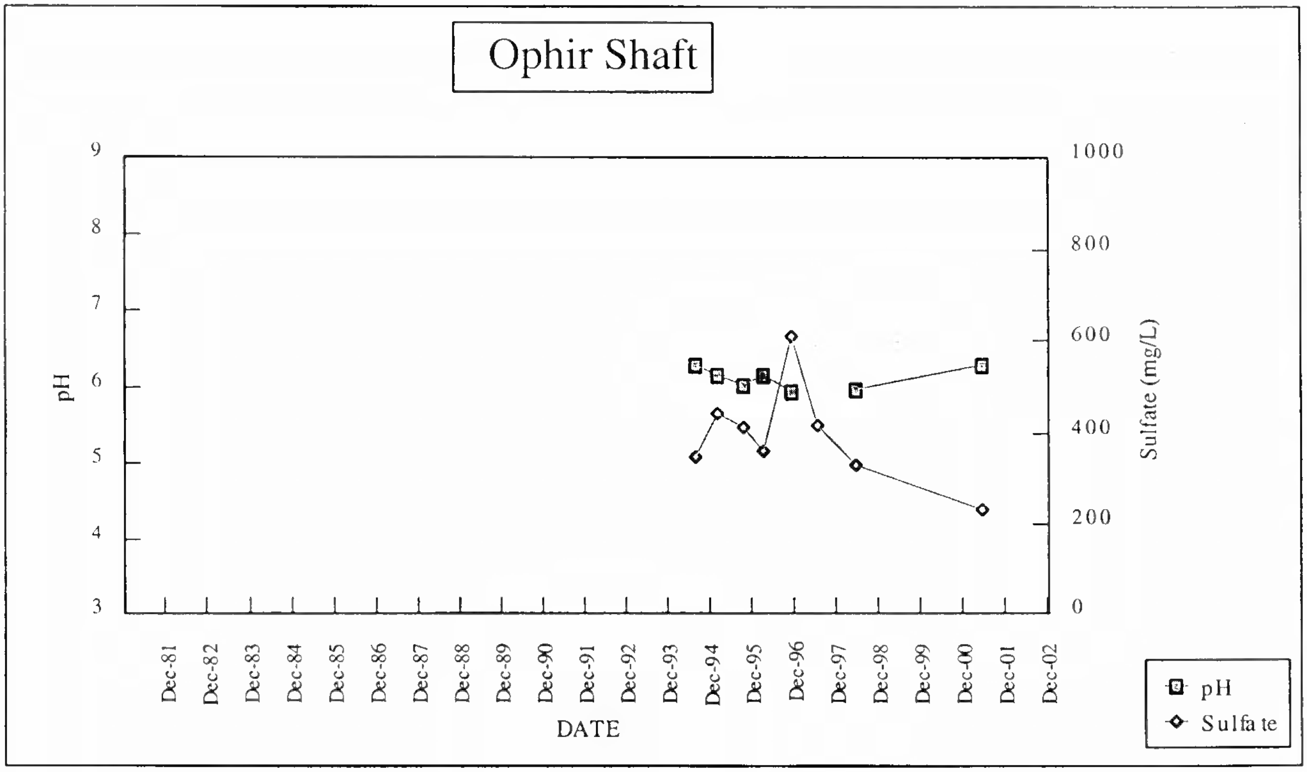
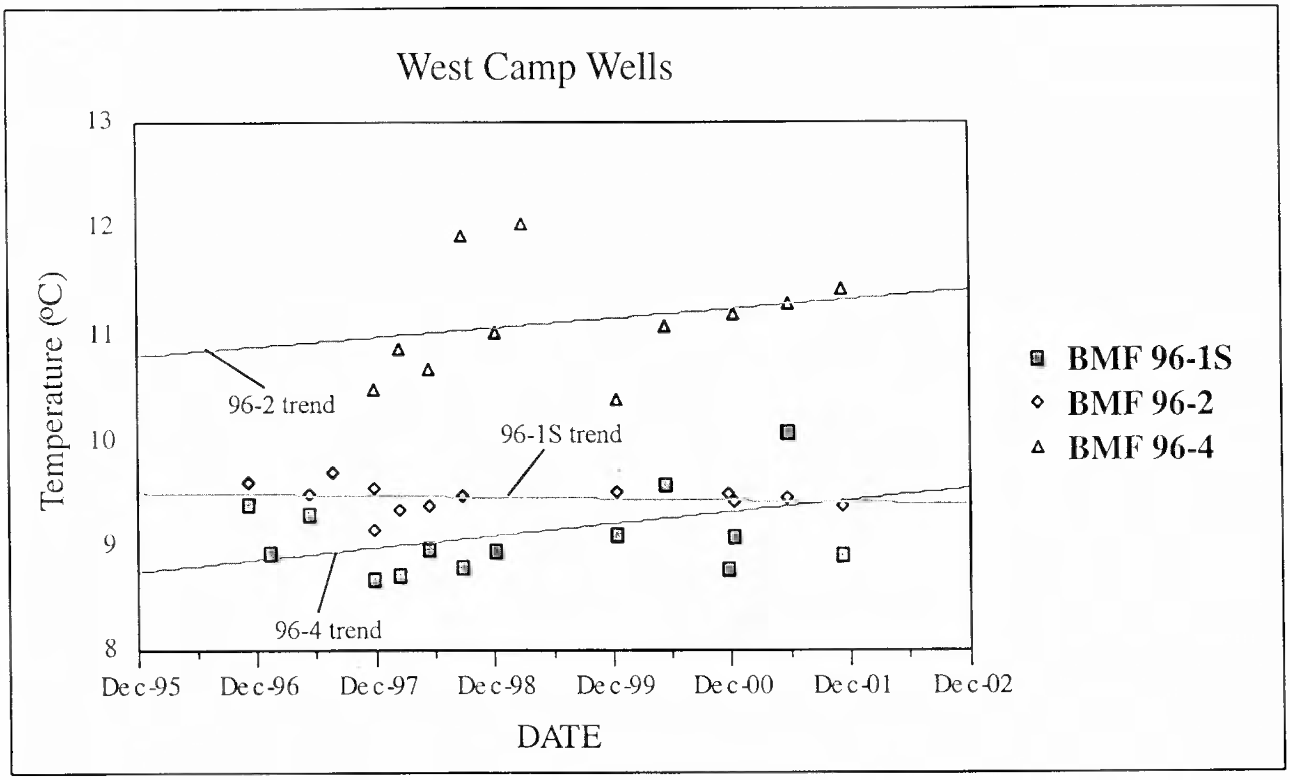


Figure 3-10. Arsenic and sulfate trends for the Ophir Shaft



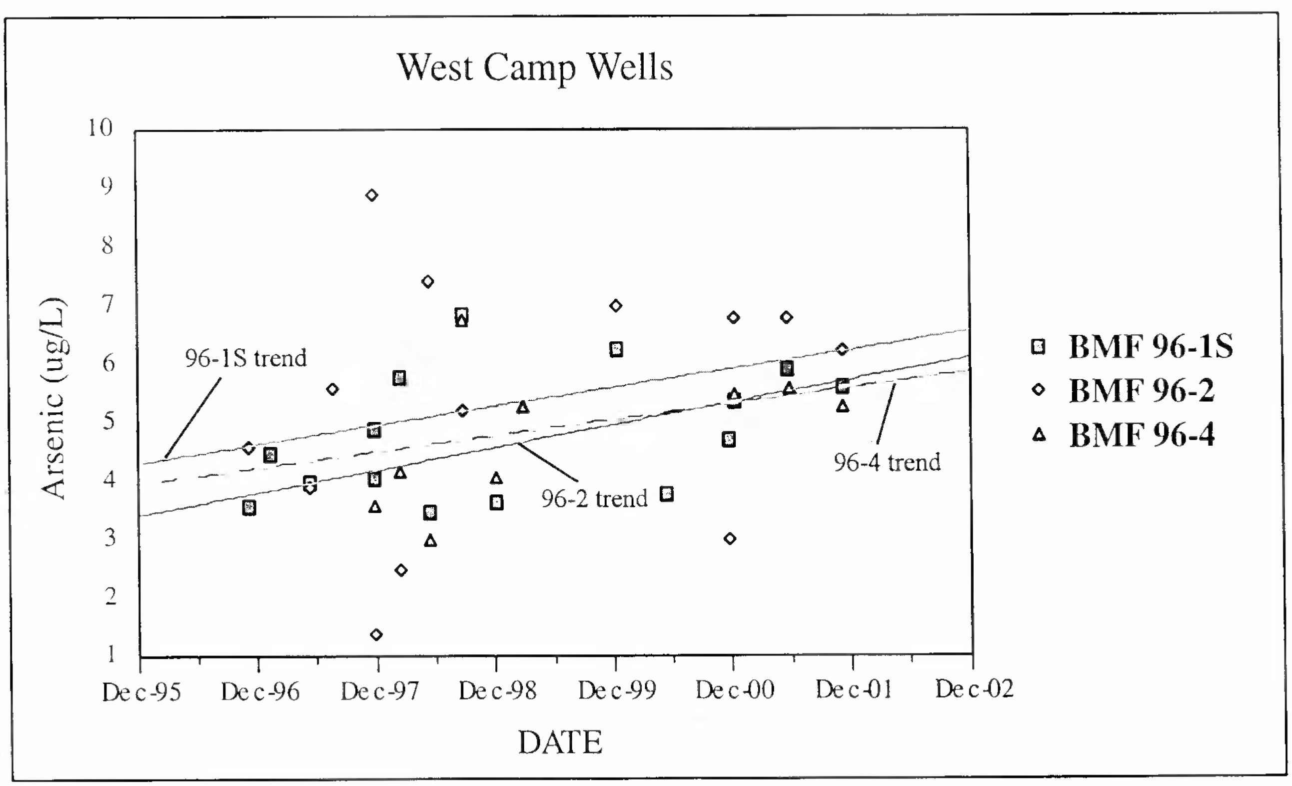
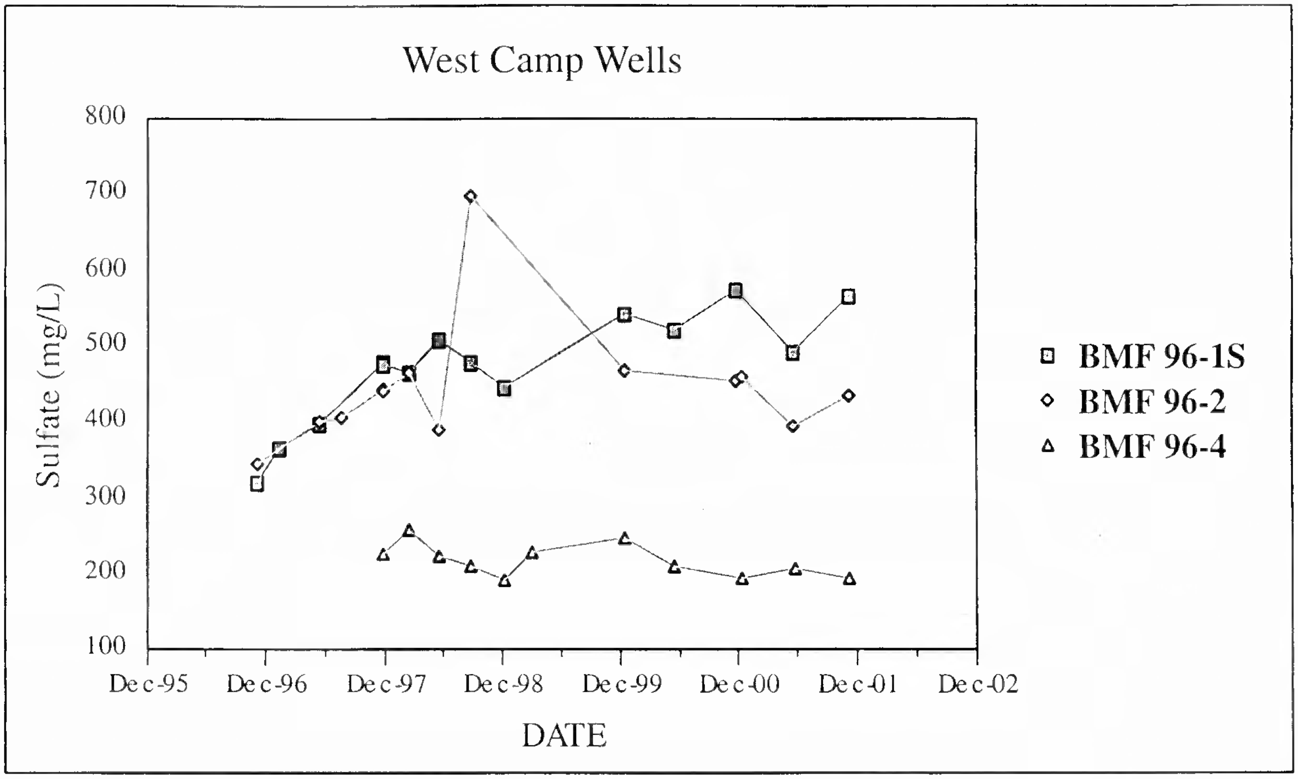


Figure 3-11. Line-fit trends of temperature and arsenic for the West Camp monitoring wells.



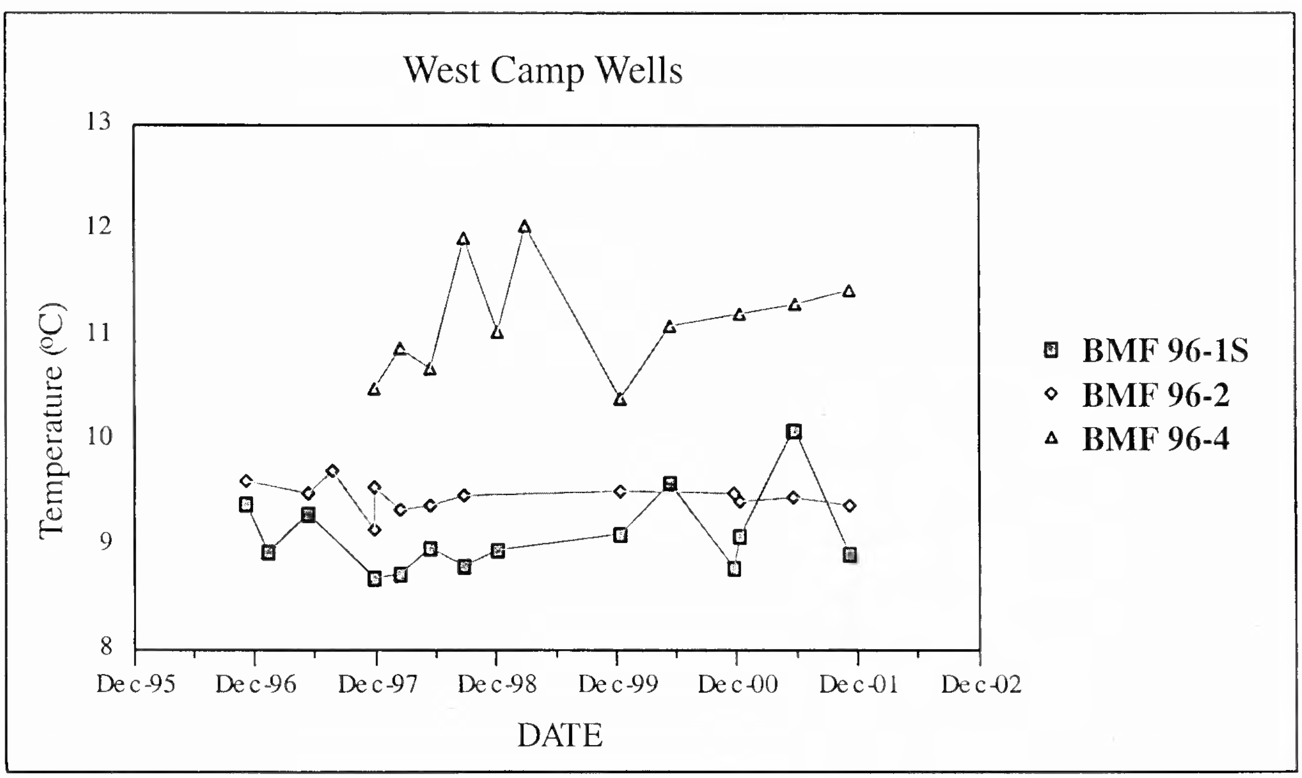


Figure 3-12. Sulfate and temperature trends for the West Camp monitoring wells.

SECTION 4.0 OUTER CAMP SYSTEM

The Outer Camp System consists of the Orphan Boy Mine, Marget Ann Mine, well S-4 and the Montana Tech well (figure 4-1). It is believed that water levels in the Outer Camp System are at or near pre-mining conditions, as these mines had not operated for many years prior to ARCO's suspension of underground mining. It is also believed the few interconnections that existed between these mines and other Butte Hill mines had been sealed off decades earlier by the placement of bulkheads.

Outer Camp water levels continued to decline in 2001, following the trend first seen in 1999. Table 4.0.1 contains yearly water level change data, while figure 4-2 shows these changes graphically.

Surface subsidence around the Orphan Boy Mine shaft has prevented monitoring of this site since June 1999. However, based upon previous observations between this site and the Montana Tech well, water levels probably continued to decline throughout 2001.

Figure 4-3 shows water levels for the Orphan Boy Mine and the Montana Tech well, along with monthly precipitation amounts. Water levels in the Montana Tech well showed the same response to precipitation events as was seen in years prior to 2000, rising in the spring and then declining throughout the winter.

Water levels in the Marget Ann Mine and well S-4 decreased between 1.49 feet and 1.59 feet during 2001. Figure 4-4 shows water-level hydrographs for these two sites, with monthly precipitation totals shown. Water levels from 1994 through 1998 showed a consistent increase throughout this time period regardless of precipitation amounts. Since then water levels have fallen, but still appear to have little influence from precipitation. Water levels in the Marget Ann Mine and well S-4 dropped throughout 2001 regardless of precipitation trends.

Section 4.0.1 Outer Camp System Water Quality

Water quality in the Marget Ann shaft and well S-4 nearby have shown little change in recent years. Overall, the concentrations of dissolved metals are low and most are well below MCLs and SMCLs. The concentration of dissolved constituents is fairly consistent between the shaft and the well; most concentrations compare within a few percent. Most notable of the two sites is the presence of H_2S and the relatively high concentration of sulfate. The concentration of sulfate has ranged between 200 and 350 mg/L for both sites (figure 4-5) and field-redox measurements are consistently low.

Figure 4-1. Outer Camp Monitoring Sites Location Map.

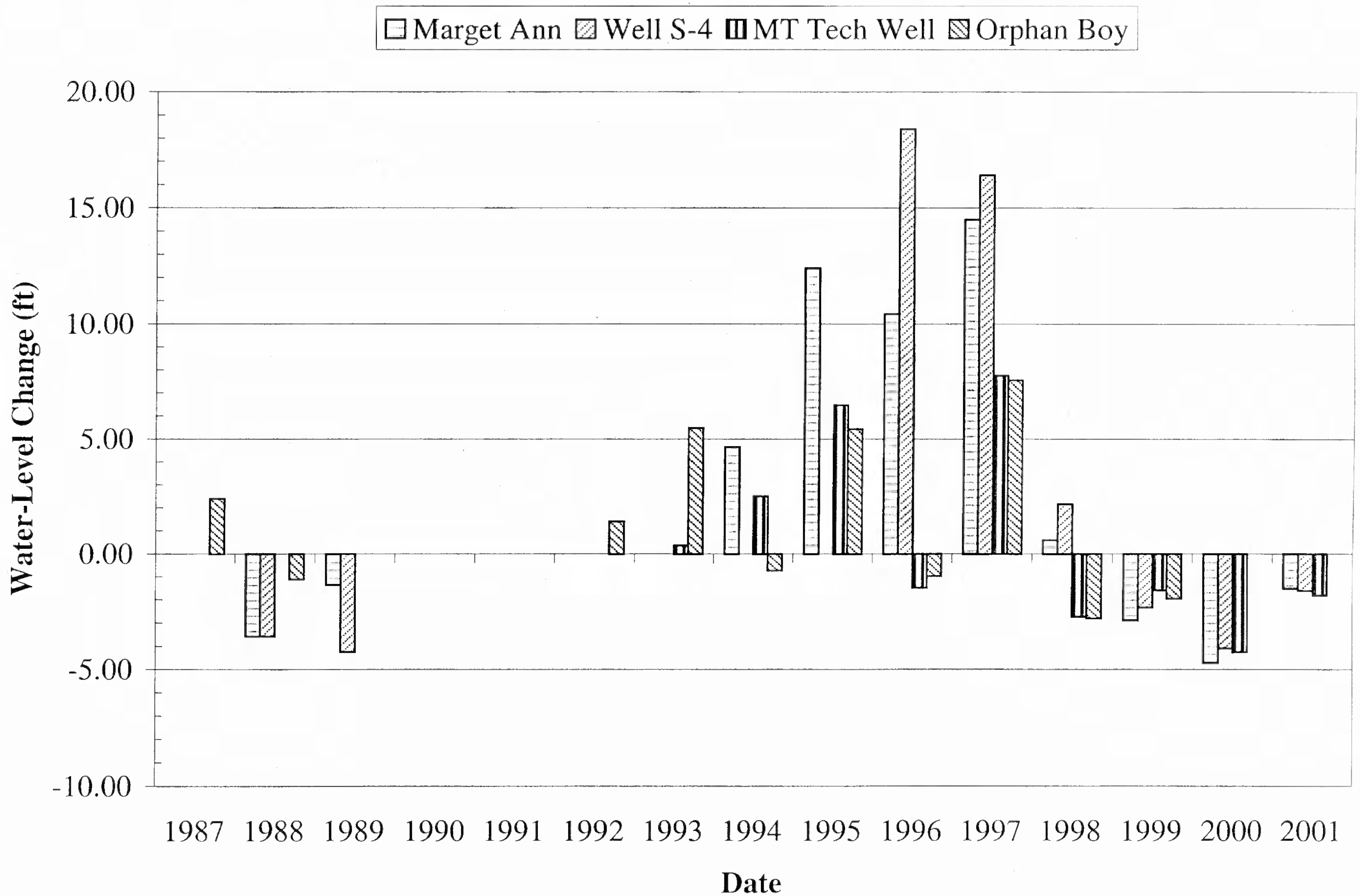


Figure 4-2. Outer Camp sites annual water-level change.

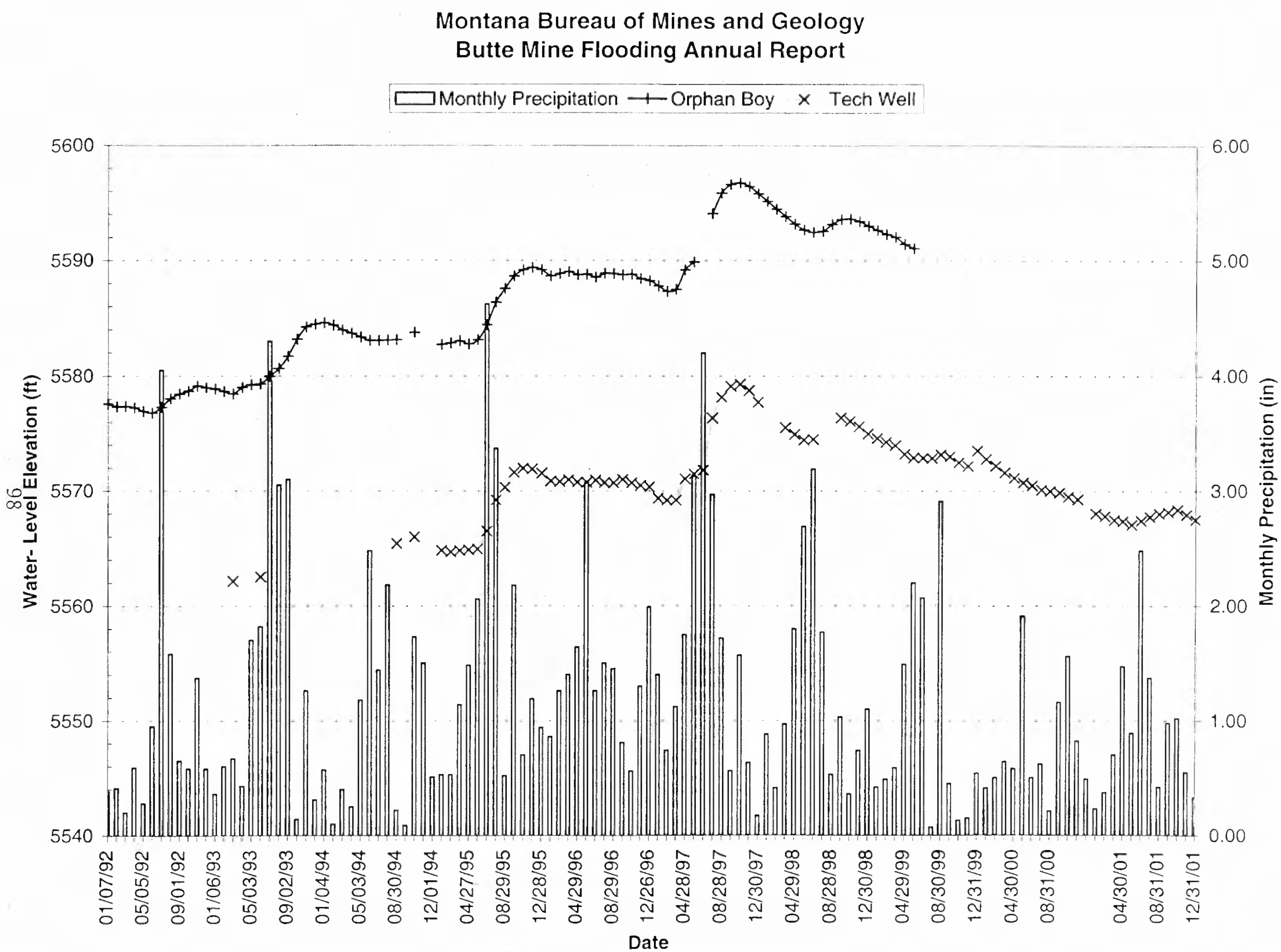


Figure 4-3. Water-level hydrographs of the Orphan Boy Mine and Montana Tech wells.

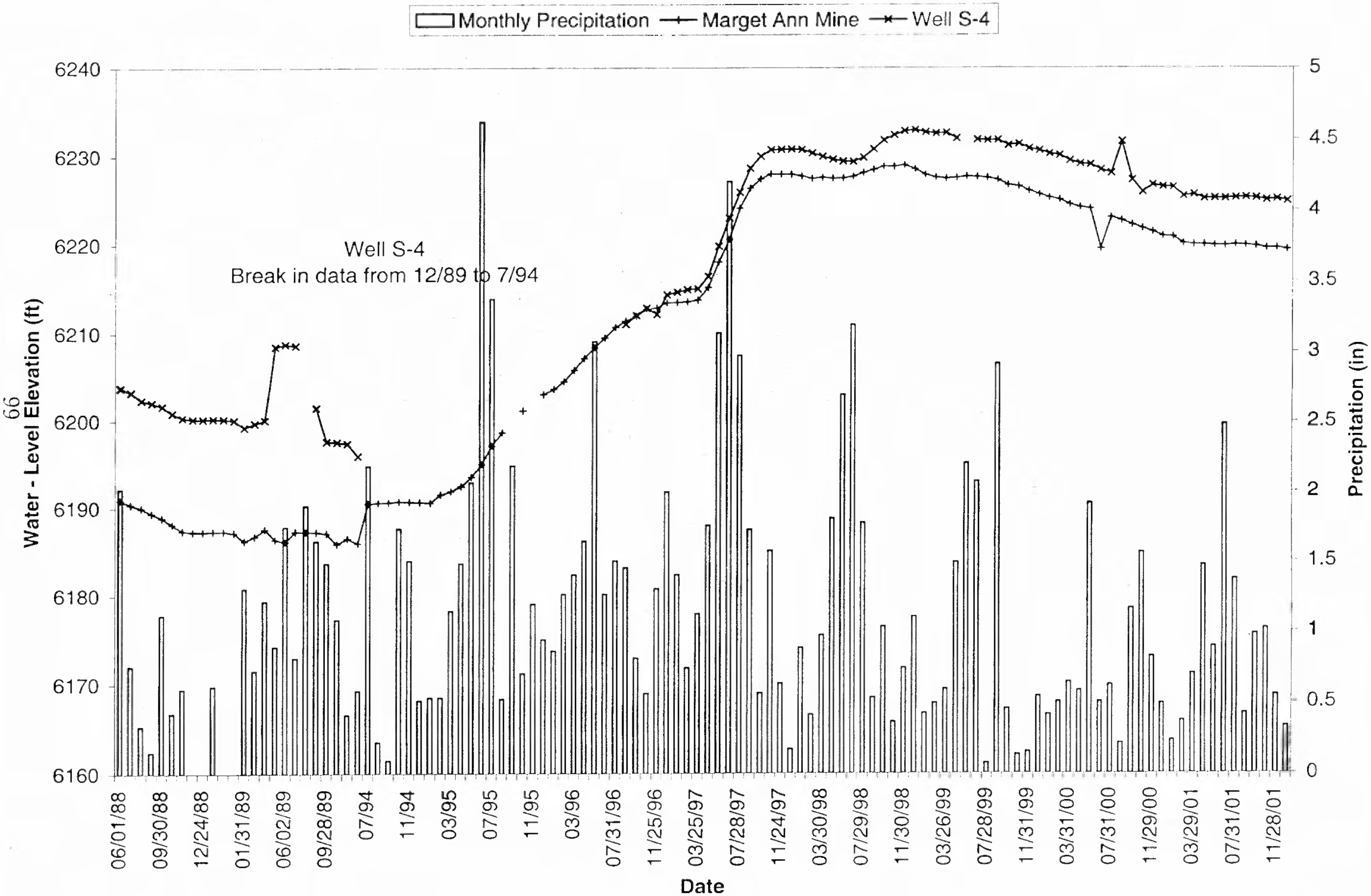
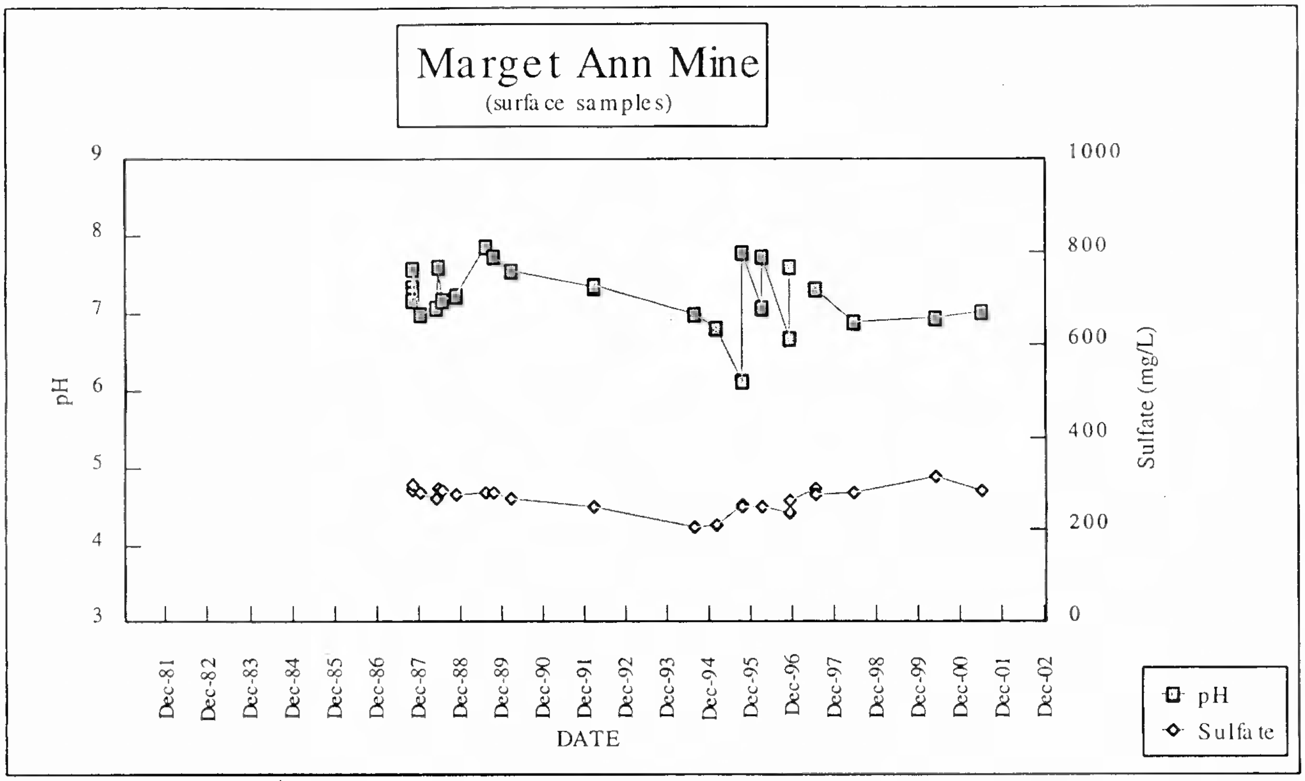


Figure 4-4. Water-level hydrographs for Marget Ann Mine and well S-4.



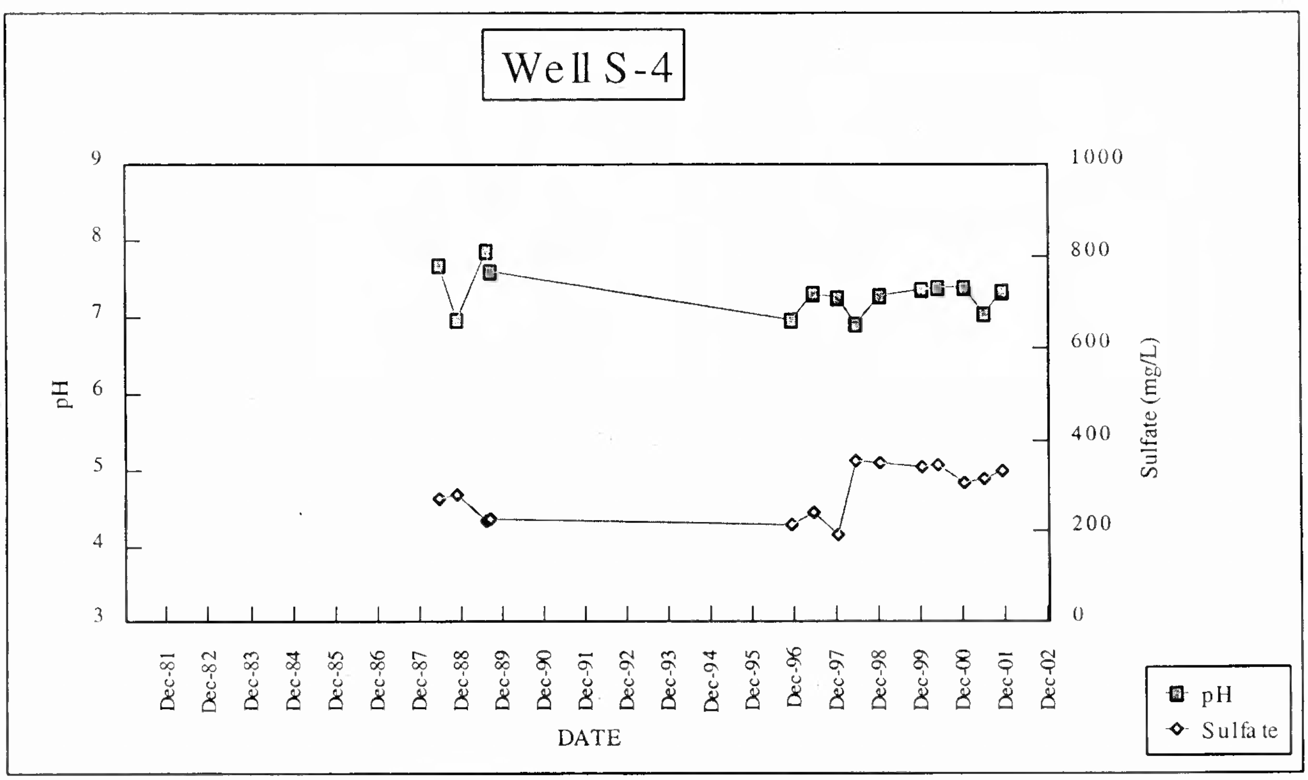


Figure 4-5. Sulfate and pH trends for the Marget Ann shaft and Well S-4.

Table 4.0.1 Annual Water-Level Changes for the Outer Camp Sites

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	-1.10	-3.56	-3.56	
1989		-1.34	-4.23	
1990				
1991				
1992	1.41			
1993	5.49			0.36
1994	-0.72	4.66		2.51
1995	5.44	12.41		6.48
1996	-0.96	10.44	18.41	-1.47
Total 10-Year Change*	*11.96*	*22.61*	*10.62*	*7.88*
1997	7.56	14.50	16.42	7.76
1998	-2.79	0.59	2.17	-2.72
1999	-1.94	-2.87	-2.32	-1.57
2000	NA	-0.95	-1.31	-4.24
2001	NA	-1.49	-1.59	-1.79
*Total Change**	*14.79*	*28.63*	*21.22*	*5.32*

(*) Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements.

SECTION 5.0 MISCELLANEOUS WELLS

The locations of the miscellaneous monitoring wells are shown on figure 5-1. These sites consist of 11 shallow alluvial monitoring wells (MF) and two bedrock monitoring wells. Two of the alluvial wells have been damaged and are no longer being monitored. A third alluvial well (MF-4) was plugged and abandoned in 2001, to allow reclamation activities associated with Butte Priority Soils work.

Water levels rose in five of the alluvial wells and fell in three of the remaining alluvial wells during 2001. Annual water-level changes are listed in Table 5.0.1. Total water-level changes since 1983 are a foot or less (up or down) in these wells.

Figures 5-2, 5-3, and 5-4 are water-level hydrographs for alluvial wells MF-1, MF-05, and MF-10, showing monthly water-level variations along with monthly precipitation totals. Water levels respond to precipitation events very quickly in all of these wells. Water-level variations are greater in wells MF-05 and MF-10 than those seen in well MF-01. Water levels gradually increased in those two wells from 1993 through 1998 before declining during most of 1999 and 2000. Water-level response to precipitation was much more dramatic than that seen in the two previous years. While precipitation totals for 2001 were still below the long-term average, they were much greater than those of 2000, which might account for the increased water-level response seen on the hydrographs for these wells.

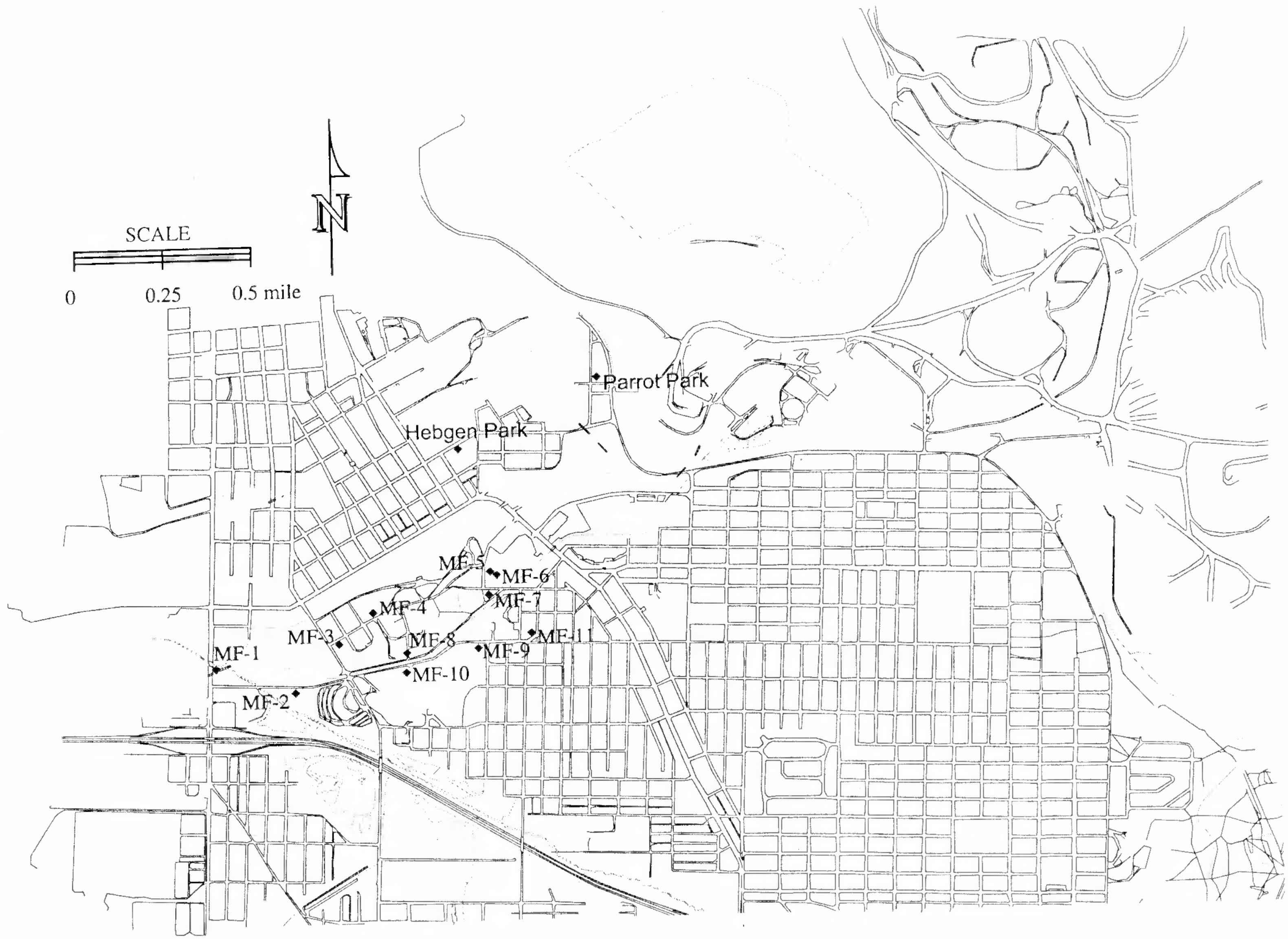


Figure 5-1. Miscellaneous Monitoring Wells Location Map.

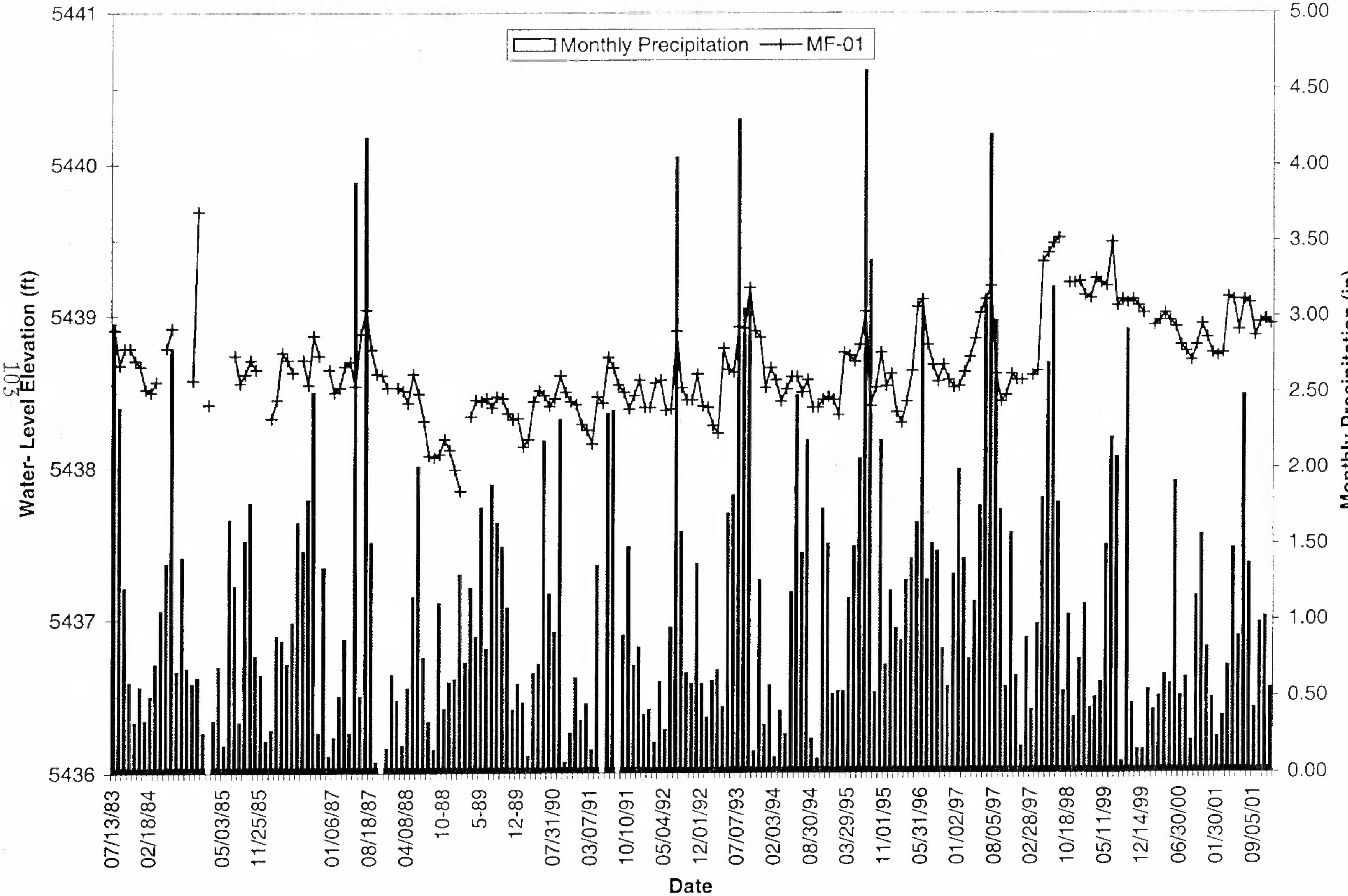


Figure 5-2. Water-level hydrograph for MF-01 well.

Montana Bureau of Mines and Geology
Butte Mine Flooding Annual Report

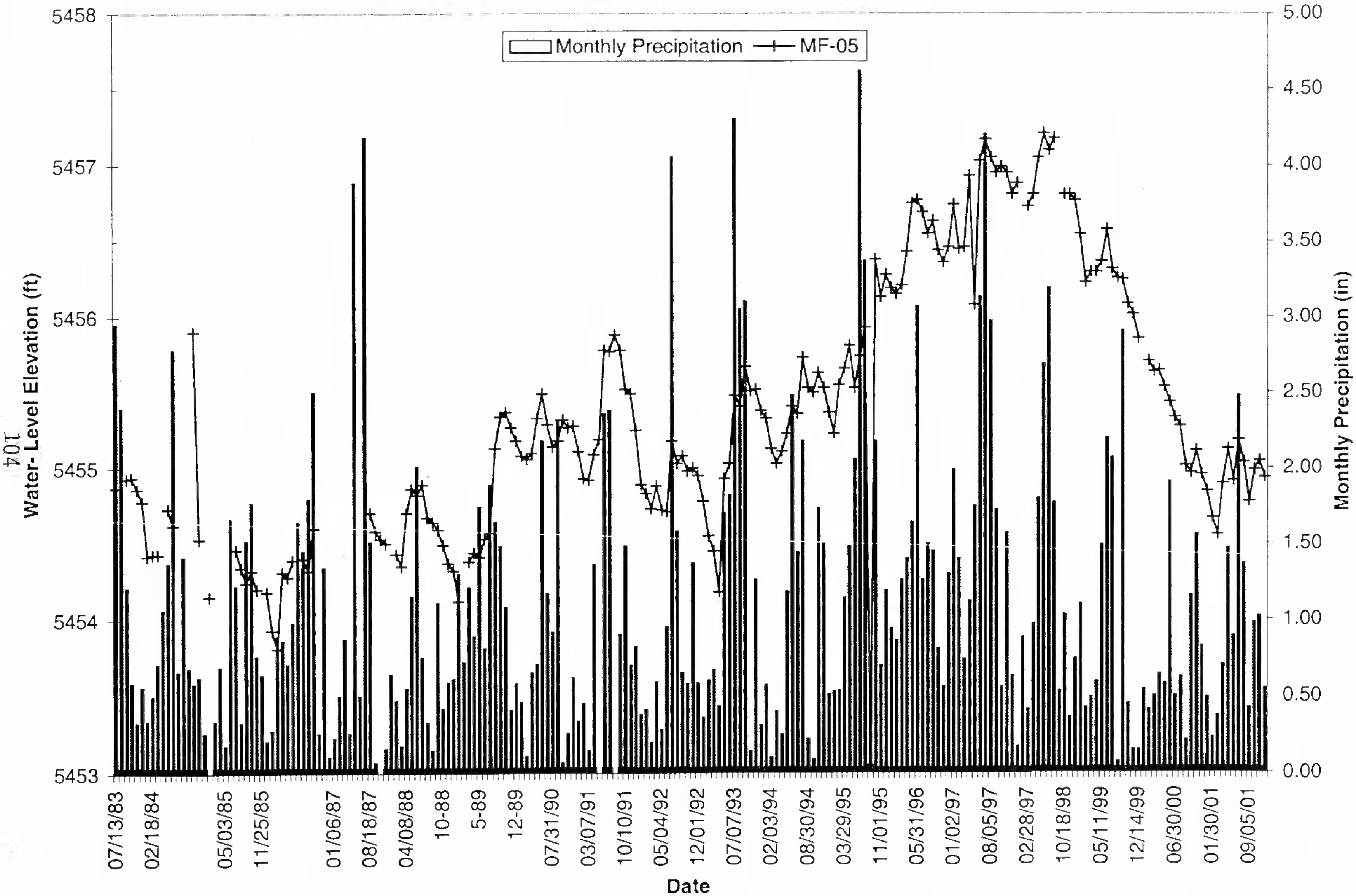


Figure 5-3. Water-level hydrograph for MF-05 well.

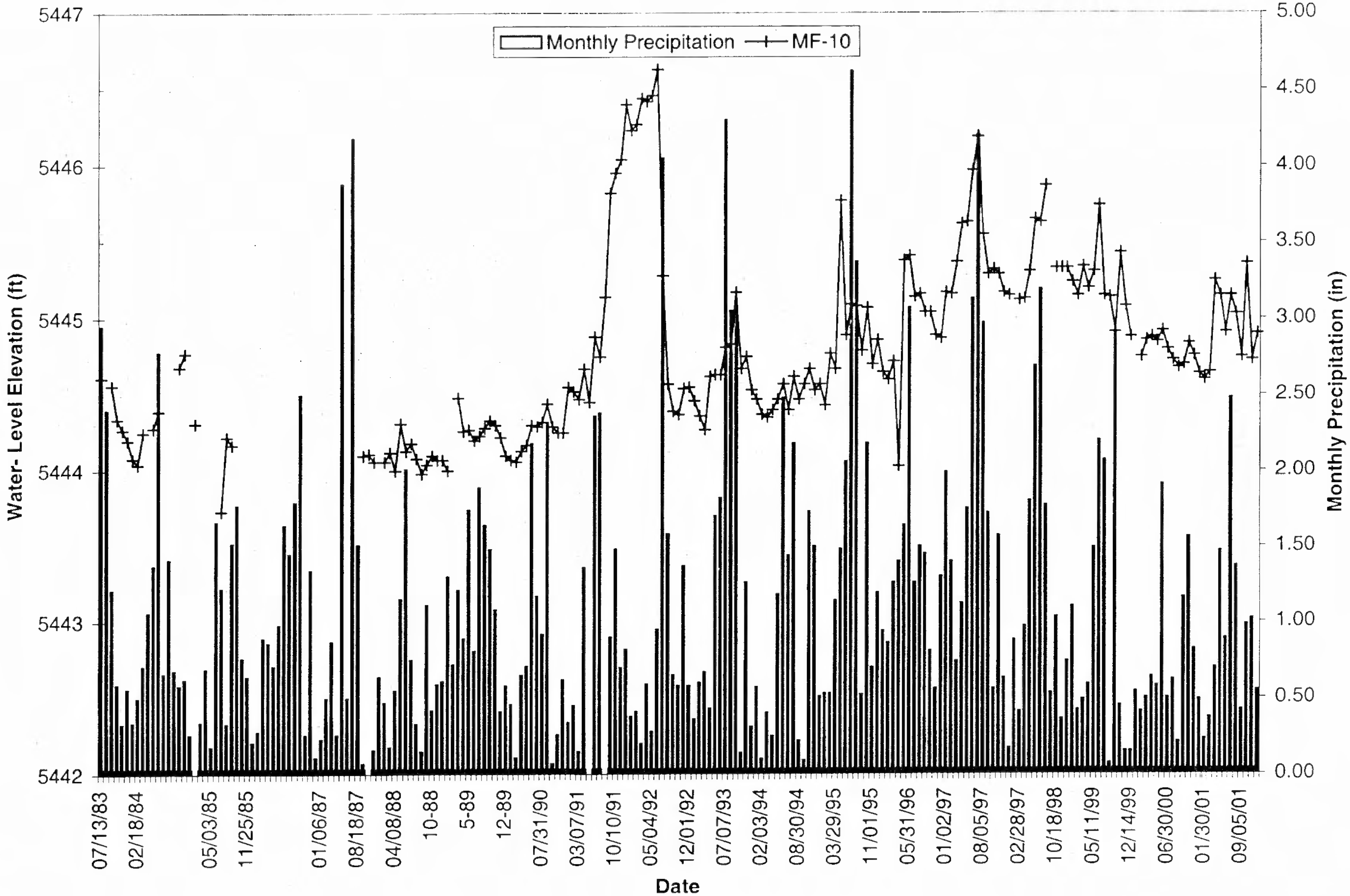


Figure 5-4. Water-level hydrograph for MF-10 well.

Water levels fell slightly in the Hebgen Park bedrock well during 2001, while having over a 6-foot rise in the Parrott Park well (Table 5.0.1).

Table 5.0.1. Miscellaneous Wells Annual Water-Level Change

Year	MF-1	MF-2	MF-3	MF-4	MF-5	MF-6	MF-7	MF-8	MF-9	MF-10	MF-11	Hebgen (1)	Parrott
1983	-0.24	-0.13	-0.64	-0.20	-0.09	-0.09	-0.93	0.53	-0.65	-0.41	-0.59		
1984	1.02	-0.09	-0.03	0.89	-0.25	-0.14	0.37	0.09	-0.28	0.57	-0.23		
1985	-1.00	-0.02	0.19	-0.21	-0.33	0.59	-1.17	-0.01	-0.10	-0.60	-0.29		
1986	0.00	0.10	0.22	0.29	0.40	0.08	1.01	0.13	-0.10	0.00	-0.35		
1987	-0.12	-0.05	-0.37	-0.88	-0.10	-0.99	-0.01	-0.03	-0.41	-0.11	0.45		
1988	-0.54	-0.05	0.08	0.38	-0.18	-0.13	-0.01	-0.05	0.17	0.01	-0.31	1.54	1.43
1989	0.34	0.18	0.20	0.38	0.86	0.24	0.10	0.08	0.21	0.03	0.13	-2.18	0.42
1990	0.09	0.13	0.26	0.08	0.10	0.14	0.16	0.14	-0.01	0.15	1.17	-1.90	5.23
1991	0.16	0.13	0.19	0.79	0.03	0.00	-0.13	0.52	0.84	2.15	-0.84	3.09	-6.10
1992	-0.18	-0.06	-0.12	-0.68	-0.47	0.00	-0.69	-0.50	-0.65	-1.94	-0.31	-1.40	0.63
*Total 10- Year Change**	*-0.47*	*0.14*	*-0.02*	*0.84*	*-0.03*	*-0.30*	*-1.30*	*0.90*	*-0.98*	*-0.15*	*-1.17*	*-0.85*	*1.61*
1993	0.13	0.06	0.13	0.77	0.60	0.00	0.13	0.20	0.38	0.07	0.52	6.27	1.39
1994	-0.06	-0.02	0.21	-0.11	0.15	0.00	0.31	0.07	-0.22	0.00	0.03	-0.25	5.96
1995	-0.10	-0.01	-0.99	0.32	0.66	0.00	0.46	0.05	-0.78	0.12	0.03	NA	2.67
1996	0.16	0.15	1.12	-0.01	0.27	0.00	0.22	-0.81	0.81	0.22	-0.70	2.75	-1.50
1997	0.05	0.16	-0.89	0.20	0.35	0.00	0.00	0.90	1.92	0.30	1.17	4.22	4.75
1998	0.65	P&A	0.46	-0.04	-0.04	P&A	0.28	0.34	-1.87	0.16	0.10	-0.62	-0.33
1999	-0.21	P&A	0.05	-0.79	-0.91	P&A	-0.33	-0.48	0.06	-0.45	-0.42	-2.93	-5.10
2000	-0.26	P&A	-0.14	-0.54	-1.01	P&A	-0.36	-0.25	-0.60	-0.24	-0.52	-6.07	1.26
2001	0.03	P&A	0.03	P&A	-0.15	P&A	0.08	-0.06	0.08	0.10	-0.12	-0.83	6.23
*Total Change**	*-0.11*	*0.48*	*-0.07*	*0.64*	*0.04*	*-0.30*	*-0.59*	*0.92*	*-1.28*	*0.03*	*-0.96*	*1.69*	*16.94*

(1) Hebgen Park Well - No data from 06-1992 to 01-1993, 01-1995 to 09-1996, and 01-1998 to 01-1999.

(*)Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements. NA- no access. P&A- well plugged and abandoned.

Water levels fell throughout the first half of 2001, before rising during the second half of the year at Hebgen Park (figure 5-5). The rise coincides with both summer precipitation and lawn watering of the park. Since the water-level rise extends into the fall and early winter, it is probable that most of the increase in water level is due to lawn watering and is not the result of precipitation.

The water-level hydrograph for the Parrott Park well is shown on figure 5-6, along with monthly precipitation totals. Water levels declined during the first part of the year before leveling off and rising during the remainder of 2001. As a result, this well had a water-level rise of over 6 feet for 2001, on top of the 1.5-foot rise in 2000. This is compared to a net decline in water levels the previous two years. It is probable that irrigation of the park lawn has more of an effect on water-level increases than precipitation, and extends these increases into the fall.

SECTION 6.0 REVIEW OF THE BERKELEY PIT MODEL

MR updated the Berkeley Pit water-level model based upon actual 2001 water-level measurements, and HSB-inflow volumes. The model update included water-level increases resulting from MR's suspension of mining and milling operations. The continued suspension of

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Butte Mine Flooding Annual Report

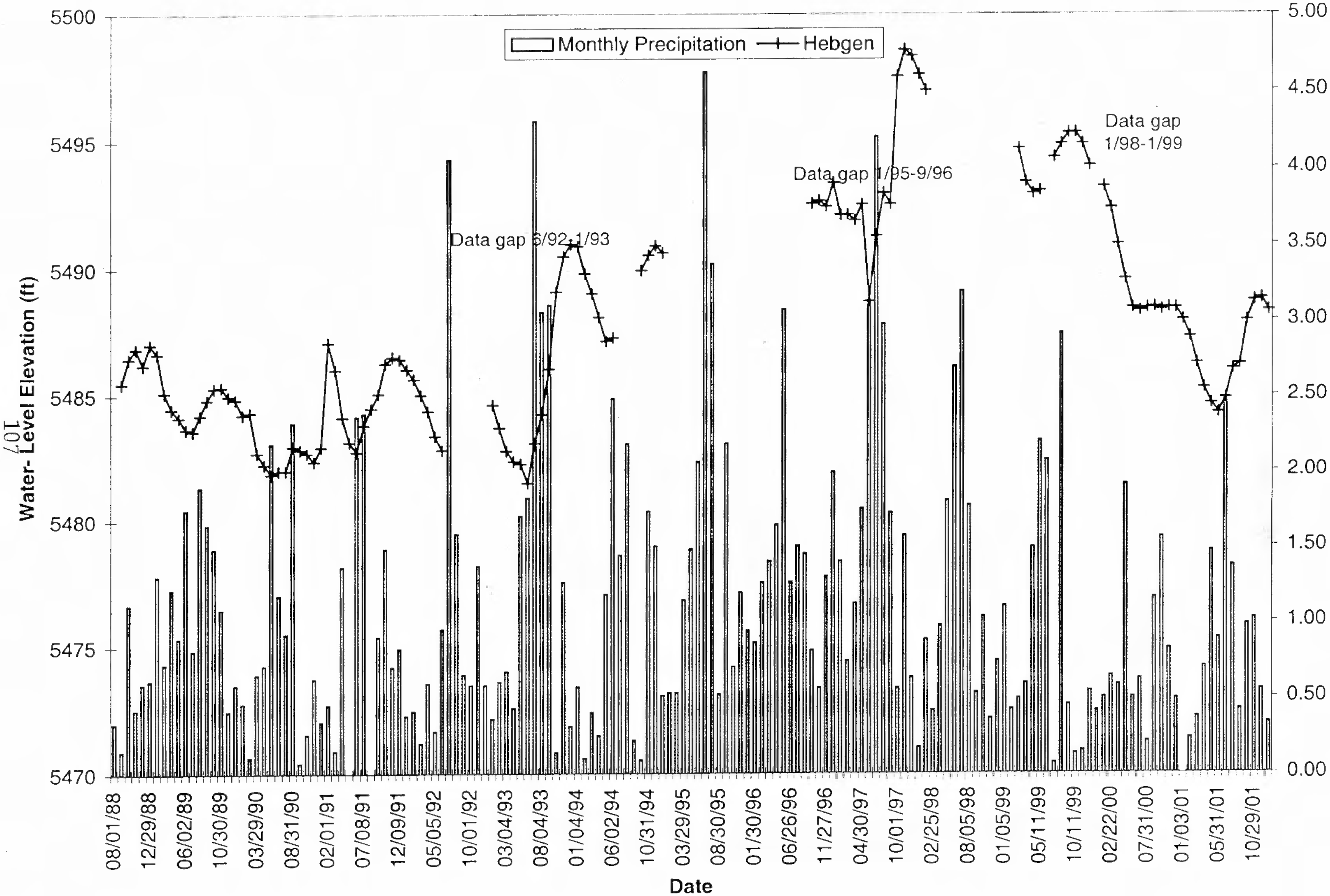

Figure 5-5. Water-level hydrograph for the Hebgen Park Well.

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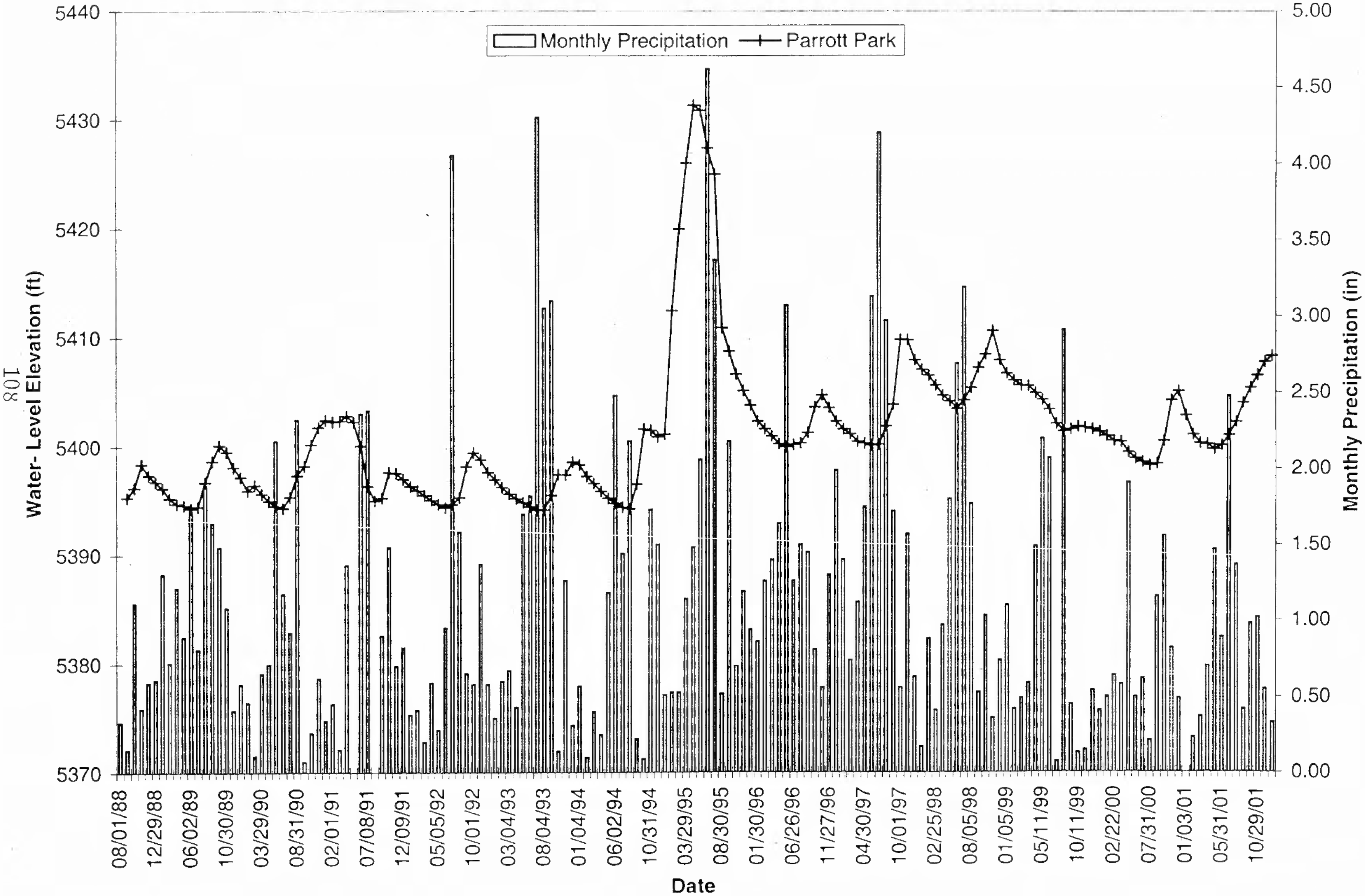

Figure 5-6. Water-level hydrograph for Parrott Park well.

mining activities has resulted in the input of water from the HSB drainage into the Berkeley Pit for the last 6 months of 2000, and all of 2001.

Based upon the model updates, it is projected that the water level of 5,410 feet, the critical water level (CWL), will be reached at the Anselmo Mine in July 2019, 12 months later than predicted in the 2000 model (MR, 2002). The model update assumes the continued input of HSB drainage water through June 2003, when the HSB water treatment plant is scheduled for completion. Water from the HSB drainage will then be diverted away from the pit and into the treatment plant. The treated water will be discharged to Silver Bow Creek or used in the mining process, if mining resumes.

The treatment technology and plant-construction time-frame for Berkeley Pit waters are based upon the schedule listed in the EPA 1994 ROD for the Butte Mine Flooding Operable Unit (EPA, 1994). If mining were to resume, or the treatment plant came on-line sooner, the dates listed above would be extended.

SECTION 7.0 CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system were similar to those noted in previous reports at most of the monitored sites. A decrease in water levels continued in a majority of the alluvial wells during 2001. The decline in water levels continued in alluvial monitoring wells to the south and southeast of the September 1998 Berkeley Pit landslide.

Precipitation events still have little or no influence on water levels in the LP series alluvial wells near the Berkeley Pit and leach pads. Water levels in these wells have continued to decline regardless of precipitation changes.

Water levels in a majority of the alluvial monitoring wells, located outside the mine area, show a response to seasonal precipitation events. The response time varies from immediate to a two- to three-month lag time. Therefore, the decrease in annual precipitation in the Butte Basin during 1999 and 2000 probably accounted for a good portion of the overall water-level decrease seen in a number of monitoring wells.

No notable precipitation influence was seen in any of the East Camp bedrock wells or underground mines water levels. The increased water-level changes are independent of precipitation, and are a result of the cessation of long-term mine dewatering activities in 1982. However, the addition of HSB drainage water into the Berkeley Pit did have a substantial influence on East Camp bedrock water levels. Water levels rose an average of 0.89 foot per month for the first 6 months of 2000, while rising an average of 1.93 feet during the remainder of the year. This increase doubled the amount of the monthly rise. The average 2001 monthly water-level rise was about 1.33 feet, which was probably the result of the lower flow of water from the HSB drainage.

The date the East Camp system water level was predicted to reach the CWL elevation of 5,410 feet was increased by one year from 2018 to 2019. This new date reflects the lower volume of water entering the pit from the HSB drainage. The CWL date is assumed to be the date the 5,410-foot elevation would be reached at the Anselmo Mine. The Anselmo Mine is the anticipated compliance point in order to keep the Berkeley Pit the low point in the East Camp bedrock-mine system. This will ensure that all water in the historic underground mine system will continue to flow towards the Berkeley Pit.

The pumping of ground water in the West Camp System continues to control water levels in this system. The volume of water pumped during 2001 was less than that of previous years. Water levels fell about 1.5 feet throughout this system and are now over 12 feet below the maximum allowed level.

Results of the 2001 water-level monitoring continue to show that the current monitoring program is adequate for ensuring that contaminated bedrock ground water is flowing into the Berkeley Pit, and that West Camp water levels are being sufficiently controlled by West Camp pumping operations. These are two of the main environmental concerns associated with the flooding of Butte's historic underground mines and the Berkeley Pit.

Continued long-term water-level monitoring throughout the entire Butte Hill Mine system (East Camp, West Camp and Outer Camp) and the associated shallow alluvial aquifer should continue to enable better recognition, prediction and interpretation of the trends seen to date. Water-level changes caused by the September 1998 Berkeley Pit landslide act to verify this need for continued monitoring. The influence on water levels continues to be seen for a considerable distance south of the pit, extending into areas outside the active mine area. This shows considerable interconnection of the shallow alluvial system previously not seen, nor thought to occur, as the result of discontinuous clay lenses in the alluvial system (Canonie, 1993).

Monitoring wells in the alluvial aquifers associated with the Mine Flooding Operable Unit continue to show a wide range of concentrations, both spatially and temporally. Both the AMC series and GS series wells show a wide variation and few trends with respect to the concentration of dissolved constituents. The LP series wells show a continuation of previous trends in most wells for most constituents; a few wells may show an initial reversal of some concentration trends. Wells such as LP-14 show a sustained reversal of concentration trends and may reflect a changing ground-water flow pattern.

Chemistry data from the East Camp mines show a continuing slight improvement in water quality. However, dissolved constituents such as arsenic, zinc, and sulfate remain well above MCLs and SCMLs. The chemistry of the Berkeley Pit may be reflecting the suspension of mining in 2000, and the addition of HSB drainage water; pH values of surface samples in the last few years show trends similar to those trends before the mining shutdown in 1981. The water quality of HSB almost certainly reflects the shutdown of the leach pads. There was a slight downward trend in concentrations throughout the life of the leaching operations, but probably due to the loss of mass and decreasing permeability of the waste rock. There was an abrupt decrease in metals concentration when acidified water was no longer added to the pads.

Recent data from the West Camp monitoring sites generally indicate a continuation of recent trends in water quality. Although the concentrations of several dissolved constituents trend upward, they are generally well below values observed during initial flooding.

Water-quality trends at monitoring sites of the Outer Camp remain unremarkable. As with the overall trend of water levels, the water chemistry at these sites tends to reflect stable conditions.

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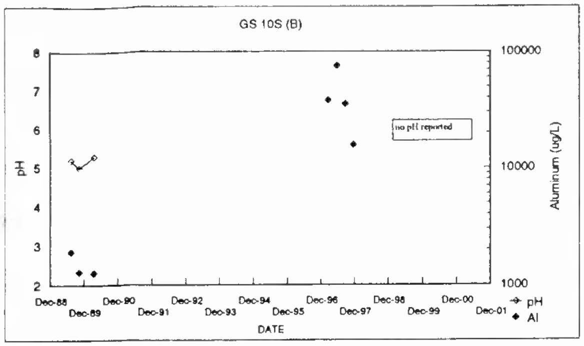
APPENDIX A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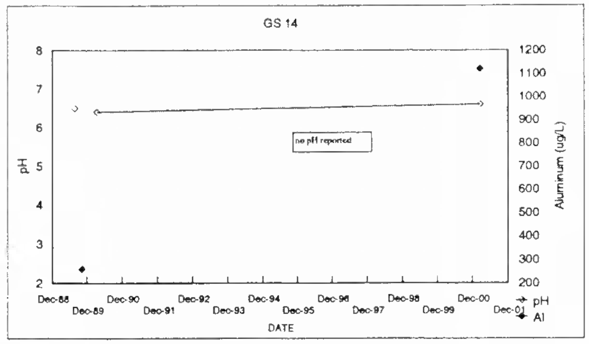
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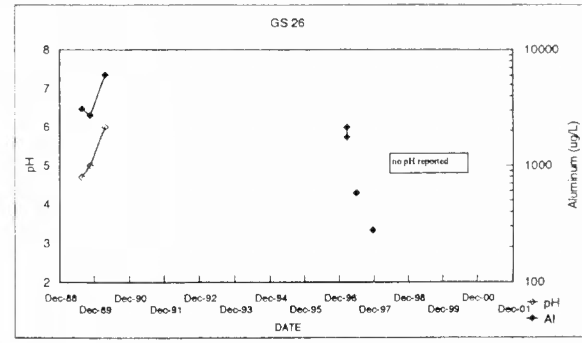
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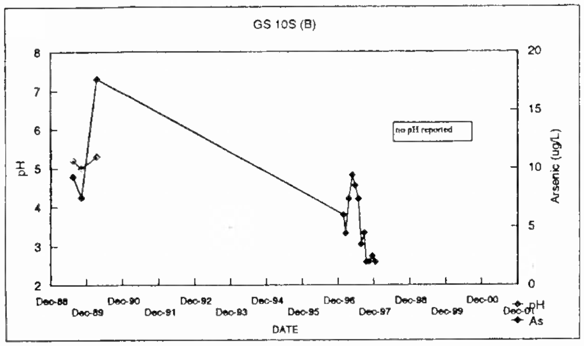
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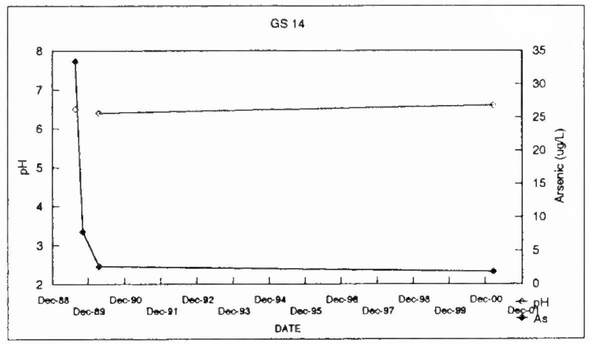
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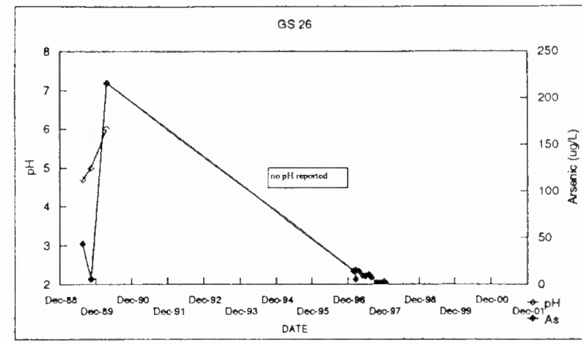
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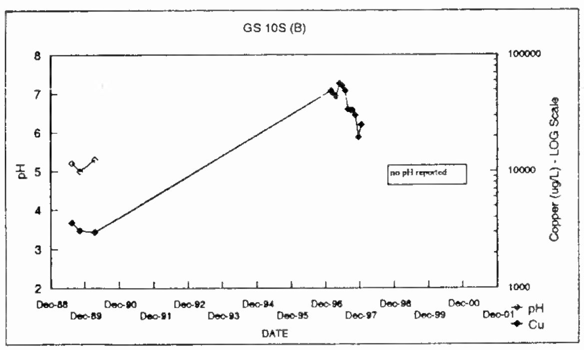
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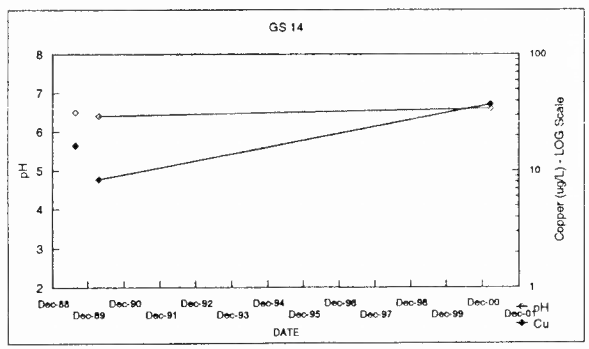
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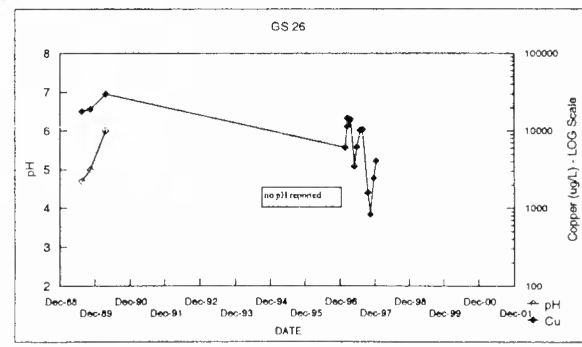
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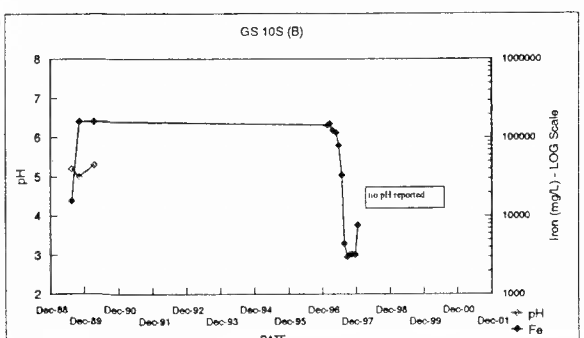
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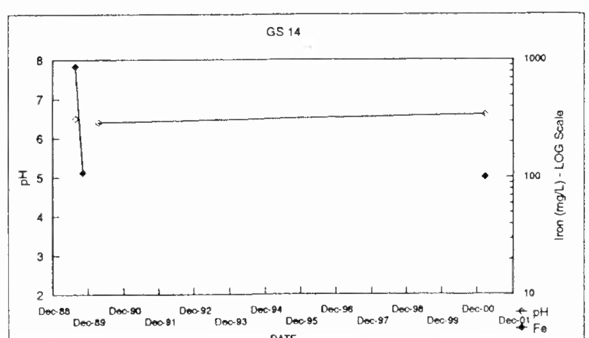
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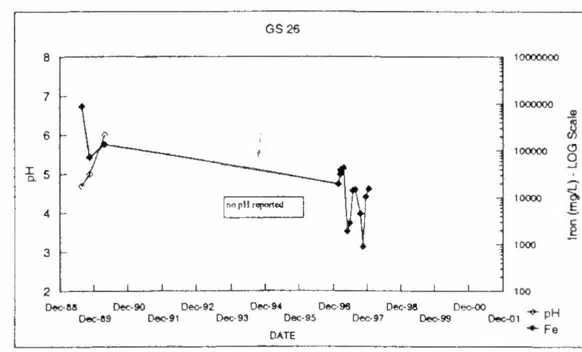
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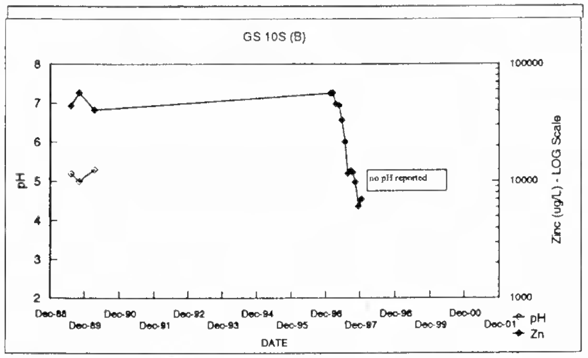
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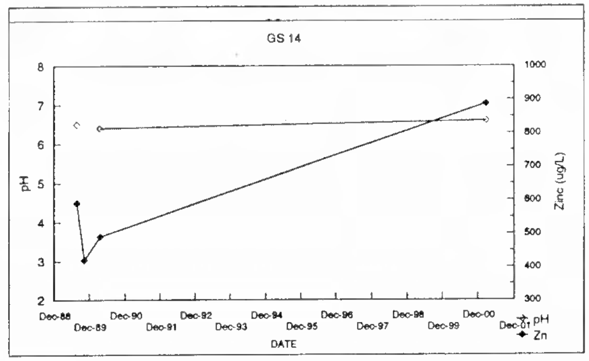
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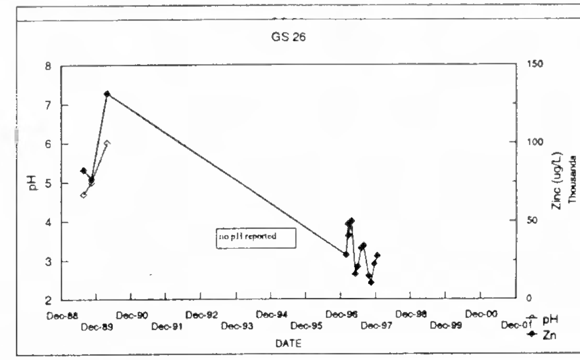
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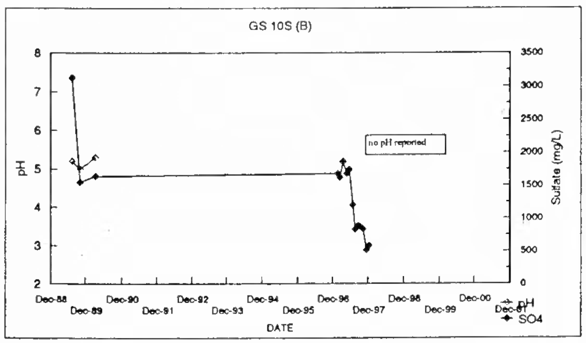
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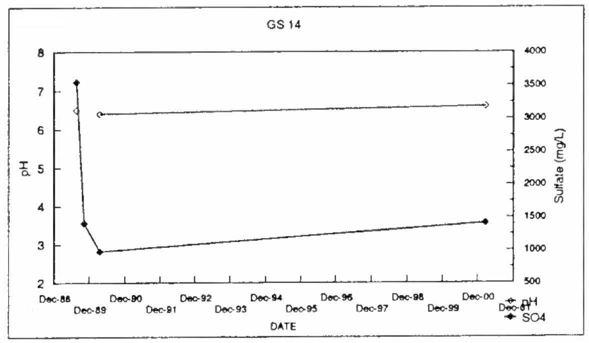
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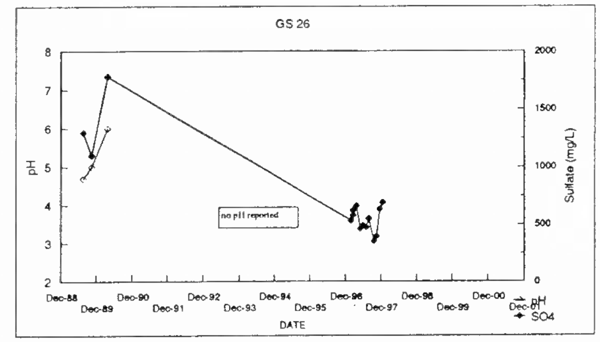
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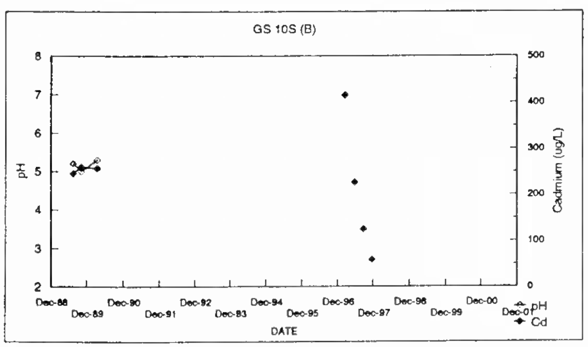
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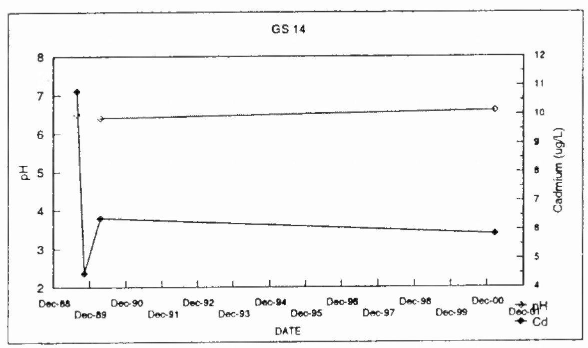
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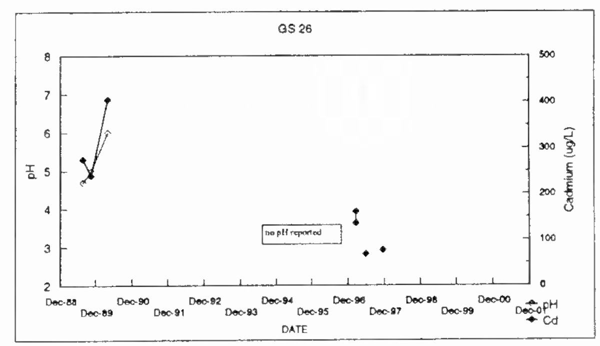
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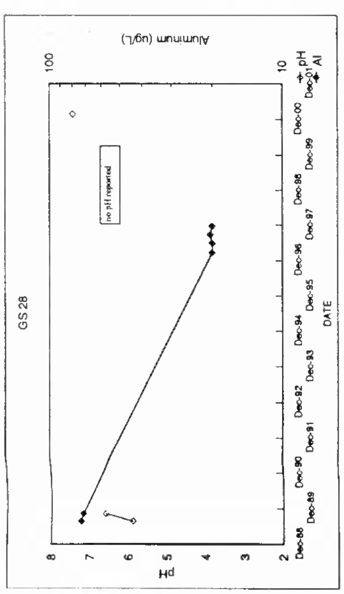
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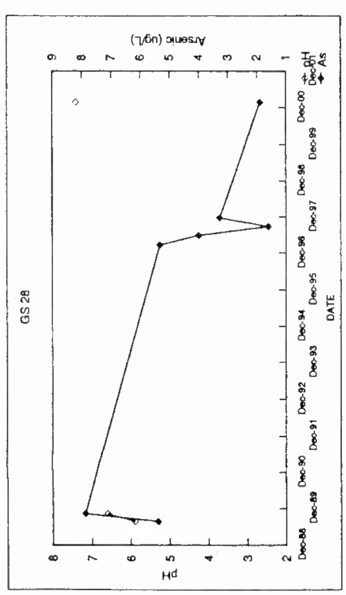
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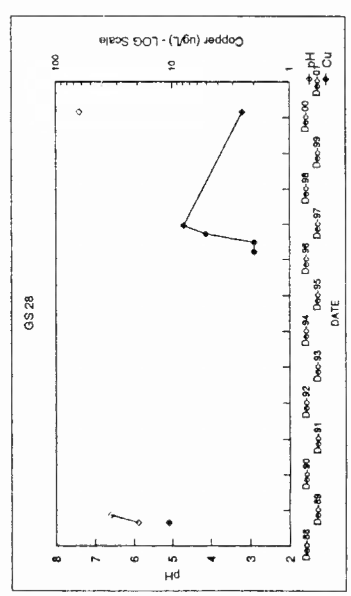
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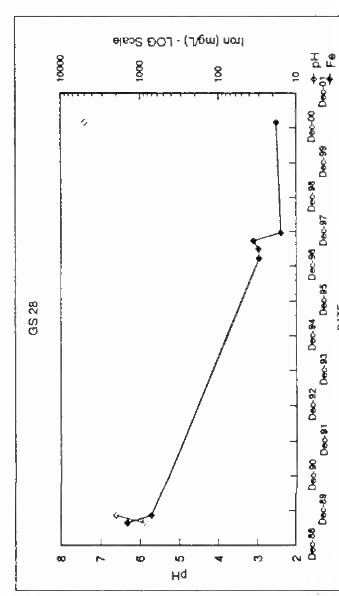
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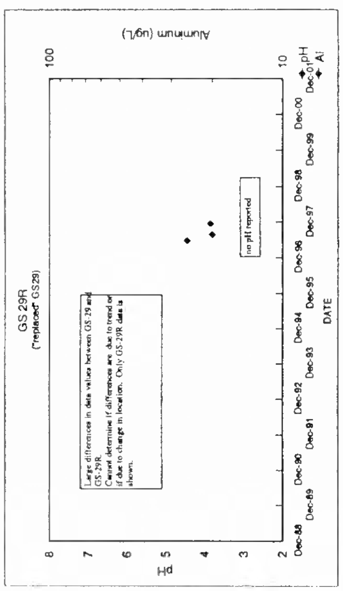
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Aluminum (ug/L)
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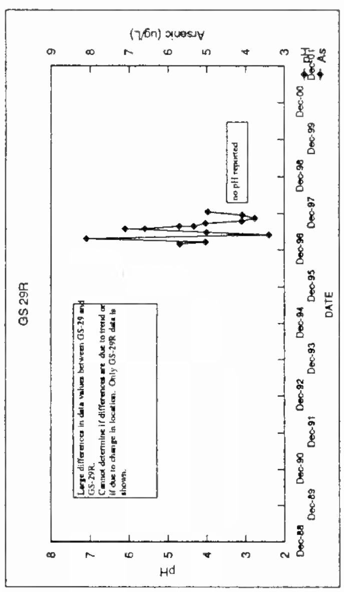
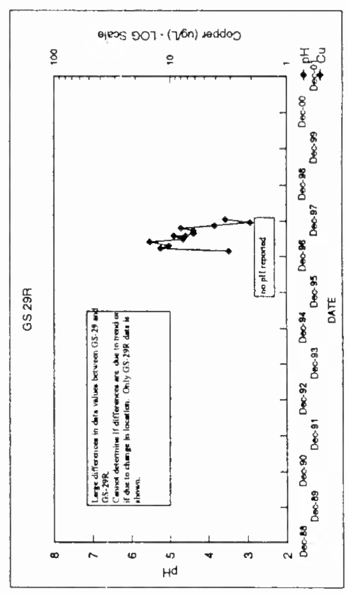
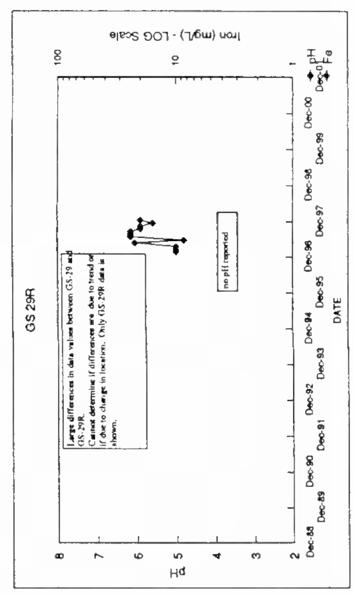
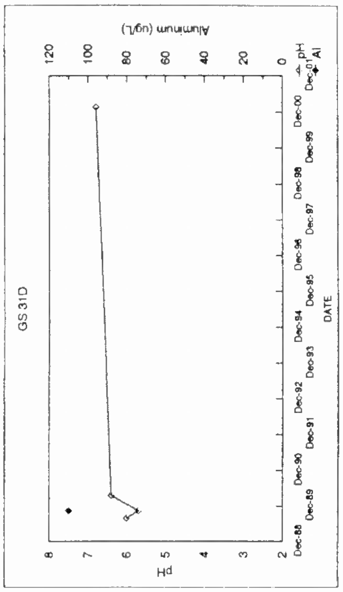
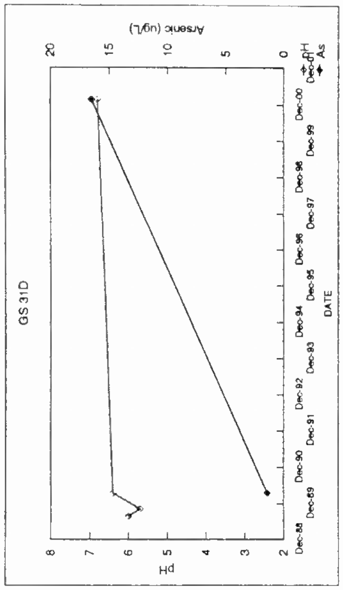
pH
Al

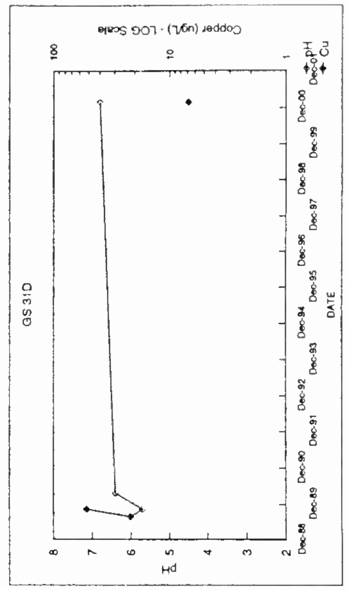

GS 29R
pH
Arsenic (ug/L)
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
As

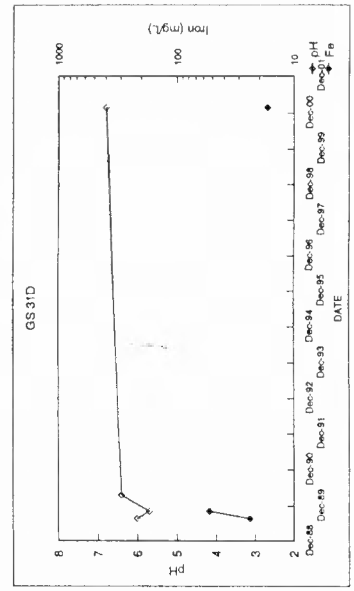

GS 29R
pH
Copper (ug/L) - LOG Scale
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
Cu

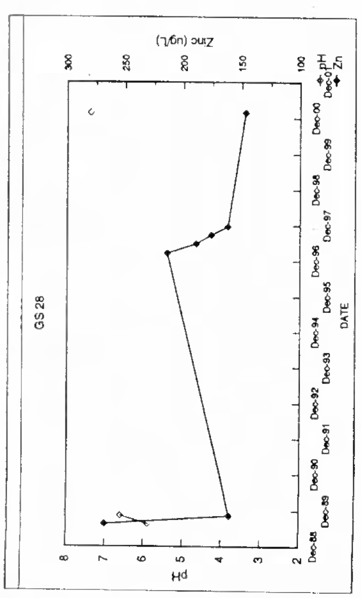

GS 29R
pH
Iron (mg/L) - LOG Scale
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
Fe

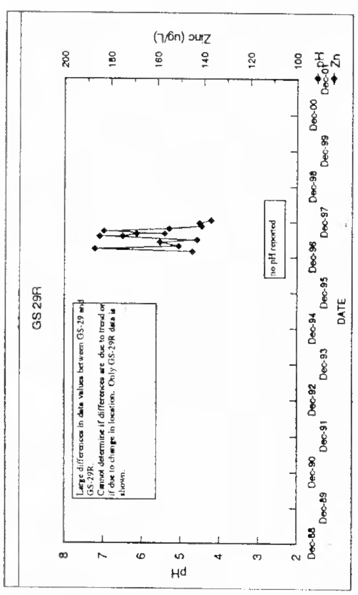

GS 31D
pH
Aluminum (ug/L)
DATE
pH
Al

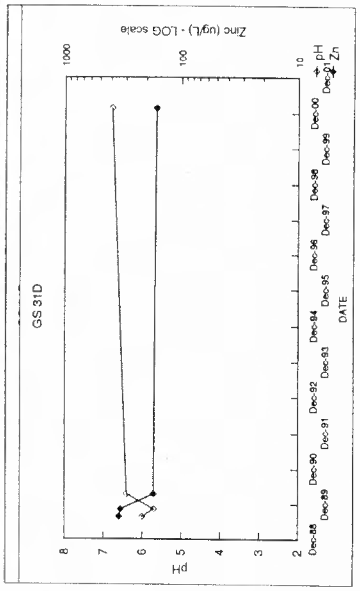

GS 31D
pH
Arsenic (ug/L)
DATE
pH
As

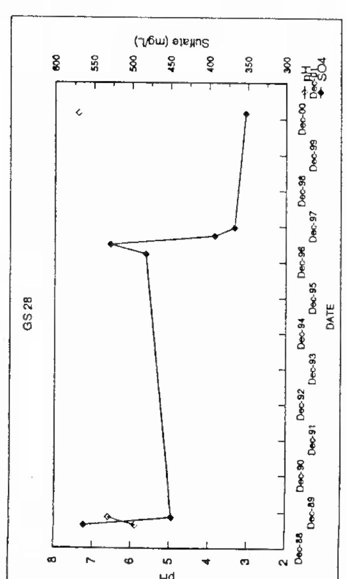

GS 31D
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

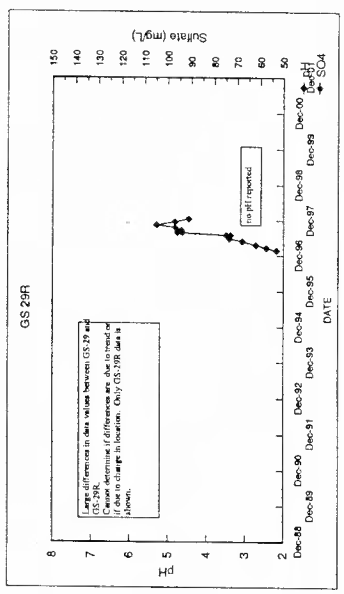

GS 31D
pH
Iron (mg/L)
DATE
pH
Fe

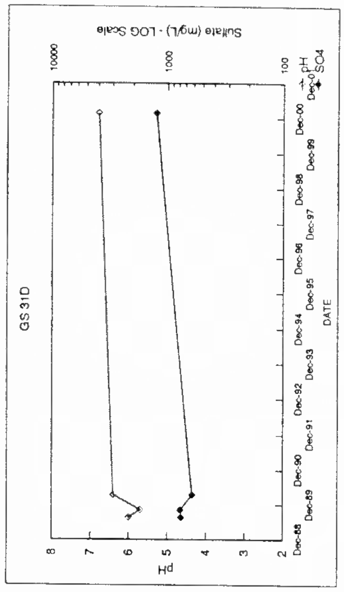

GS 28
pH
Zinc (ug/L)
DATE
pH
Zn

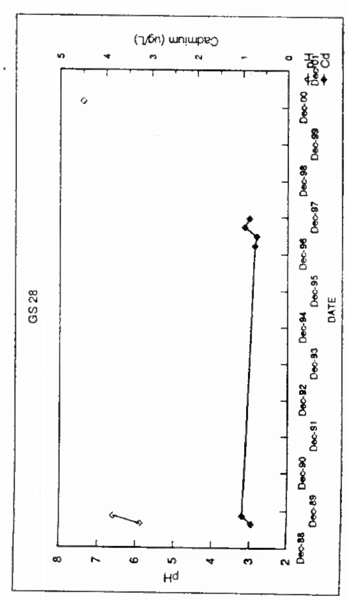

GS 29R
pH
Zinc (ug/L)
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
Zn

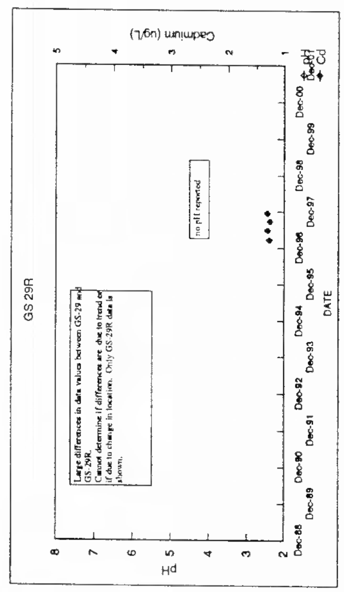

GS 31D
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

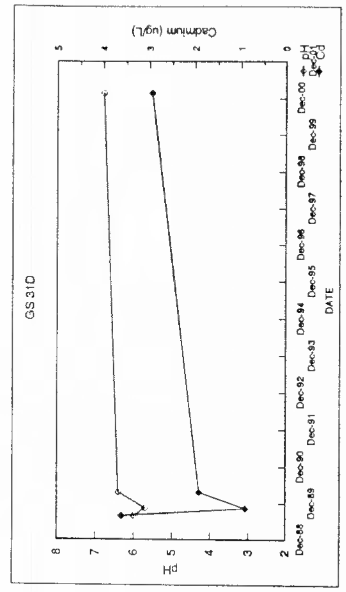

GS 28
pH
Sulfate (mg/L)
DATE
pH
SO4

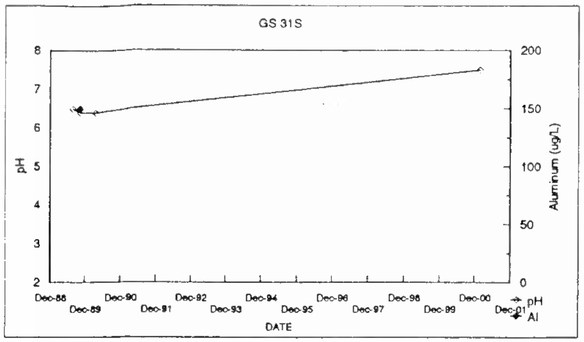

GS 29R
pH
Sulfate (mg/L)
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
SO4

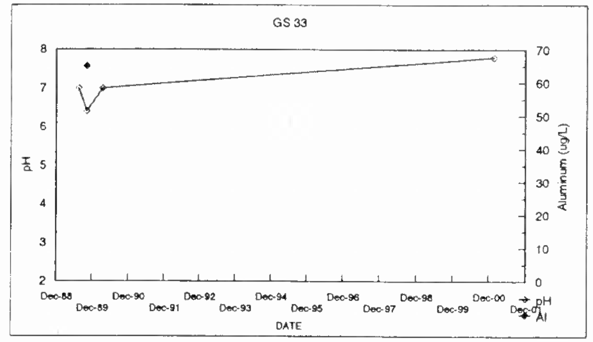

GS 31D
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

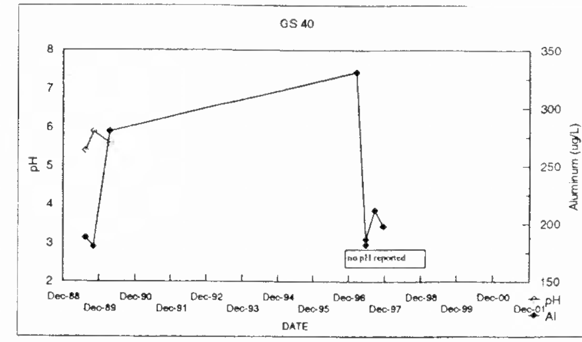

GS 28
pH
Cadmium (ug/L)
DATE
pH
Cd

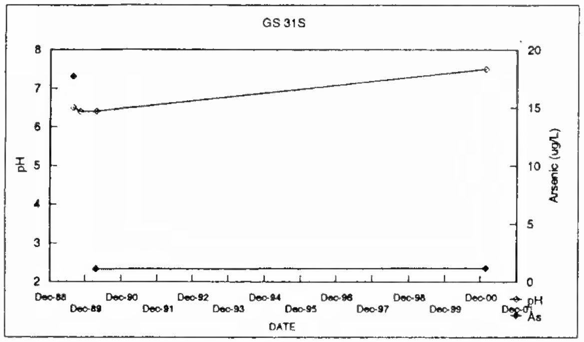

GS 29R
pH
Cadmium (ug/L)
DATE
Large differences in data values between GS-29 and GS-29R. Cannot determine if differences are due to trend or if due to change in location. Only GS-29R data is shown.
no pH reported
pH
Cd

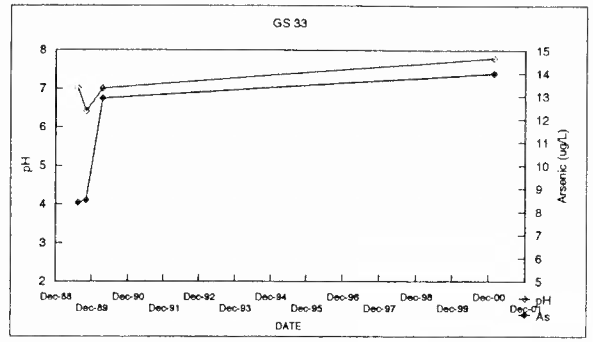

GS 31D
pH
Cadmium (ug/L)
DATE
pH
Cd

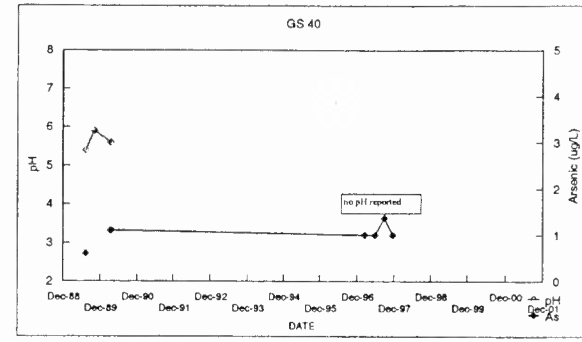

GS 31S
pH
Aluminum (ug/L)
DATE
pH
Al

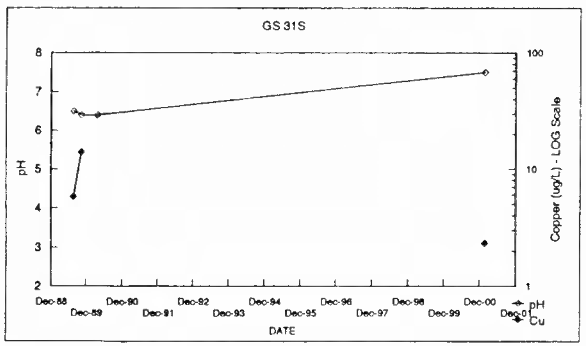

GS 33
pH
Aluminum (ug/L)
DATE
pH
Al

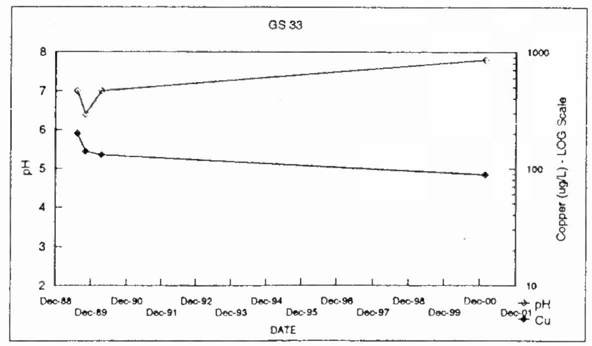

GS 40
pH
Aluminum (ug/L)
no pH reported
DATE
pH
Al

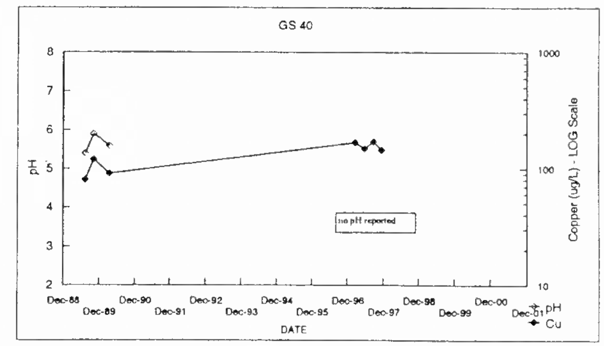

GS 31S
pH
Arsenic (ug/L)
DATE
pH
As

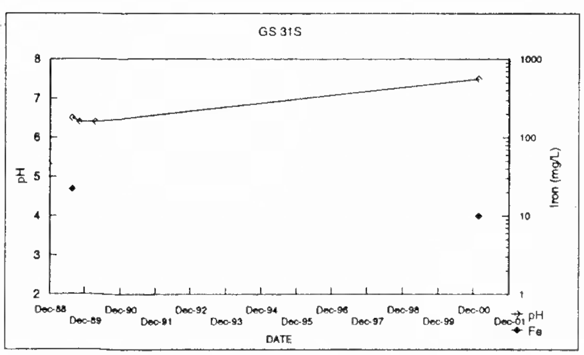

GS 33
pH
Arsenic (ug/L)
DATE
pH
As

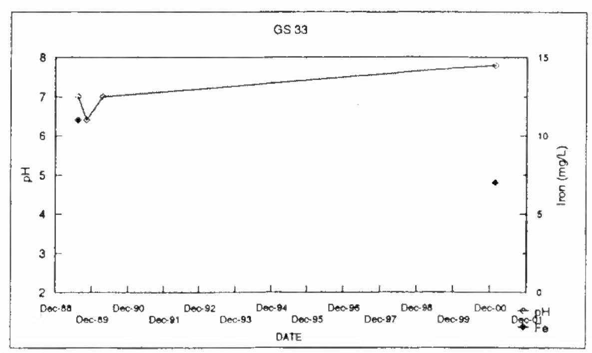

GS 40
pH
Arsenic (ug/L)
no pH reported
DATE
pH
As

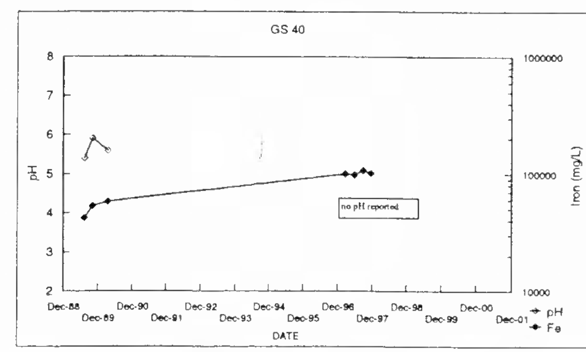

GS 31S
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

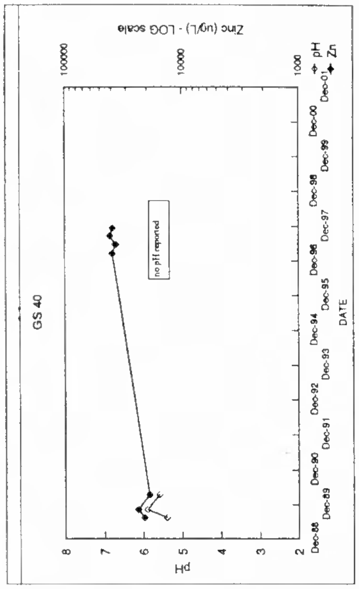

GS 33
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

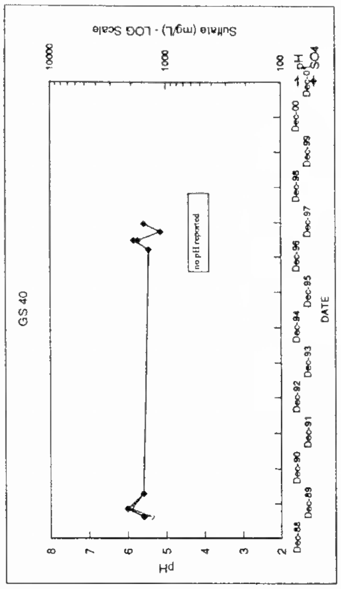

GS 40
pH
Copper (ug/L) - LOG Scale
no pH reported
DATE
pH
Cu

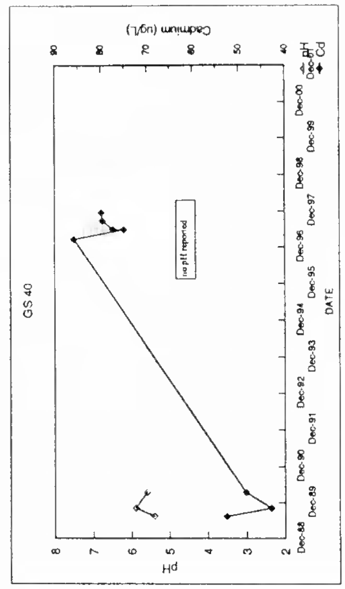

GS 31S
pH
Iron (mg/L)
DATE
pH
Fe

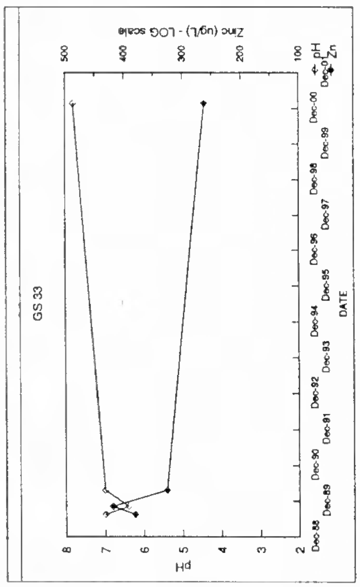

GS 33
pH
Iron (mg/L)
DATE
pH
Fe

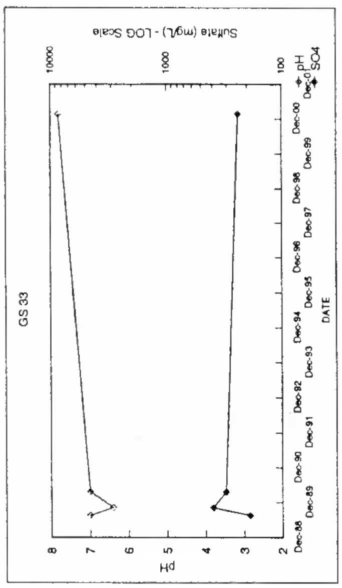

GS 40
pH
Iron (mg/L)
no pH reported
DATE
pH
Fe

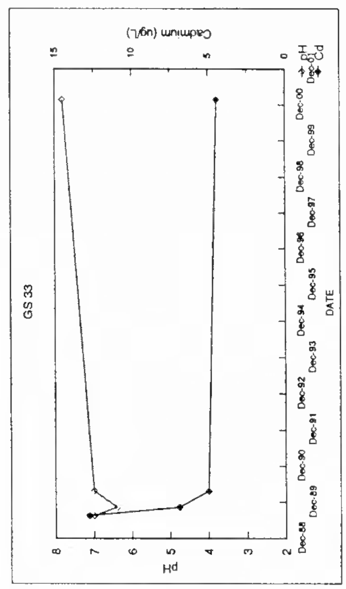

GS 40
pH
DATE
Zinc (ug/L) - LOG scale
no pH reported
pH
Zn

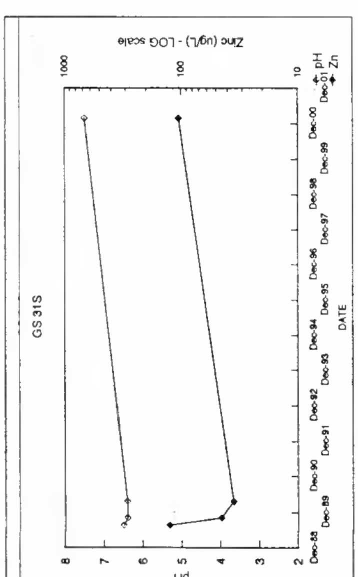

GS 40
pH
DATE
Sulfate (mg/L) - LOG Scale
no pH reported
pH
SO4

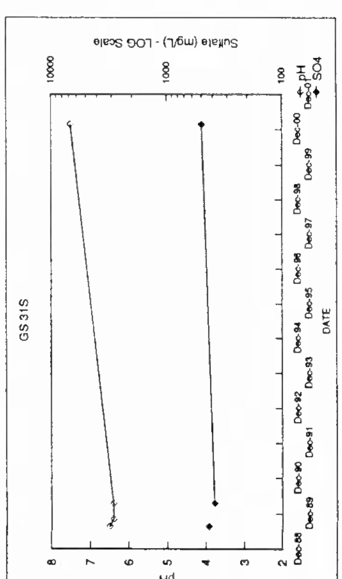

GS 40
pH
DATE
Cadmium (ug/L)
no pH reported
pH
Cd

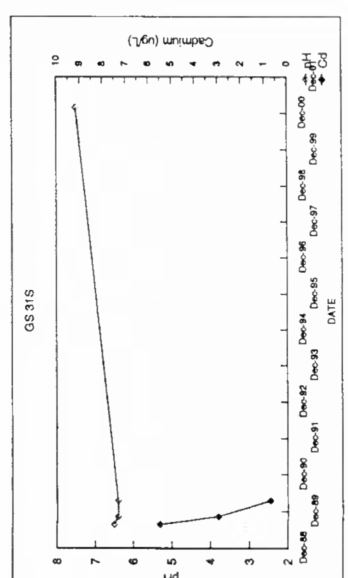

GS 33
pH
DATE
Zinc (ug/L) - LOG scale
pH
Zn

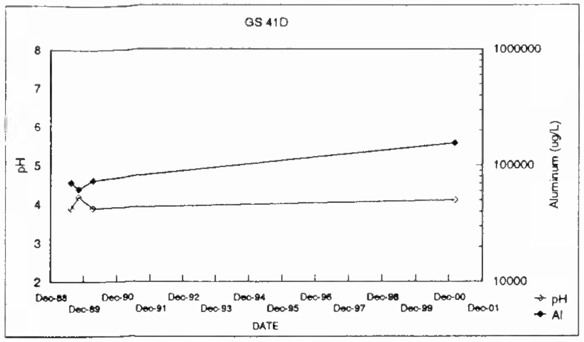

GS 33
pH
DATE
Sulfate (mg/L) - LOG Scale
pH
SO4

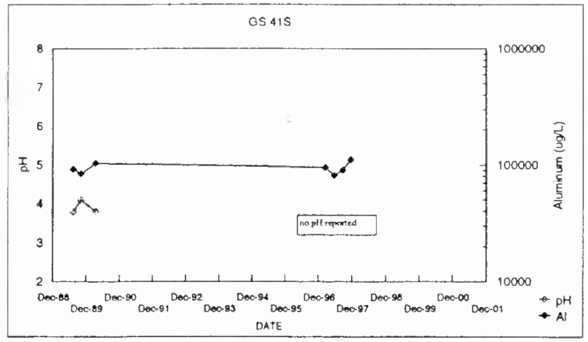

GS 33
pH
DATE
Cadmium (ug/L)
pH
Cd

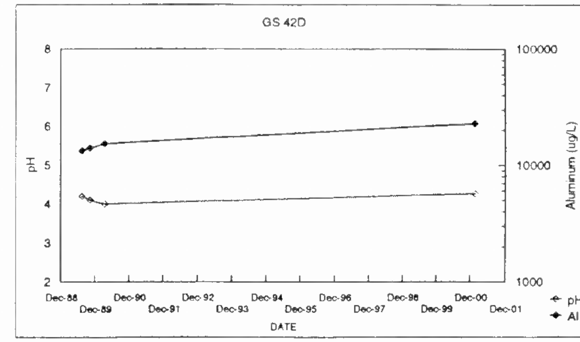

GS 31S
pH
DATE
Zinc (ug/L) - LOG scale
pH
Zn

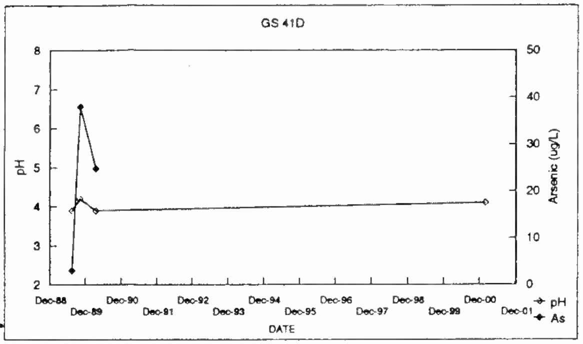

GS 31S
pH
DATE
Sulfate (mg/L) - LOG Scale
pH
SO4

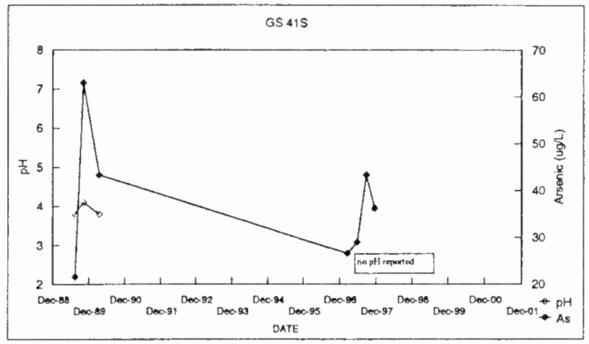

GS 31S
pH
DATE
Cadmium (ug/L)
pH
Cd

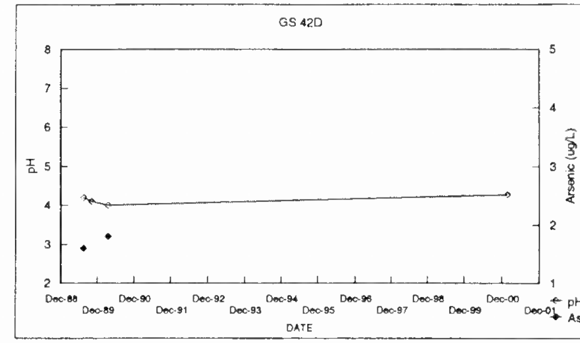

GS 41D
pH
Aluminum (ug/L)
DATE
pH
Al

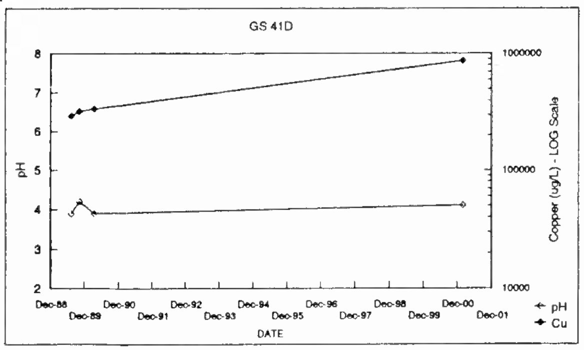

GS 41S
pH
Aluminum (ug/L)
no pH reported
DATE
pH
Al

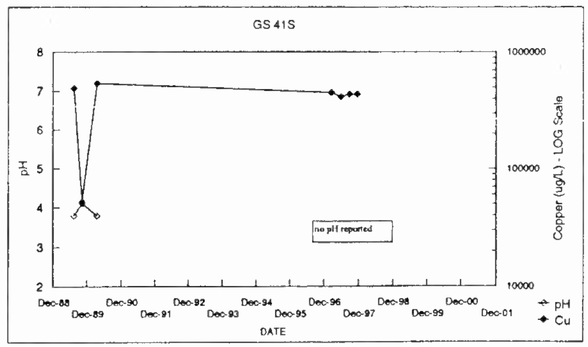

GS 42D
pH
Aluminum (ug/L)
DATE
pH
Al

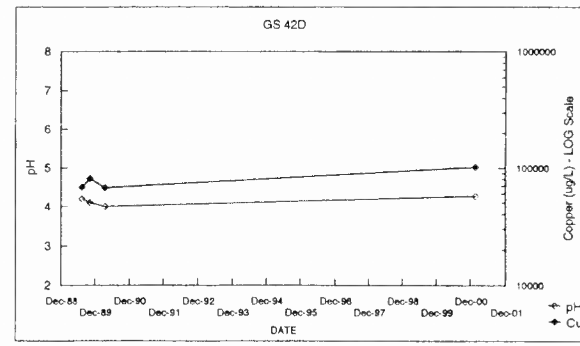

GS 41D
pH
Arsenic (ug/L)
DATE
pH
As

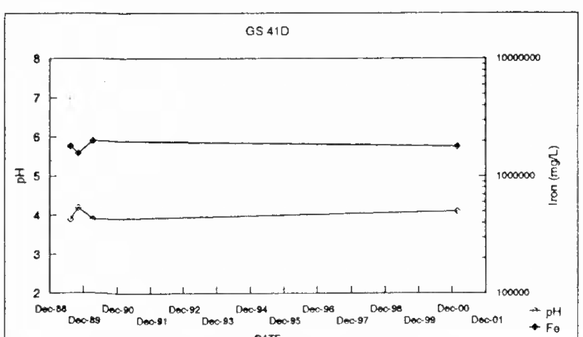

GS 41S
pH
Arsenic (ug/L)
no pH reported
DATE
pH
As

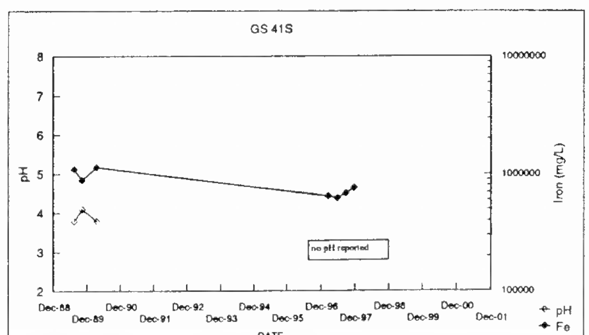

GS 42D
pH
Arsenic (ug/L)
DATE
pH
As

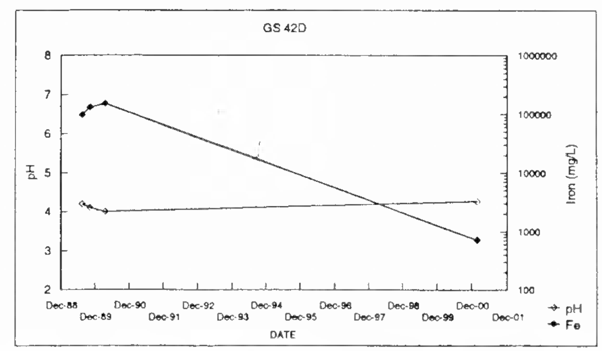

GS 41D
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

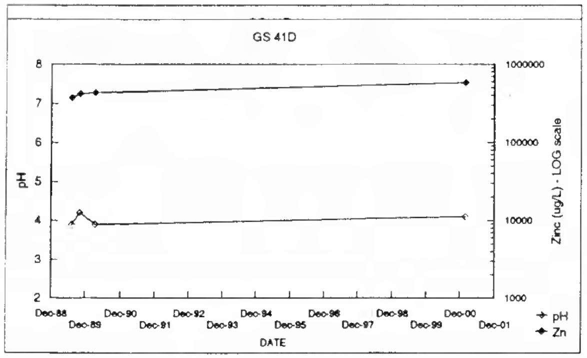

GS 41S
pH
Copper (ug/L) - LOG Scale
no pH reported
DATE
pH
Cu

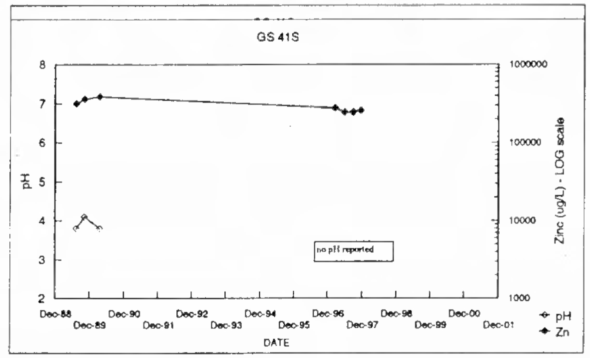

GS 42D
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

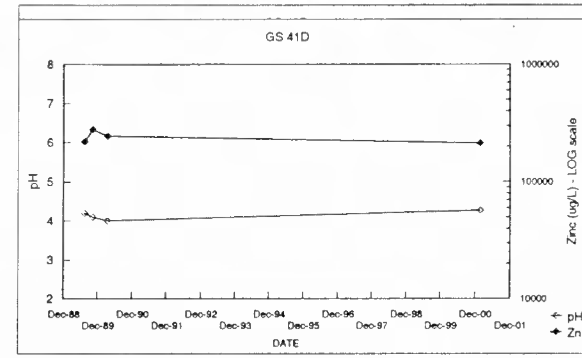

GS 41D
pH
Iron (mg/L)
DATE
pH
Fe

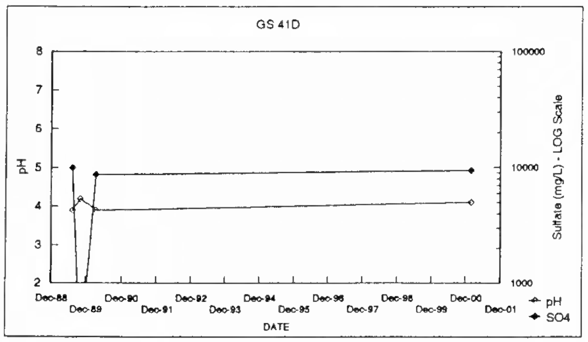

GS 41S
pH
Iron (mg/L)
no pH reported
DATE
pH
Fe

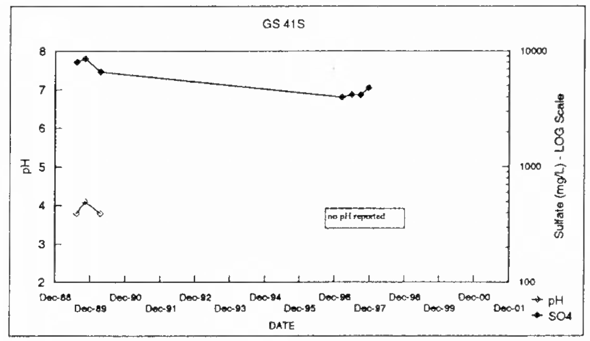

GS 42D
pH
Iron (mg/L)
DATE
pH
Fe

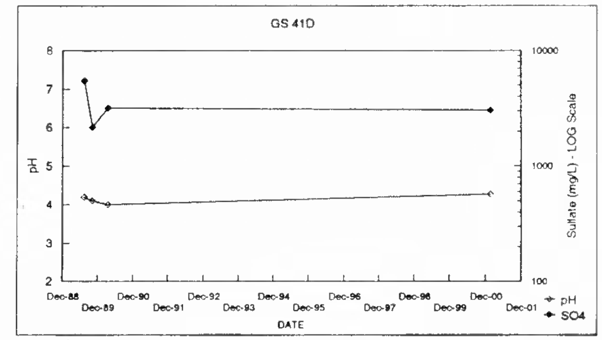

GS 41D
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn
no pH reported

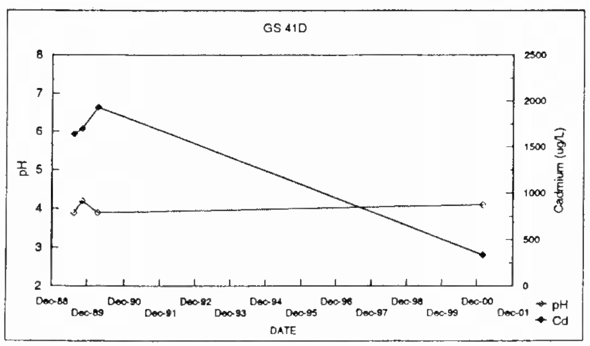

GS 41S
pH
Zinc (ug/L) - LOG scale
DATE
no pH reported
pH
Zn

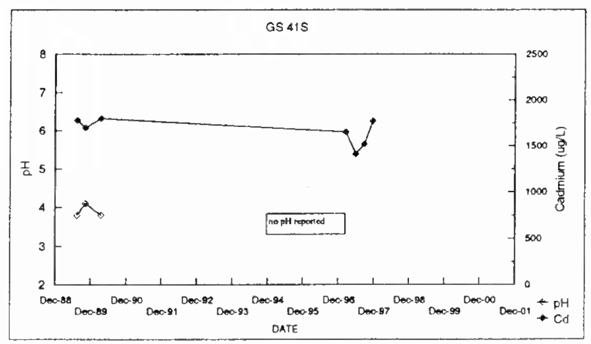

GS 41D
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

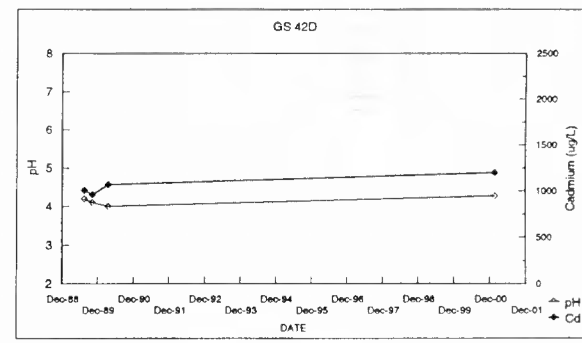

GS 41D
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

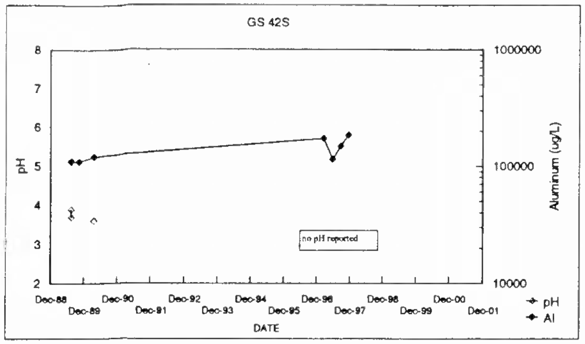

GS 41S
pH
Sulfate (mg/L) - LOG Scale
DATE
no pH reported
pH
SO4

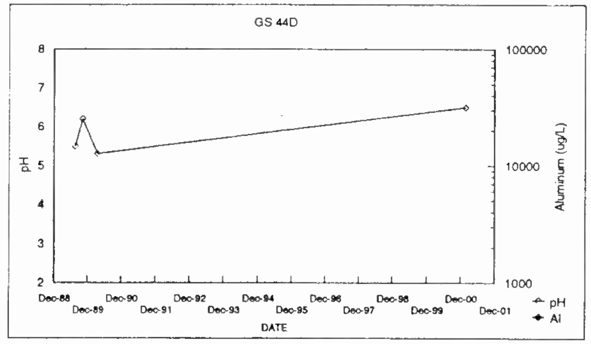

GS 41D
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

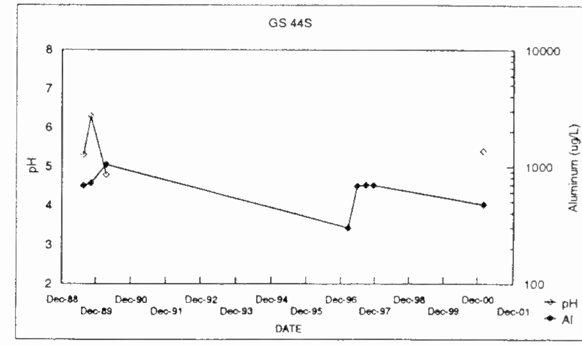

GS 41D
pH
Cadmium (ug/L)
DATE
pH
Cd

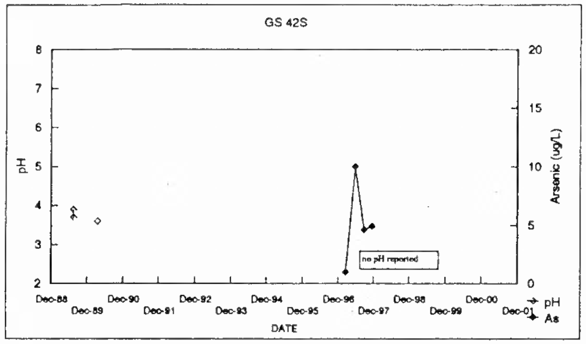

GS 41S
pH
Cadmium (ug/L)
DATE
no pH reported
pH
Cd

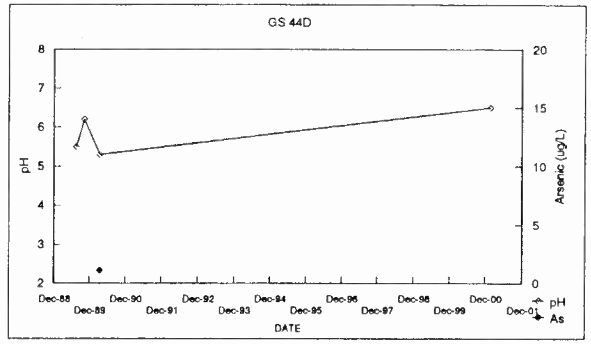

GS 42D
pH
Cadmium (ug/L)
DATE
pH
Cd

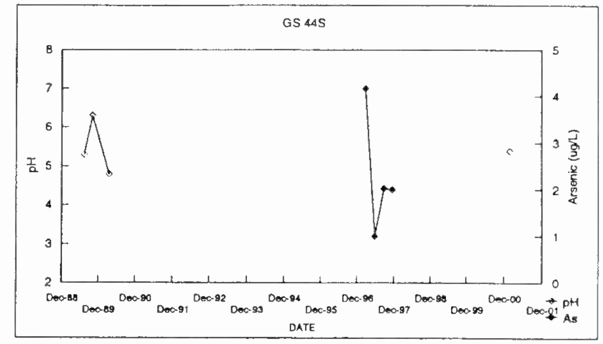

GS 42S
pH
Aluminum (ug/L)
no pH reported
DATE
pH
Al

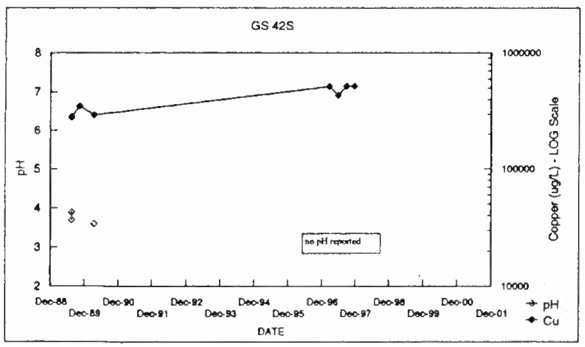

GS 44D
pH
Aluminum (ug/L)
DATE
pH
Al

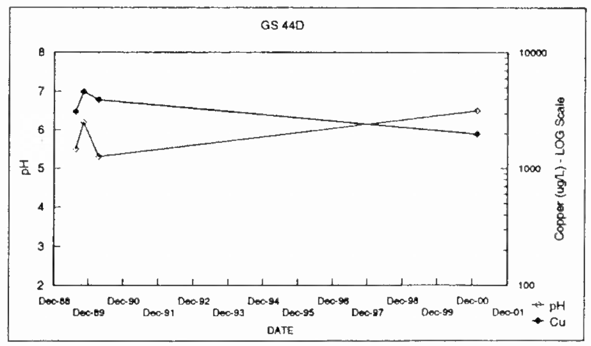

GS 44S
pH
Aluminum (ug/L)
DATE
pH
Al

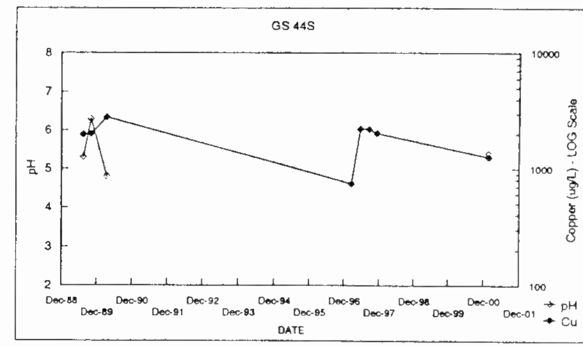

GS 42S
pH
Arsenic (ug/L)
no pH reported
DATE
pH
As

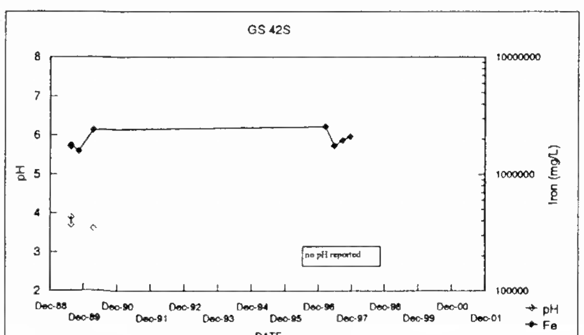

GS 44D
pH
Arsenic (ug/L)
DATE
pH
As

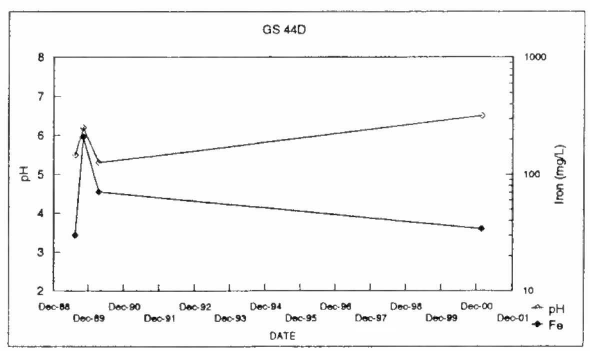

GS 44S
pH
Arsenic (ug/L)
DATE
pH
As

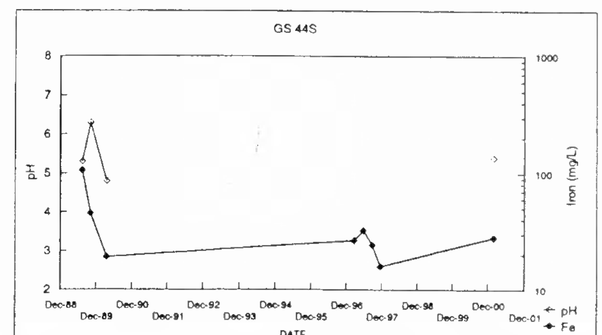

GS 42S
pH
Copper (ug/L) - LOG Scale
no pH reported
DATE
pH
Cu

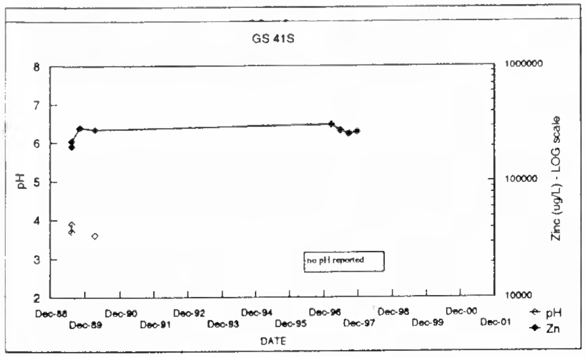

GS 44D
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

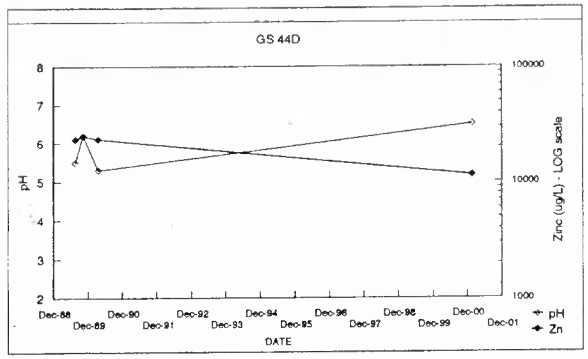

GS 44S
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

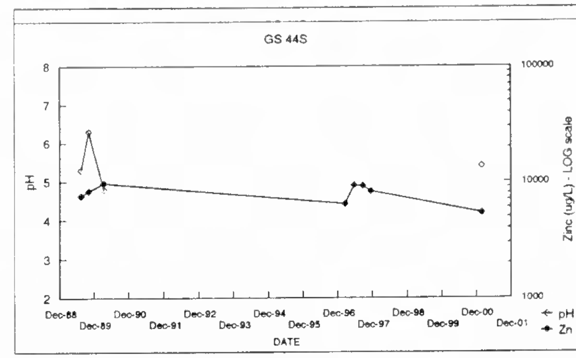

GS 42S
pH
Iron (mg/L)
no pH reported
DATE
pH
Fe

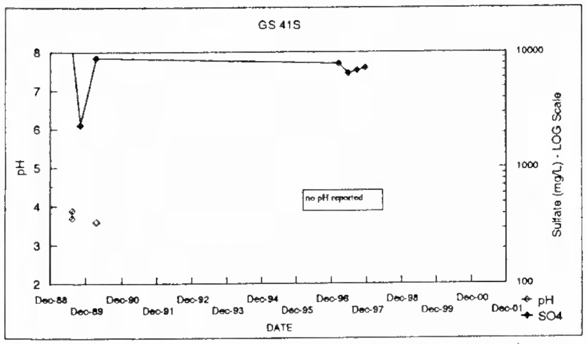

GS 44D
pH
Iron (mg/L)
DATE
pH
Fe

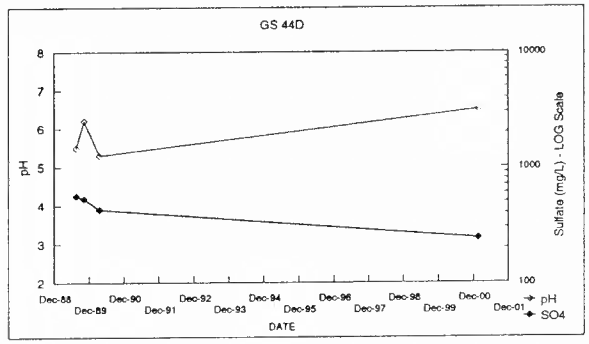

GS 44S
pH
Iron (mg/L)
DATE
pH
Fe

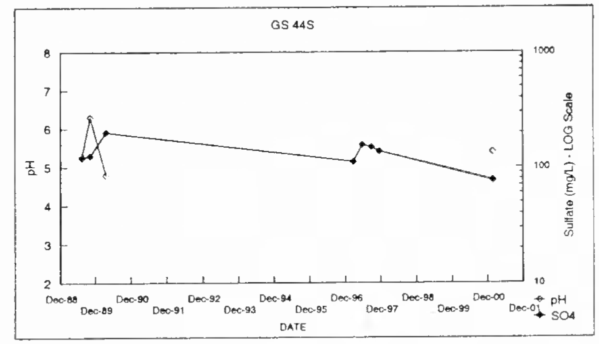

GS 41S
pH
Zinc (ug/L) - LOG scale
no pH reported
DATE
pH
Zn

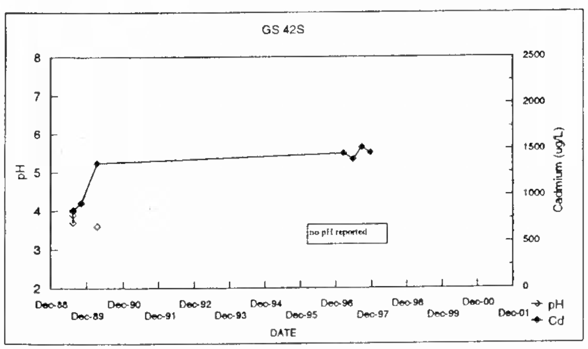

GS 44D
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

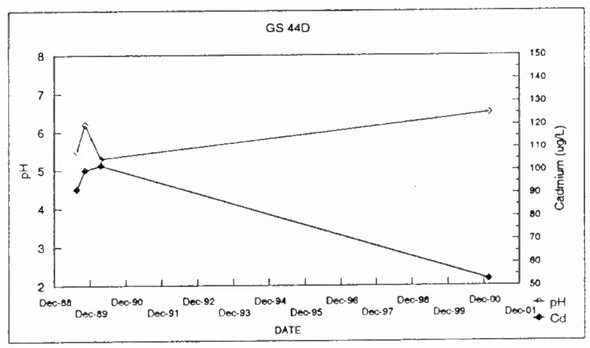

GS 44S
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

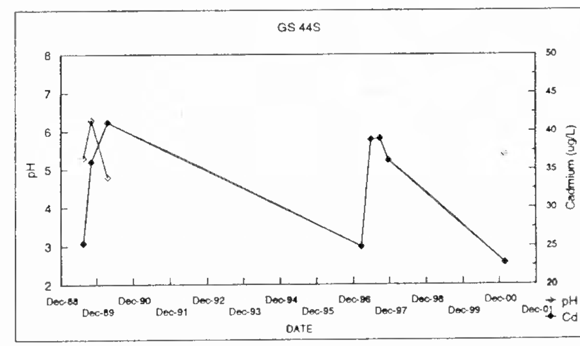

GS 41S
pH
Sulfate (mg/L) - LOG Scale
no pH reported
DATE
pH
SO4

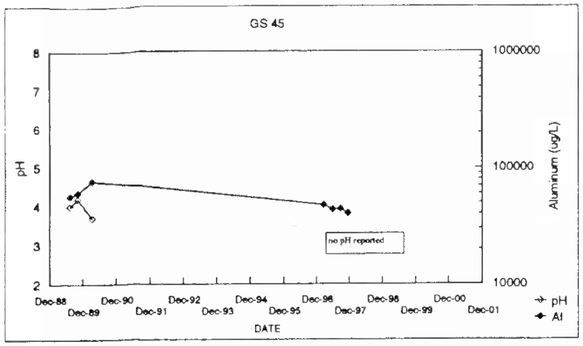

GS 44D
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

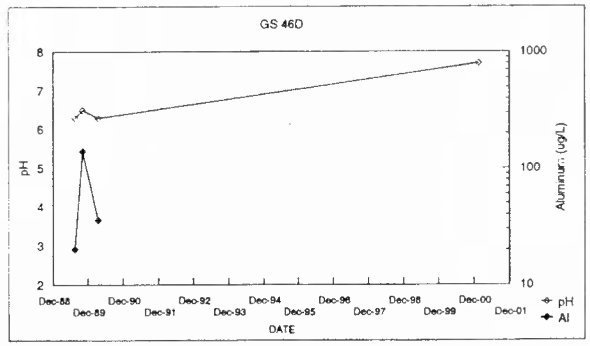

GS 44S
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

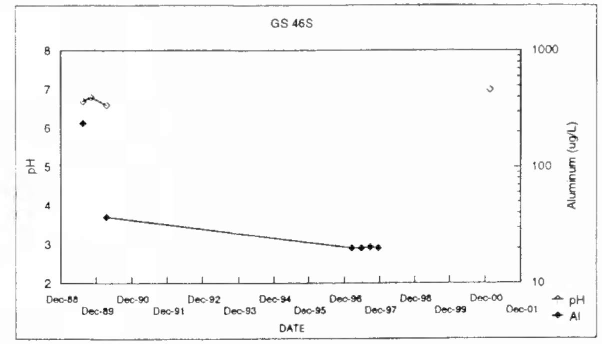

GS 42S
pH
Cadmium (ug/L)
no pH reported
DATE
pH
Cd

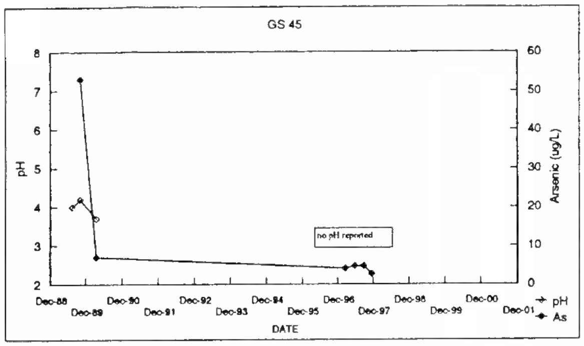

GS 44D
pH
Cadmium (ug/L)
DATE
pH
Cd

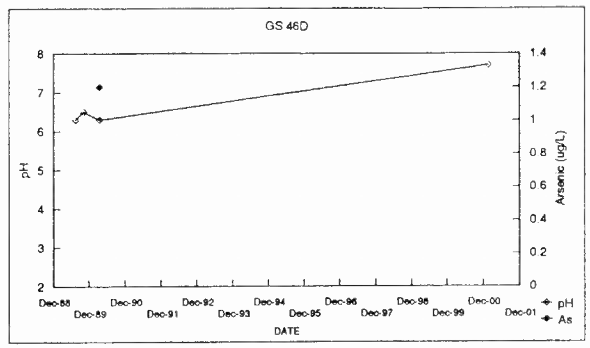

GS 44S
pH
Cadmium (ug/L)
DATE
pH
Cd

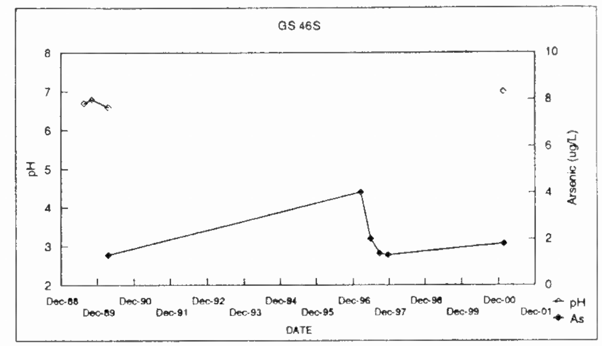

GS 45
pH
Aluminum (ug/L)
no pH reported
DATE
pH
Al

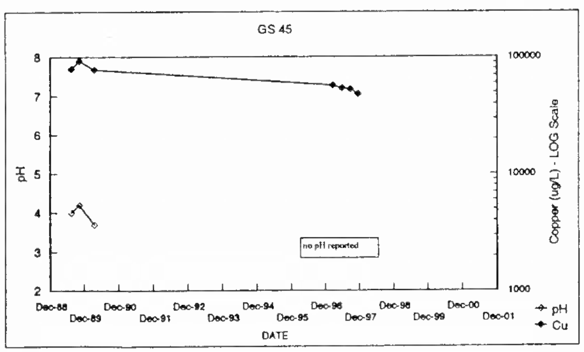

GS 46D
pH
Aluminum (ug/L)
DATE
pH
Al

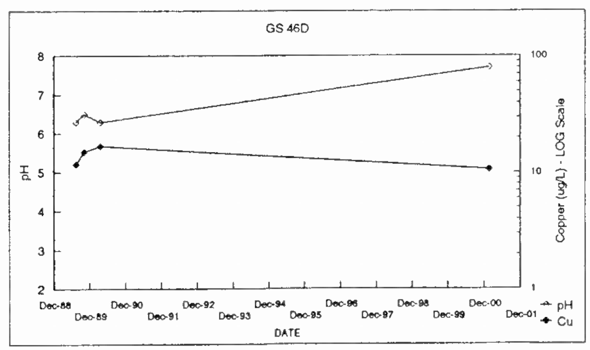

GS 46S
pH
Aluminum (ug/L)
DATE
pH
Al

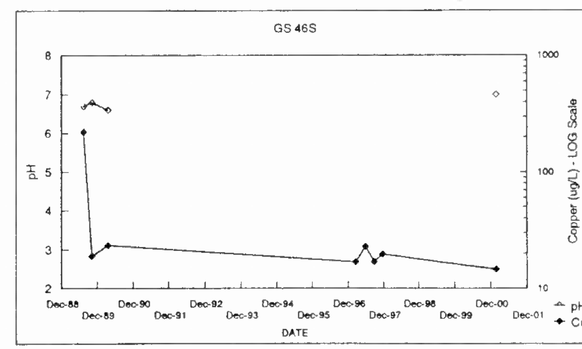

GS 45
pH
Arsenic (ug/L)
no pH reported
DATE
pH
As

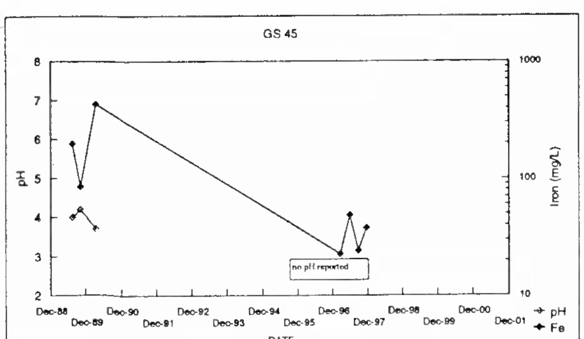

GS 46D
pH
Arsenic (ug/L)
DATE
pH
As

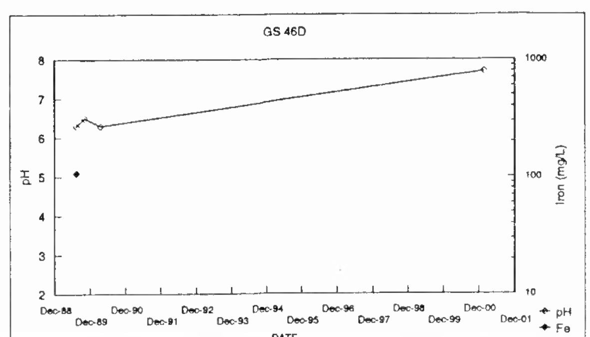

GS 46S
pH
Arsenic (ug/L)
DATE
pH
As

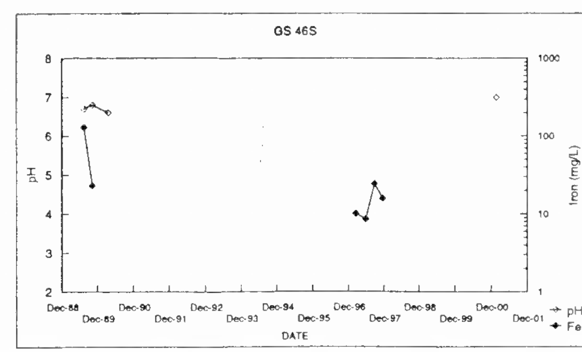

GS 45
pH
Copper (ug/L) - LOG Scale
no pH reported
DATE
pH
Cu

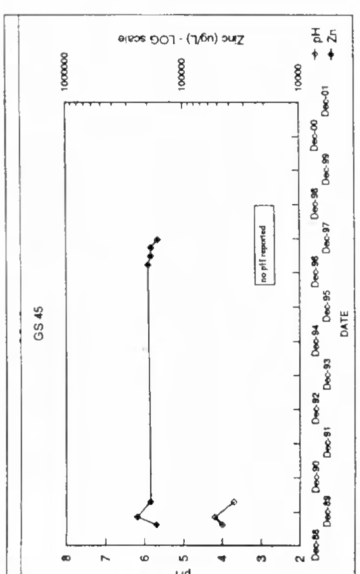

GS 46D
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

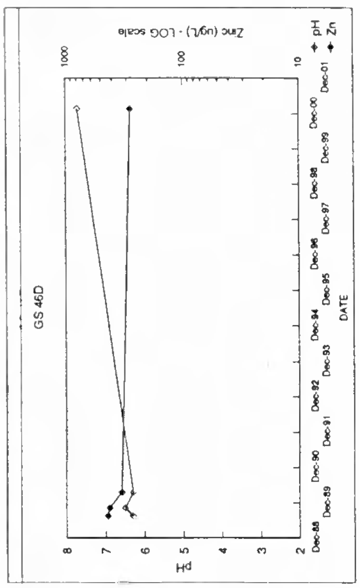

GS 46S
pH
Copper (ug/L) - LOG Scale
DATE
pH
Cu

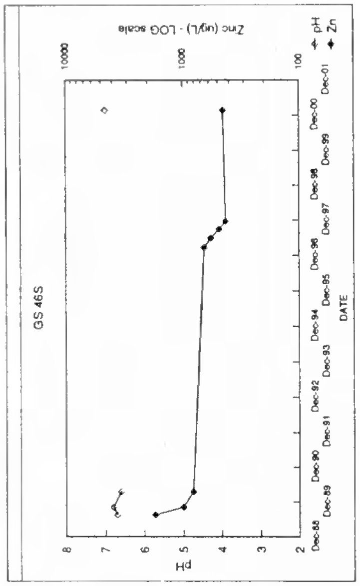

GS 45
pH
Iron (mg/L)
no pH reported
DATE
pH
Fe

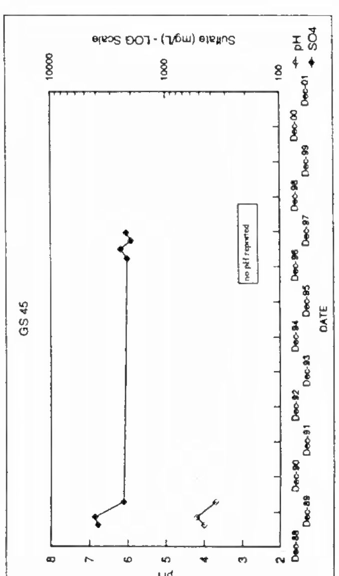

GS 46D
pH
Iron (mg/L)
DATE
pH
Fe

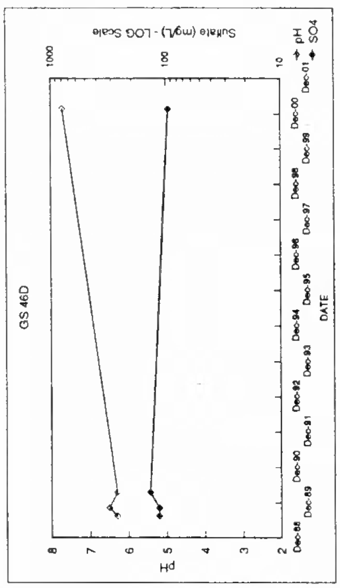

GS 46S
pH
Iron (mg/L)
DATE
pH
Fe

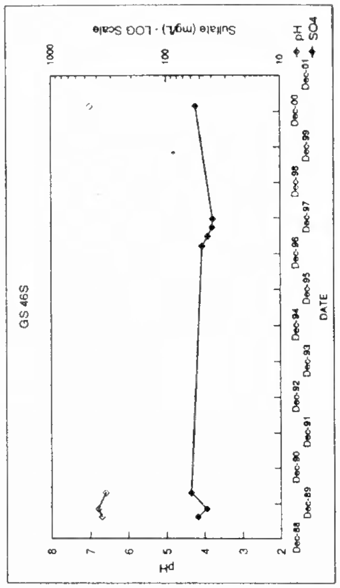

GS 45
pH
Zinc (ug/L) - LOG scale
DATE
no pH reported
pH
Zn

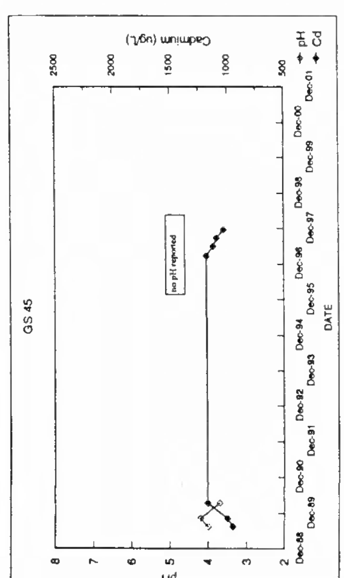

GS 46D
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

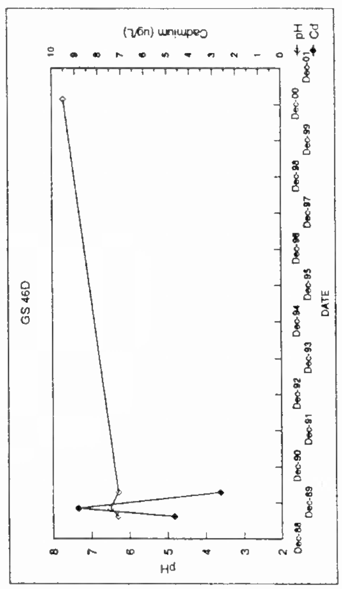

GS 46S
pH
Zinc (ug/L) - LOG scale
DATE
pH
Zn

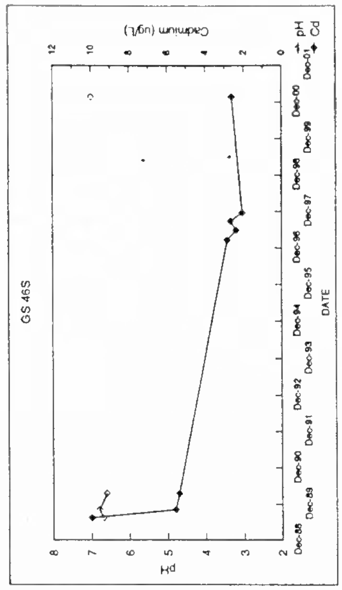

GS 45
pH
Sulfate (mg/L) - LOG Scale
DATE
no pH reported
pH
SO4

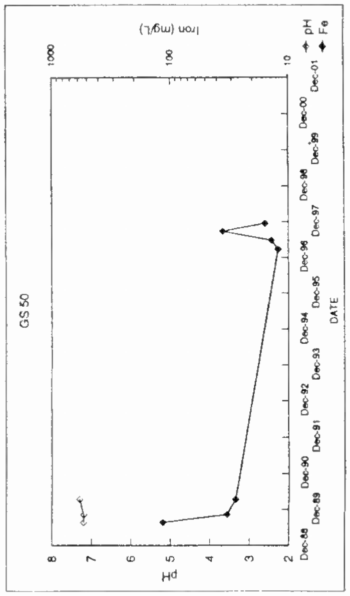

GS 46D
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

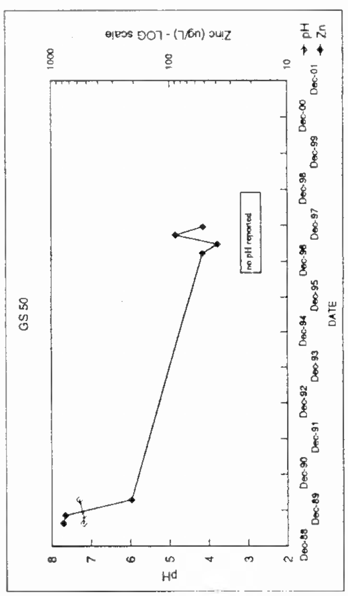

GS 46S
pH
Sulfate (mg/L) - LOG Scale
DATE
pH
SO4

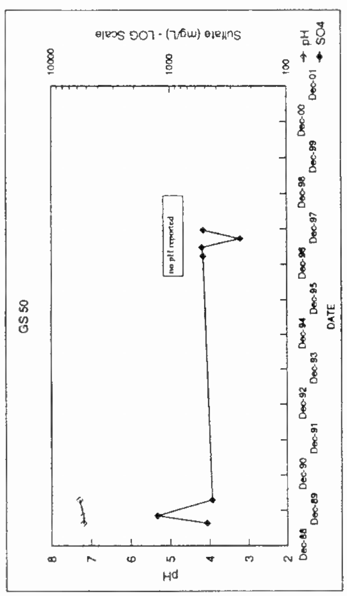

GS 45
pH
Cadmium (ug/L)
DATE
no pH reported
pH
Cd

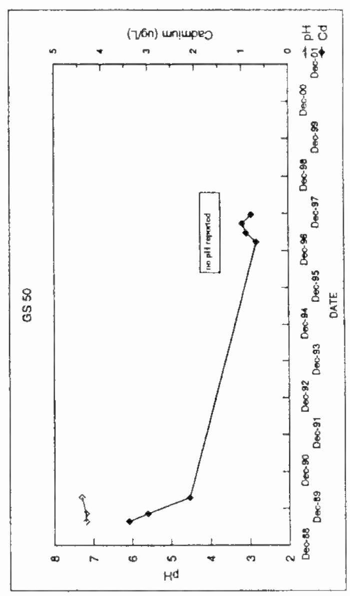

GS 46D
pH
Cadmium (ug/L)
DATE
pH
Cd

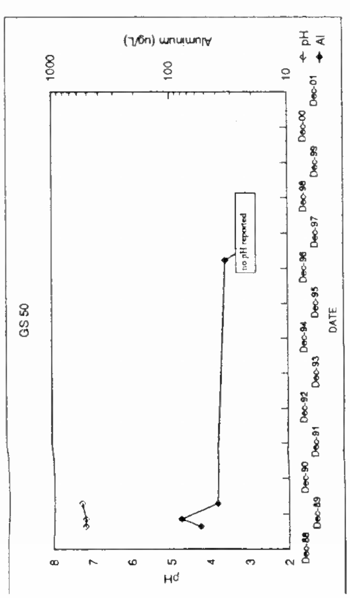

GS 46S
pH
Cadmium (ug/L)
DATE
pH
Cd

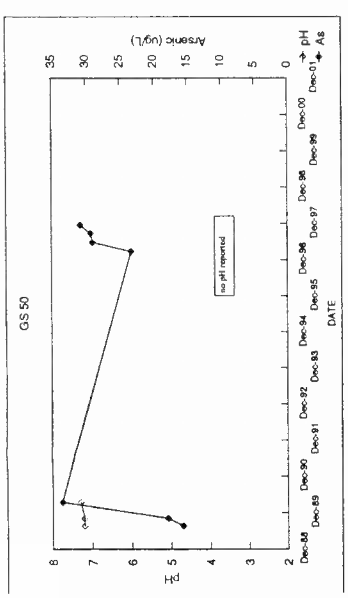

GS 50
pH
Iron (mg/L)
DATE
pH
Fe

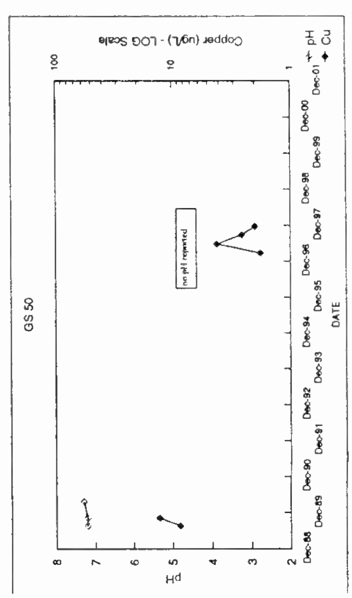

GS 50
pH
Zinc (ug/L) - LOG scale
DATE
no pH reported
pH
Zn


GS 50
pH
Sulfate (mg/L) - LOG Scale
DATE
no pH reported
pH
SO4

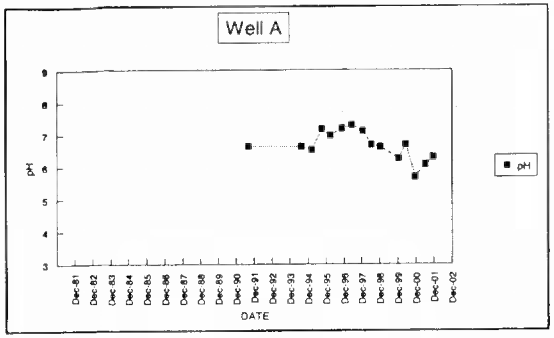

GS 50
pH
Cadmium (ug/L)
DATE
no pH reported
pH
Cd

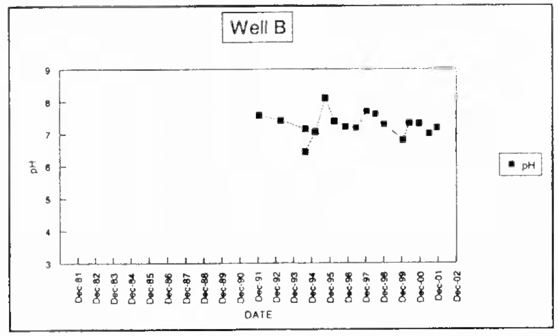

GS 50
pH
Aluminum (ug/L)
DATE
no pH reported
pH
Al

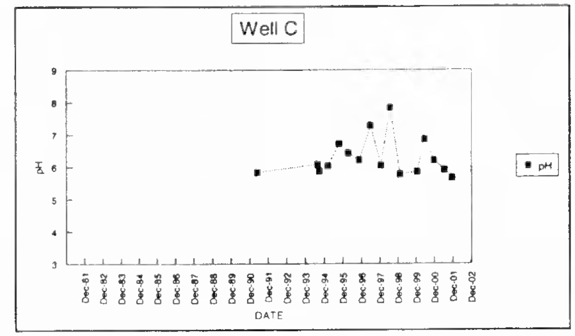

GS 50
pH
Arsenic (ug/L)
DATE
no pH reported
pH
As

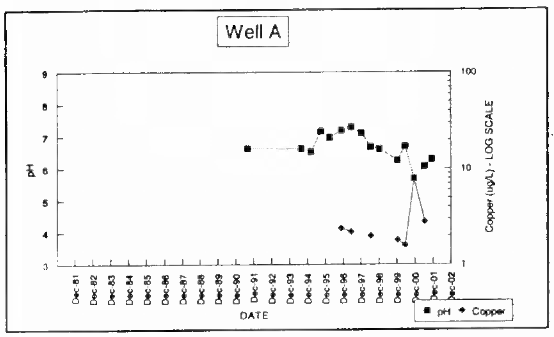

GS 50
pH
Copper (ug/L) - LOG Scale
DATE
no pH reported
pH
Cu

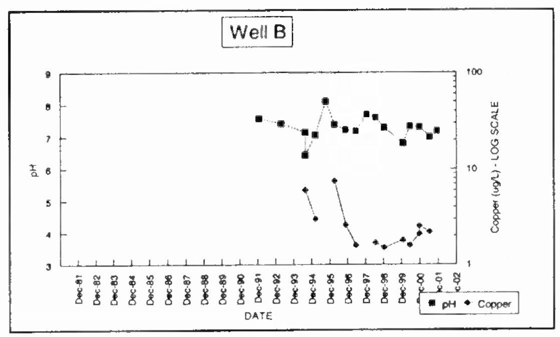
APPENDIX B

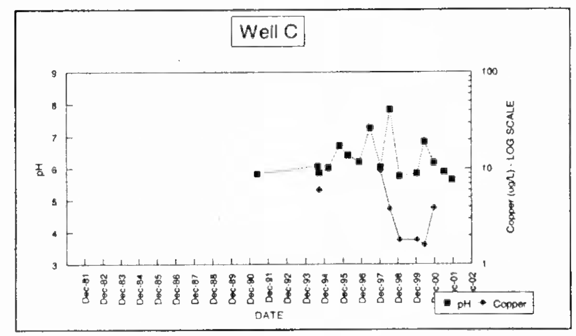

Well A
pH
DATE

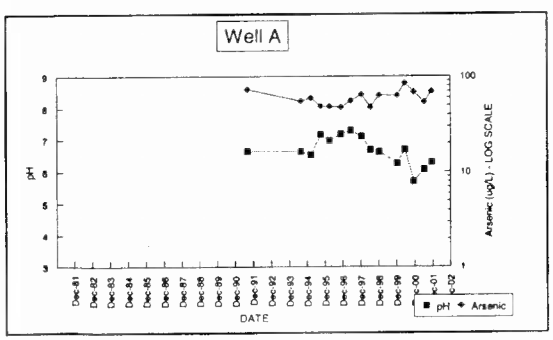

Well B
pH
DATE

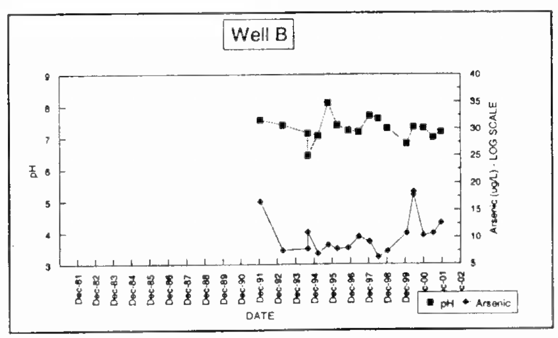

Well C
pH
DATE

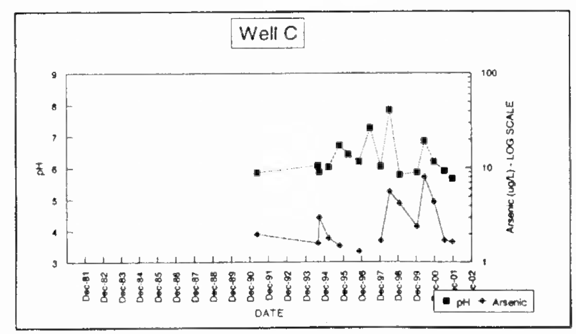

Well A
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

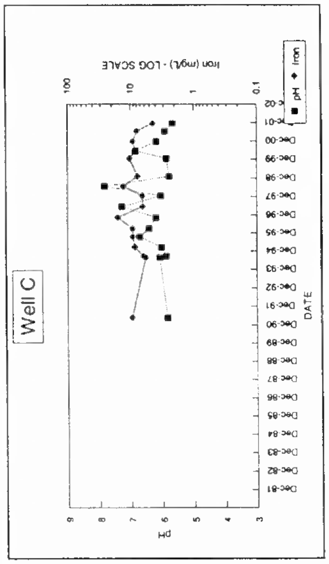

Well B
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

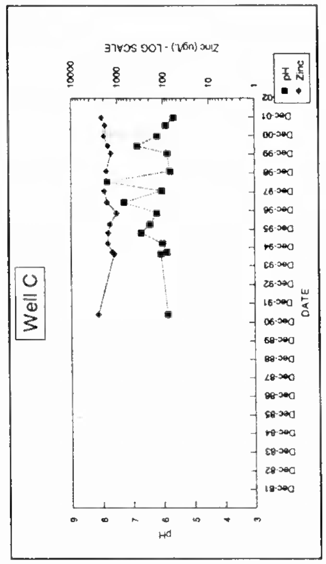

Well C
pH
Copper (ug/L) - LOG SCALE
DATE
pH
Copper

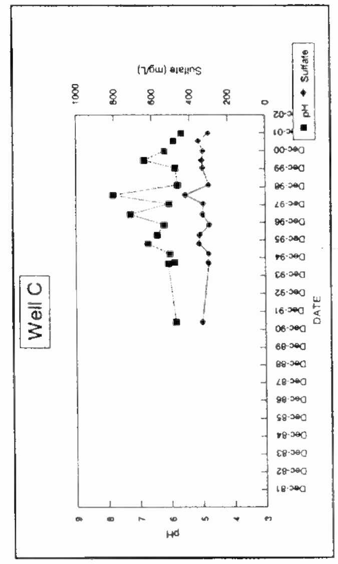

Well A
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

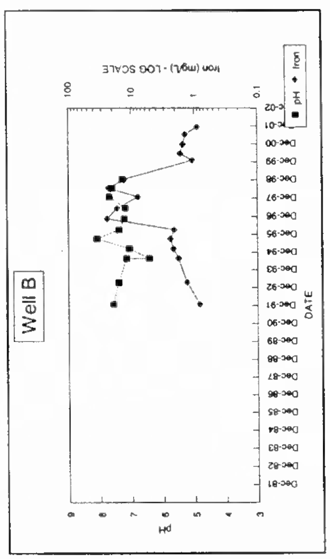

Well B
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

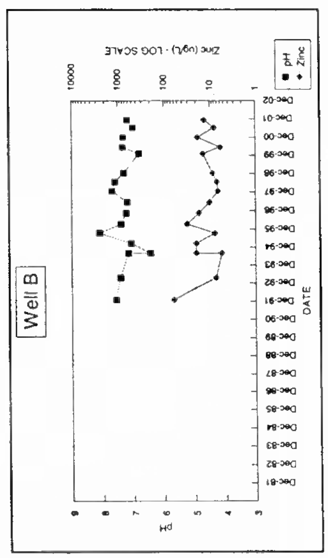

Well C
pH
Arsenic (ug/L) - LOG SCALE
DATE
pH
Arsenic

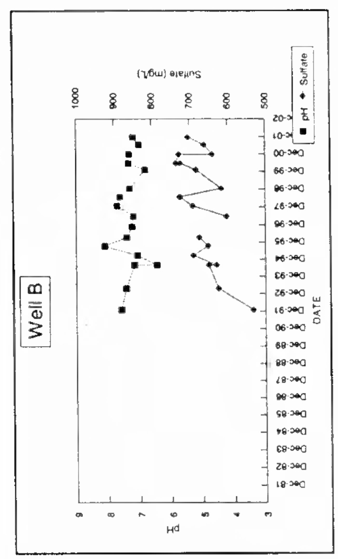

Well C
Iron (mg/L) - LOG SCALE
pH
DATE
pH
Iron

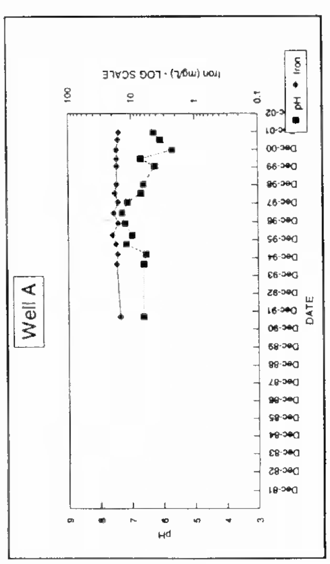

Well C
Zinc (ug/L) - LOG SCALE
pH
DATE
pH
Zinc

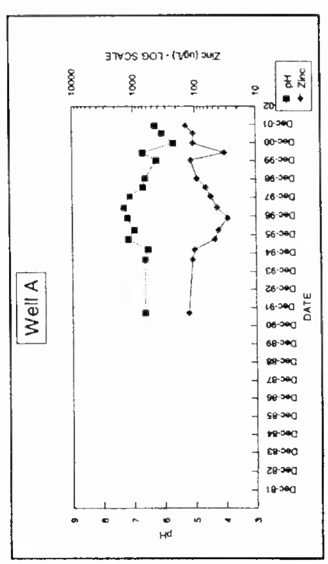

Well C
Sulfate (mg/L)
pH
DATE
pH
Sulfate

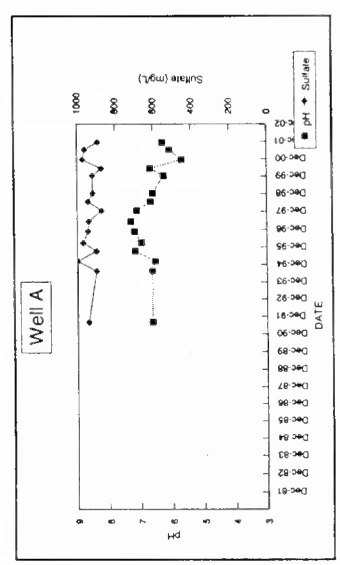

Well B
Iron (mg/L) - LOG SCALE
pH
DATE
pH
Iron

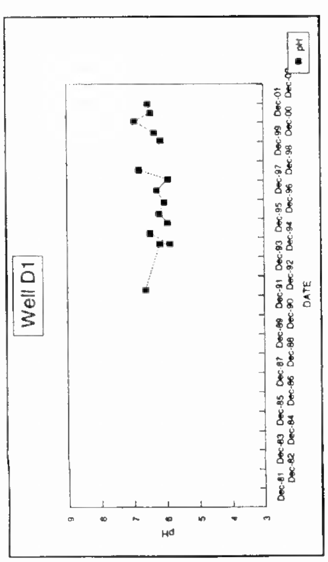

Well B
Zinc (ug/L) - LOG SCALE
pH
DATE
pH
Zinc

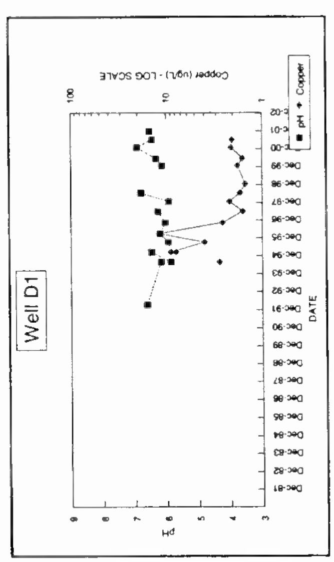

Well B
Sulfate (mg/L)
pH
DATE
pH
Sulfate

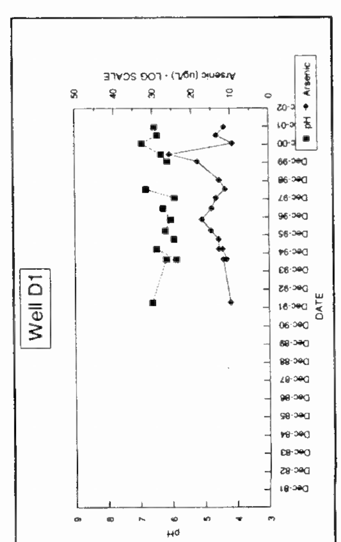

Well A
Iron (mg/L) - LOG SCALE
pH
DATE
pH
Iron

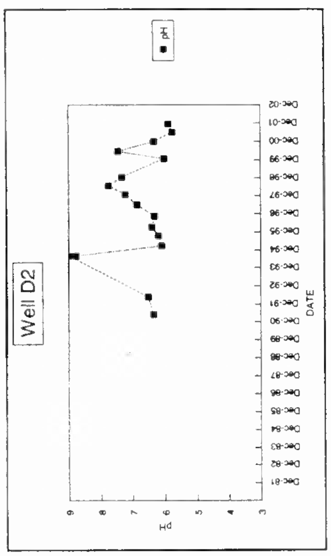

Well A
Zinc (ug/L) - LOG SCALE
pH
DATE
pH
Zinc

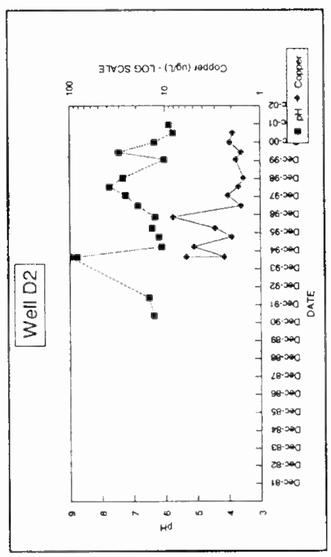

Well A
Sulfate (mg/L)
pH
DATE
pH
Sulfate

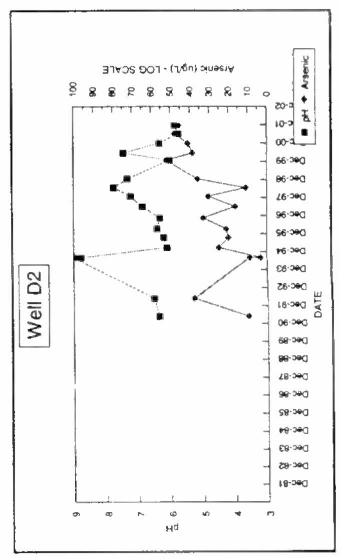

Well D1
pH
DATE
pH

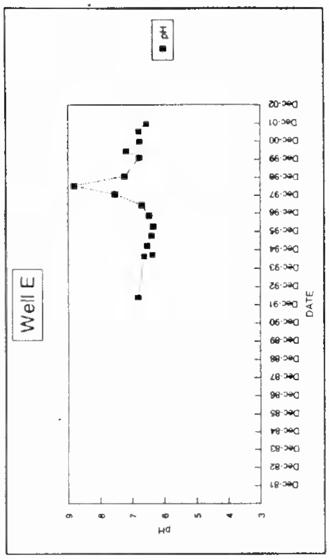

Well D1
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper

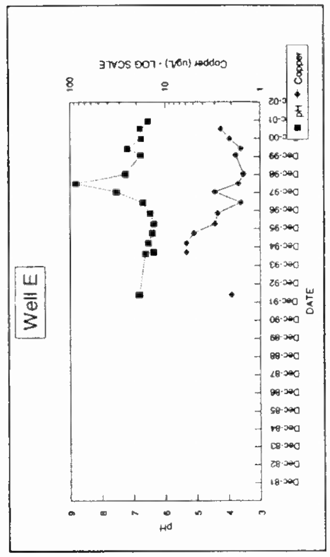

Well D1
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic

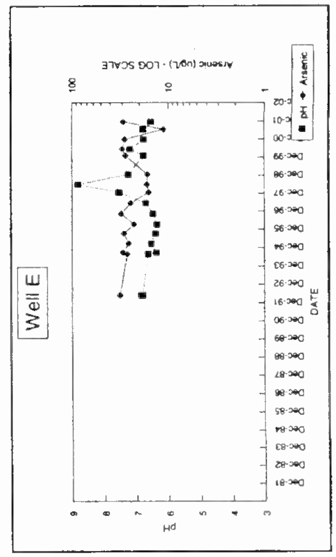

Well D2
pH
DATE
pH

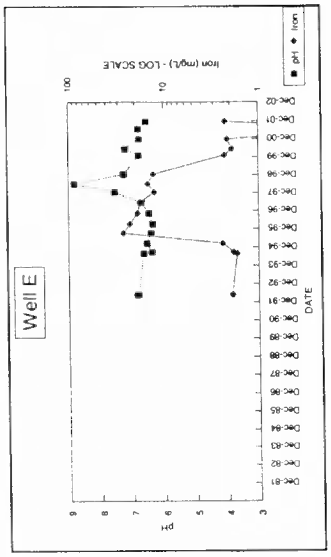

Well D2
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper

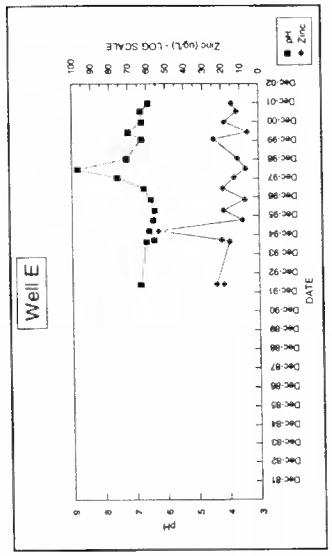

Well D2
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic


Well E
pH
DATE
pH


Well E
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper


Well E
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic


Well E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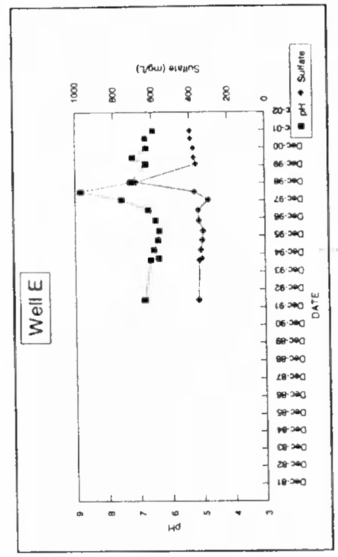
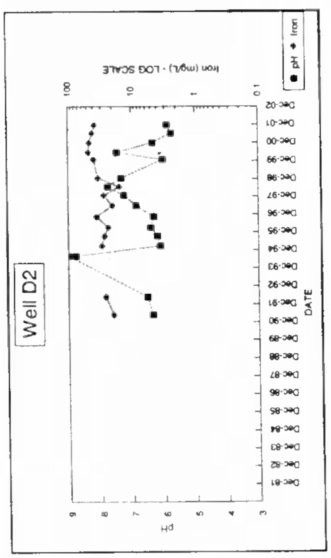
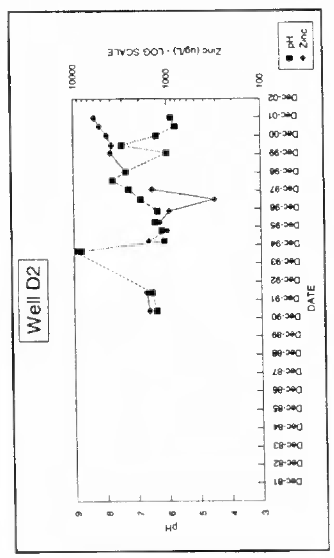
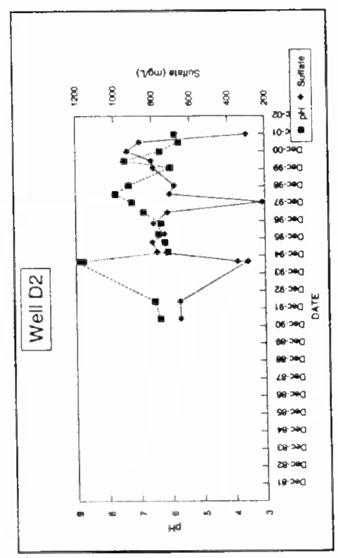
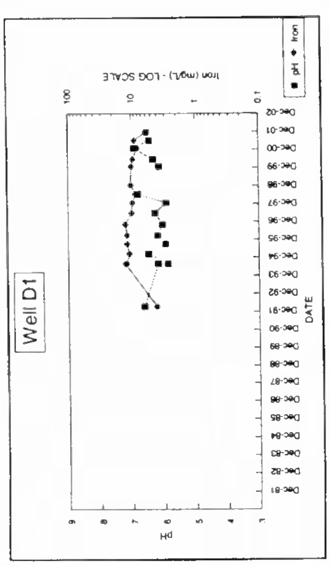
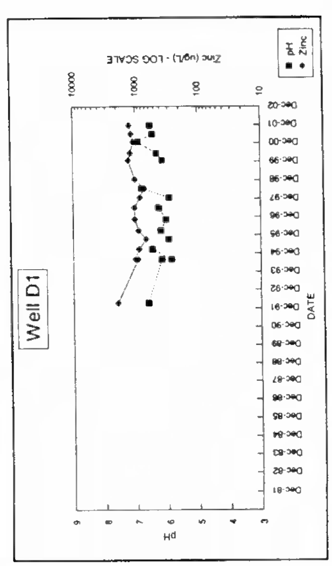

Well E

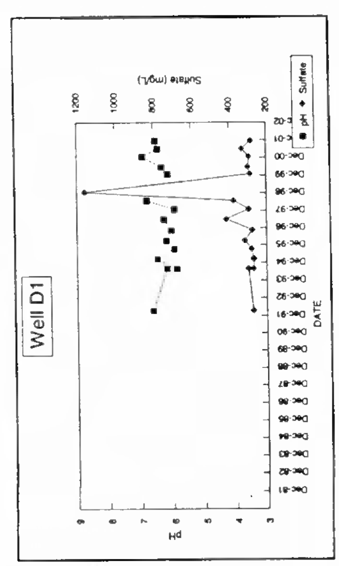

Well D2

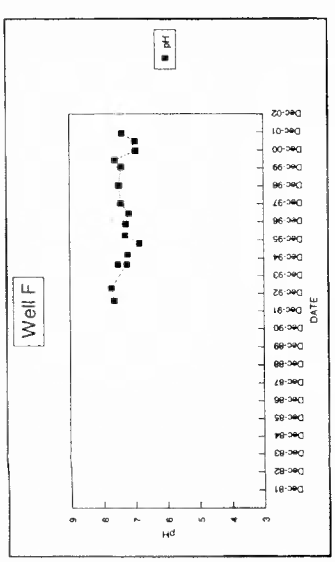

Well D2

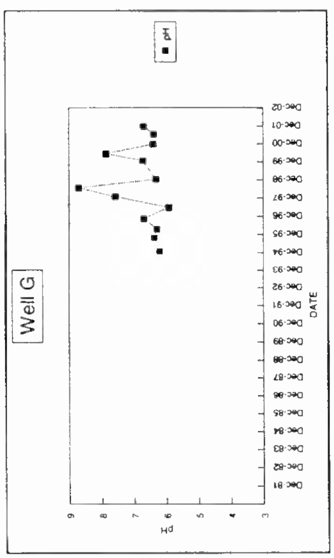

Well D2

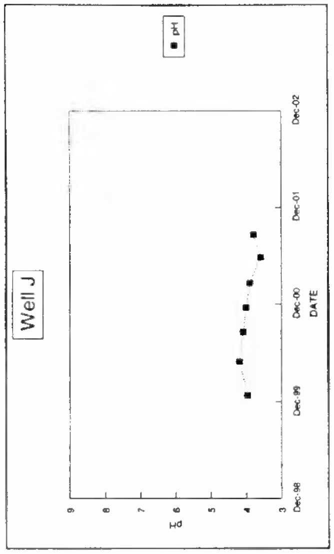

Well D1

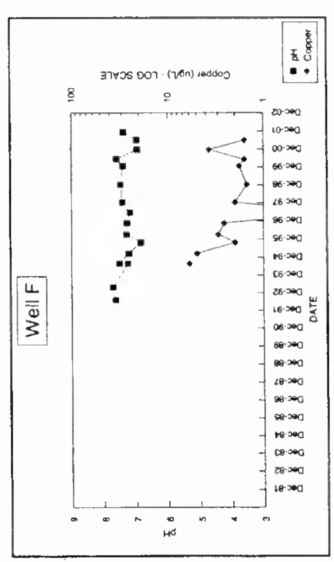

Well D1

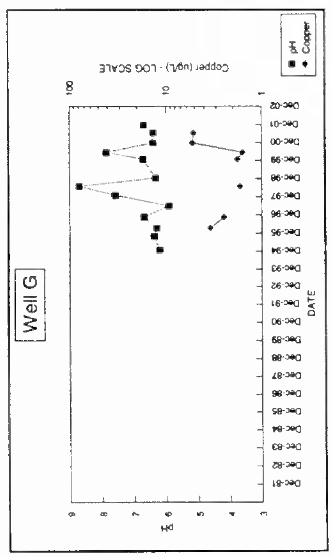

Well D1

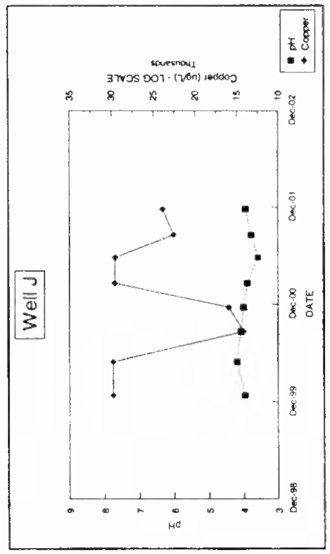

Well F
pH
DATE
■ pH

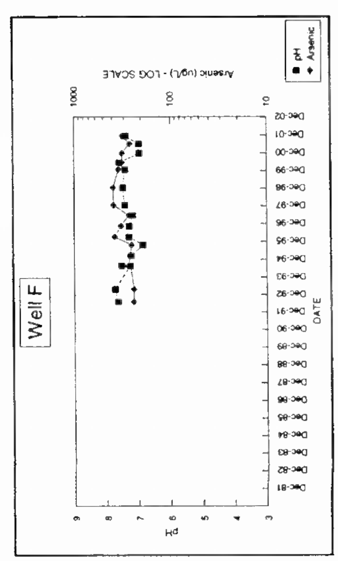

Well G
pH
DATE
■ pH

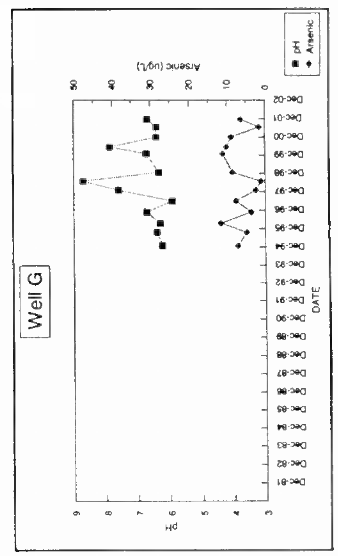

Well J
pH
DATE
■ pH

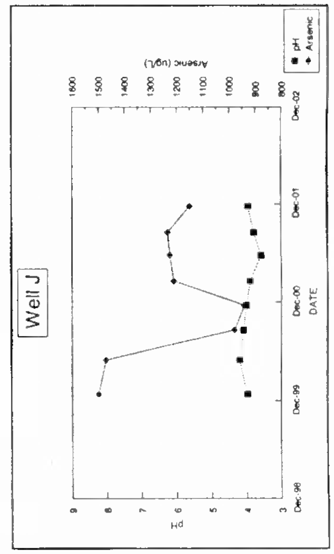

Well F
pH
DATE
Copper (ug/L) - LOG SCALE
■ pH
◆ Copper

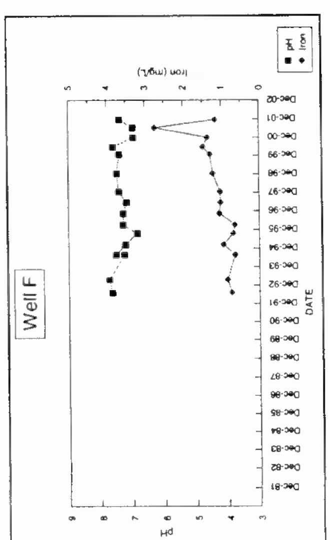

Well G
pH
DATE
Copper (ug/L) - LOG SCALE
■ pH
◆ Copper

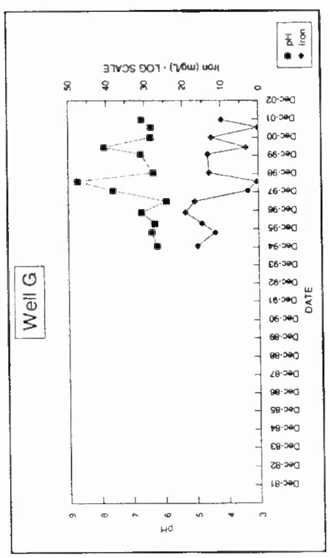

Well J
pH
DATE
Copper (ug/L) - LOG SCALE
Thousands
■ pH
◆ Copper

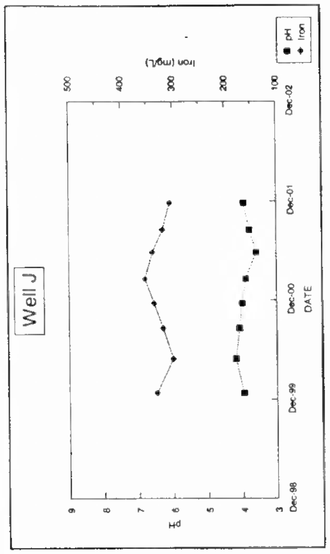

Well F
pH
DATE
Arsenic (ug/L) - LOG SCALE
■ pH
◆ Arsenic

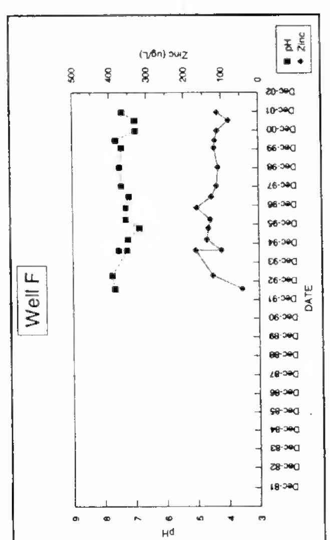

Well G
pH
DATE
Arsenic (ug/L)
■ pH
◆ Arsenic

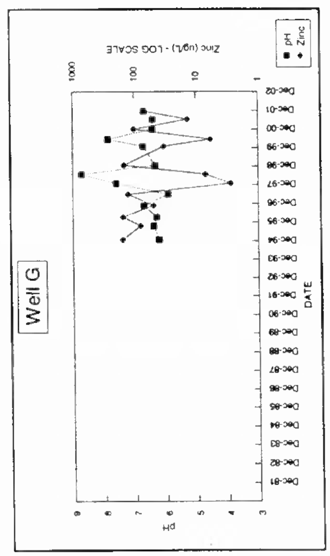

Well J
pH
DATE
Arsenic (ug/L)
■ pH
◆ Arsenic

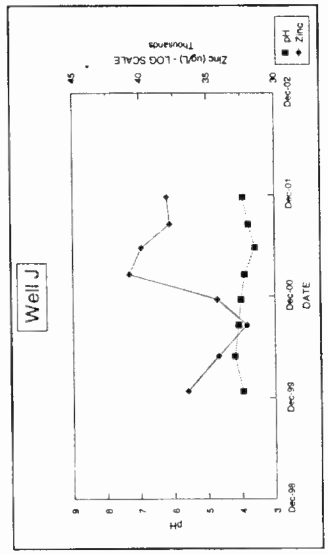

Well F
pH
Iron (mg/L)
DATE
pH
Iron

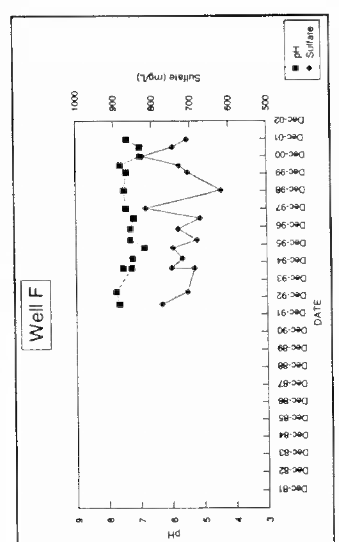

Well G
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

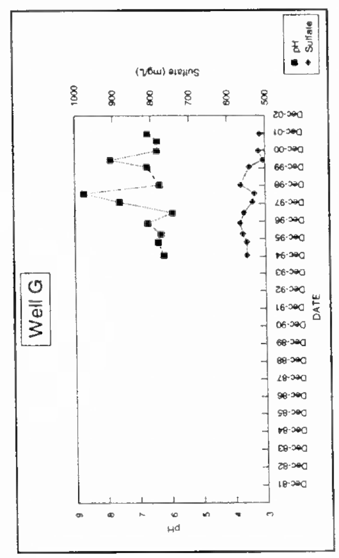

Well J
pH
Iron (mg/L)
DATE
pH
Iron

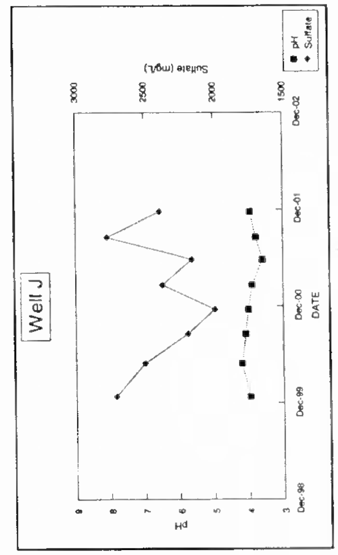

Well F
pH
Zinc (ug/L)
DATE
pH
Zinc

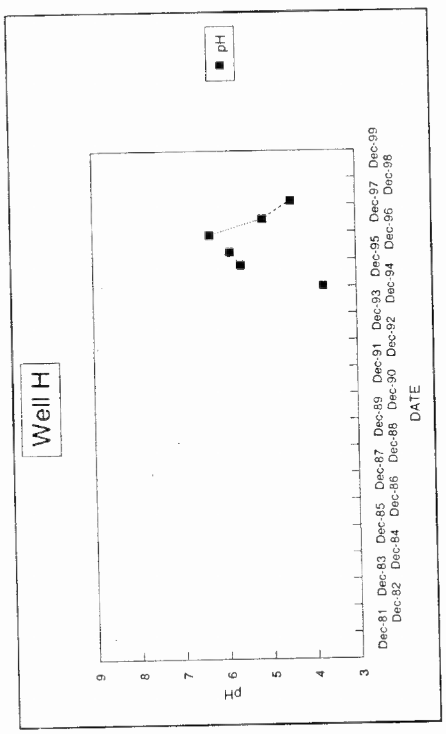

Well G
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

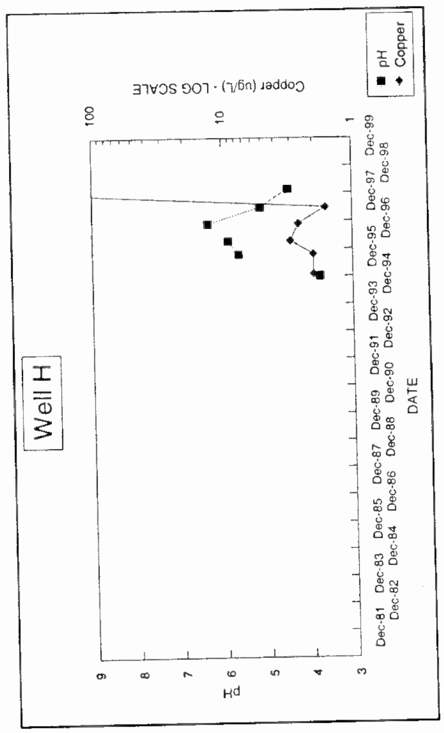

Well J
pH
Zinc (ug/L) - LOG SCALE
Thousands
DATE
pH
Zinc

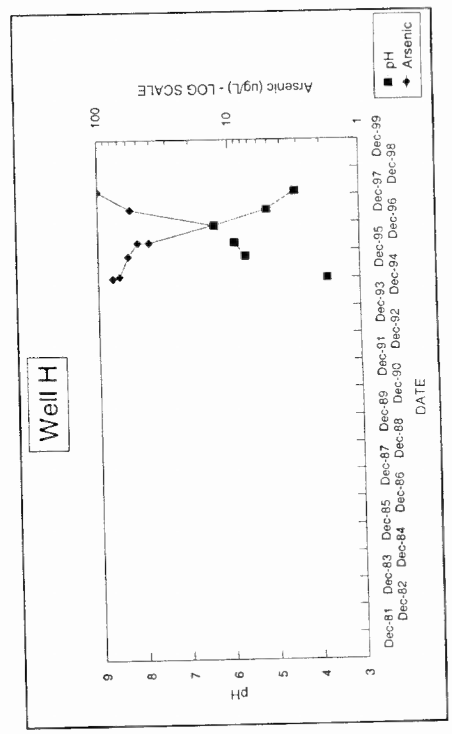

Well F
pH
Sulfate (mg/L)
DATE
pH
Sulfate

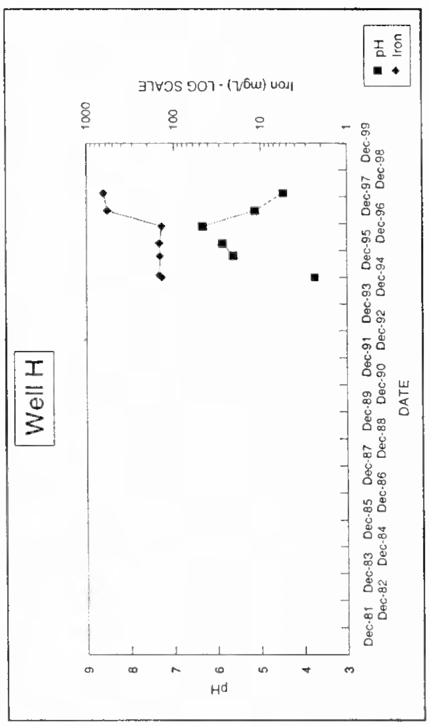

Well G
pH
Sulfate (mg/L)
DATE
pH
Sulfate


Well J
pH
Sulfate (mg/L)
DATE
pH
Sulfate

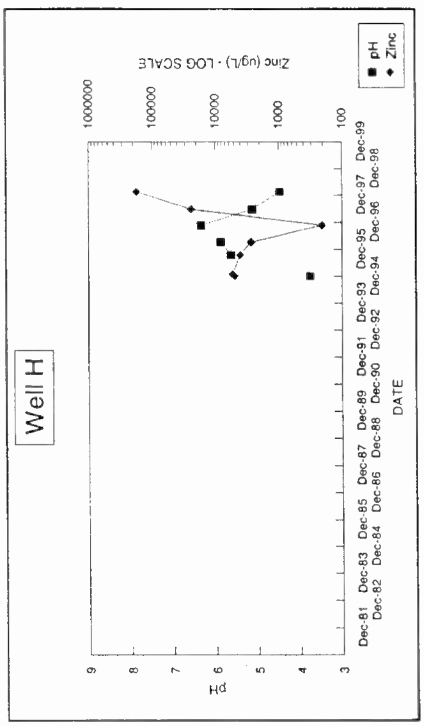

Well H
pH
DATE
Dec-81 Dec-83 Dec-85 Dec-87 Dec-89 Dec-91 Dec-93 Dec-95 Dec-97 Dec-99
Dec-82 Dec-84 Dec-86 Dec-88 Dec-90 Dec-92 Dec-94 Dec-96 Dec-98
pH


Well H
pH
Copper (ug/L) - LOG SCALE
DATE
Dec-81 Dec-83 Dec-85 Dec-87 Dec-89 Dec-91 Dec-93 Dec-95 Dec-97 Dec-99
Dec-82 Dec-84 Dec-86 Dec-88 Dec-90 Dec-92 Dec-94 Dec-96 Dec-98
pH
Copper

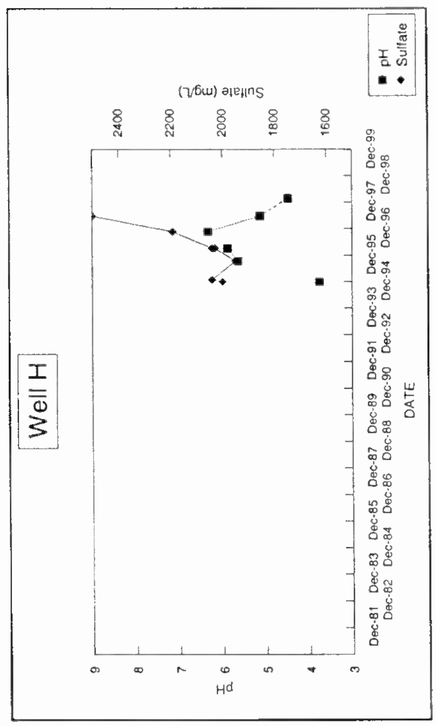

Well H
pH
Arsenic (ug/L) - LOG SCALE
DATE
Dec-81 Dec-83 Dec-85 Dec-87 Dec-89 Dec-91 Dec-93 Dec-95 Dec-97 Dec-99
Dec-82 Dec-84 Dec-86 Dec-88 Dec-90 Dec-92 Dec-94 Dec-96 Dec-98
pH
Arsenic



Well H
pH
Iron (mg/L) - LOG SCALE
pH
Iron
DATE

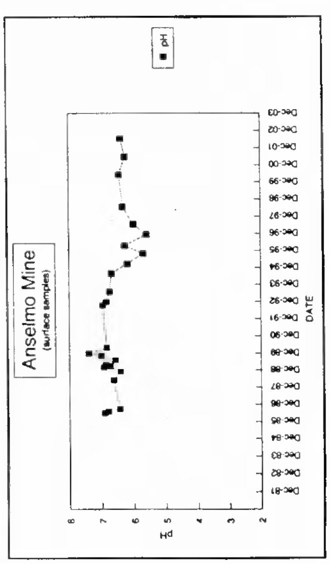


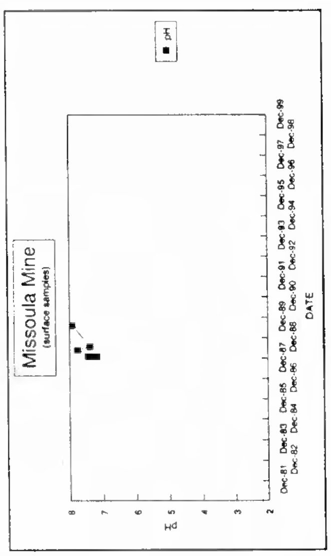
Well H
pH
Zinc (ug/L) - LOG SCALE
pH
Zinc
DATE

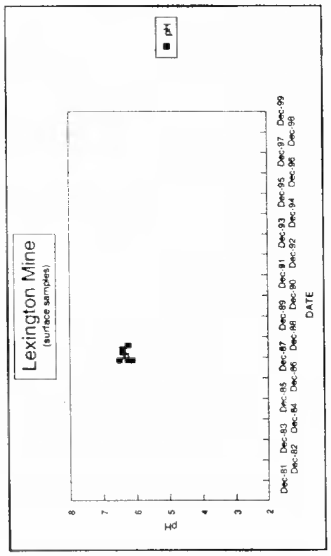


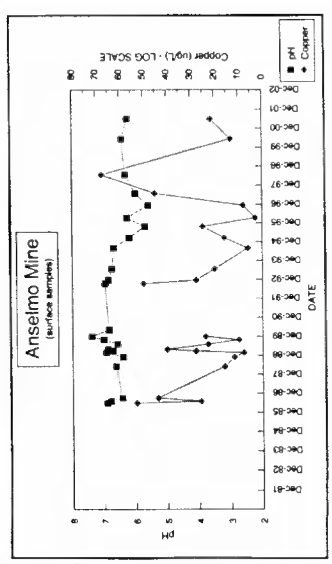
Well H
pH
Sulfate (mg/L)
pH
Sulfate
DATE

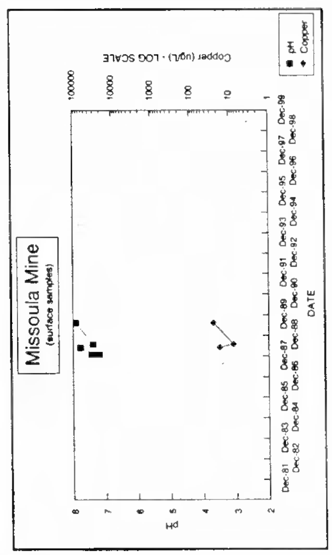
APPENDIX C

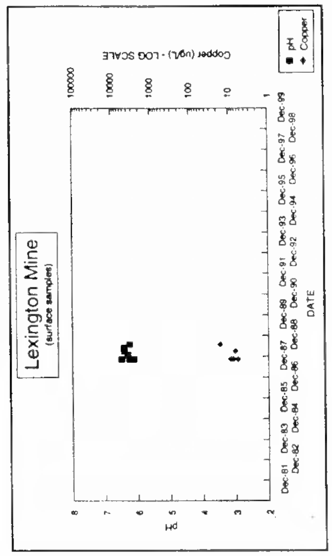

Anselmo Mine
(surface samples)
pH
DATE

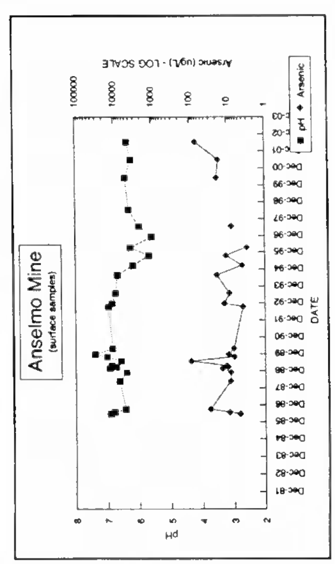

Missoula Mine
(surface samples)
pH
DATE

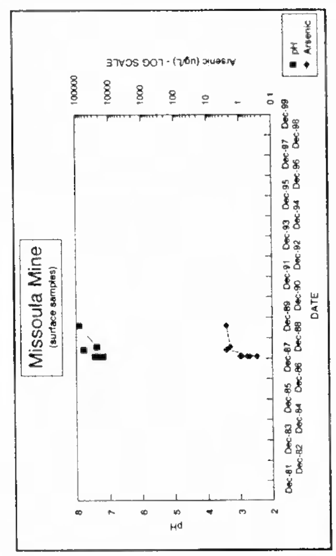

Lexington Mine
(surface samples)
pH
DATE

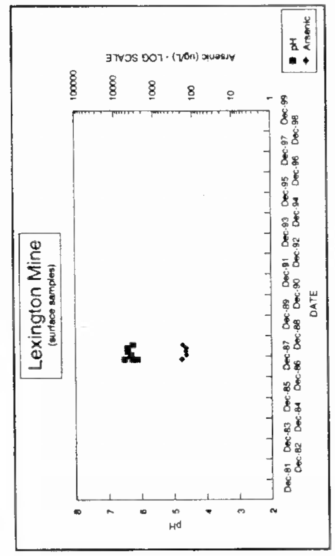

Anselmo Mine
(surface samples)
pH
Copper
Copper (ug/L) - LOG SCALE
DATE

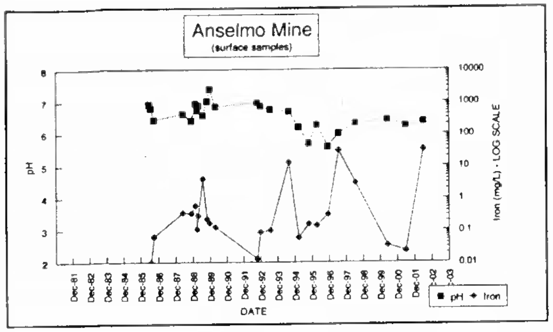

Missoula Mine
(surface samples)
pH
Copper
Copper (ug/L) - LOG SCALE
DATE

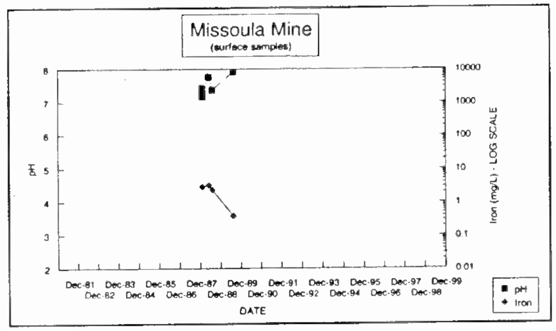

Lexington Mine
(surface samples)
pH
Copper
Copper (ug/L) - LOG SCALE
DATE

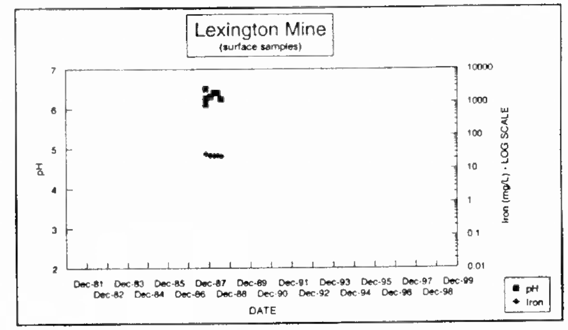

Anselmo Mine
(surface samples)
pH
Arsenic
Arsenic (ug/L) - LOG SCALE
DATE

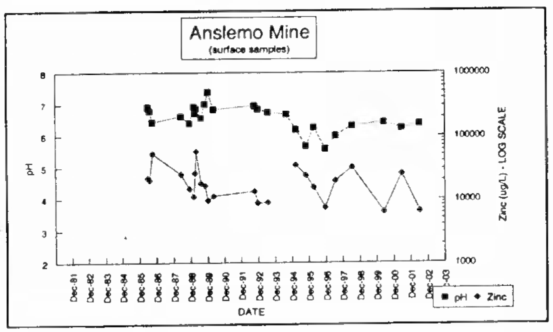

Missoula Mine
(surface samples)
pH
Arsenic
Arsenic (ug/L) - LOG SCALE
DATE

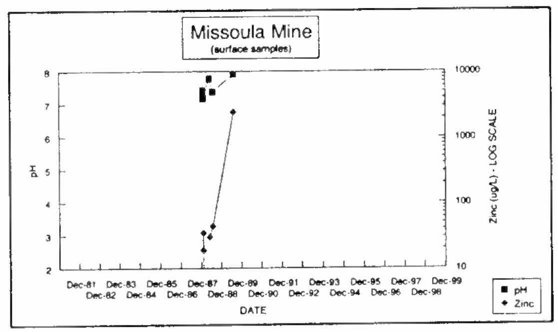

Lexington Mine
(surface samples)
pH
Arsenic
Arsenic (ug/L) - LOG SCALE
DATE

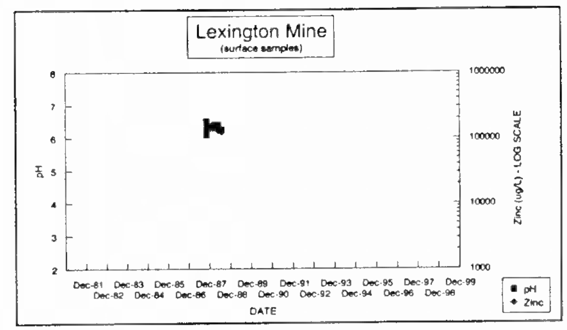

Anselmo Mine
(surface samples)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

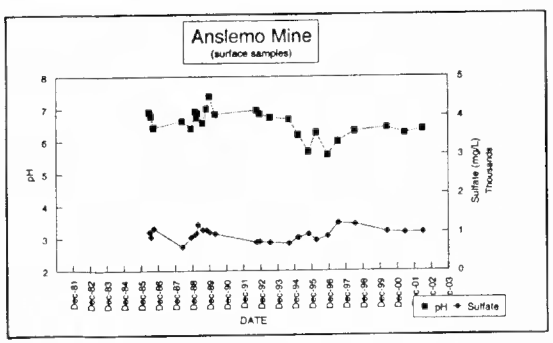

Missoula Mine
(surface samples)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

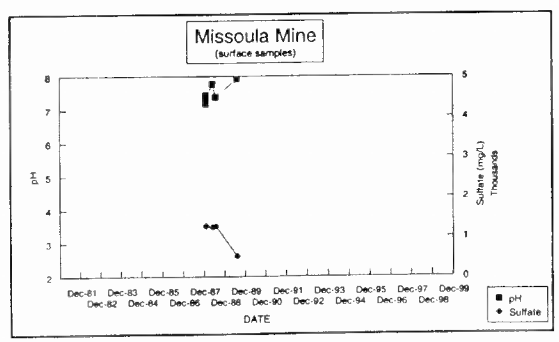

Lexington Mine
(surface samples)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

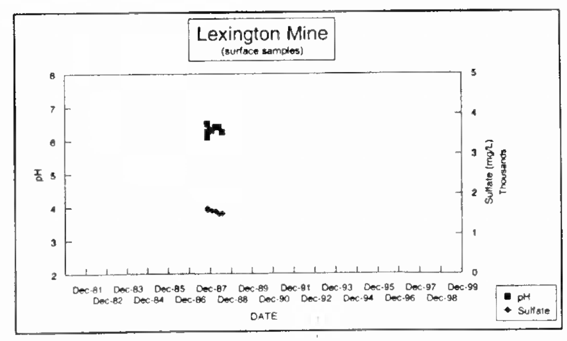

Anslemo Mine
(surface samples)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

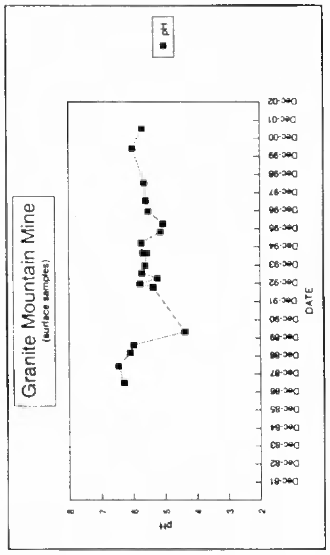

Missoula Mine
(surface samples)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

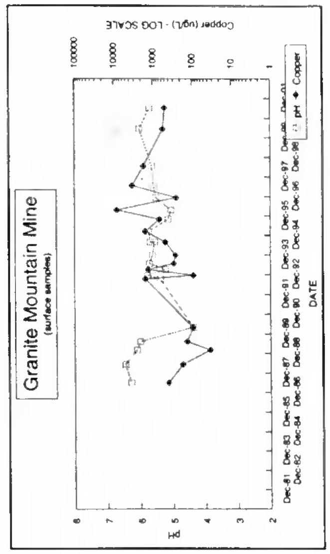

Lexington Mine
(surface samples)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

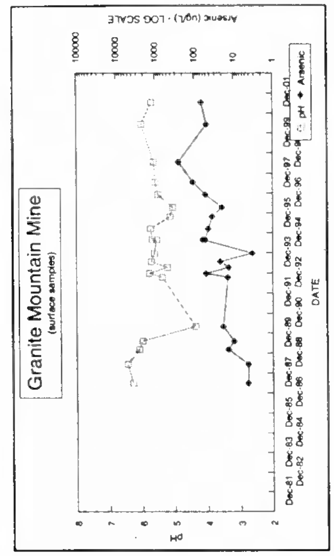

Anslemo Mine
(surface samples)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate

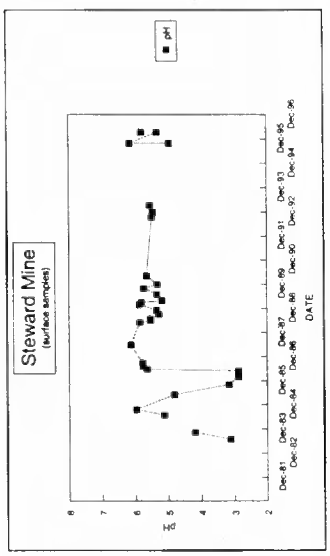

Missoula Mine
(surface samples)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate

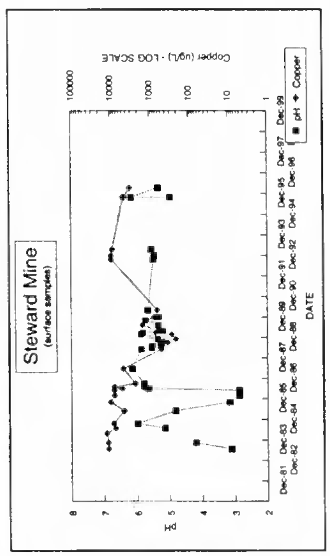

Lexington Mine
(surface samples)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate

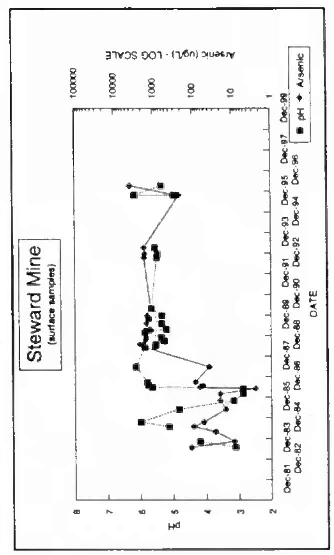

Granite Mountain Mine
(surface samples)
pH
DATE

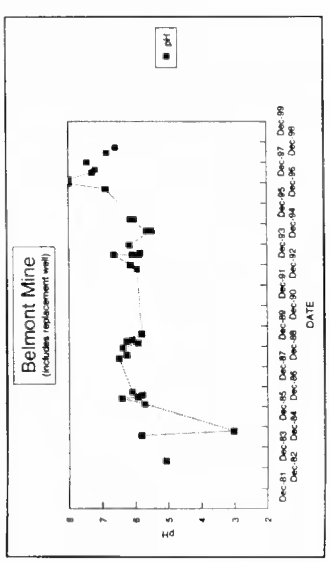

Granite Mountain Mine
(surface samples)
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper

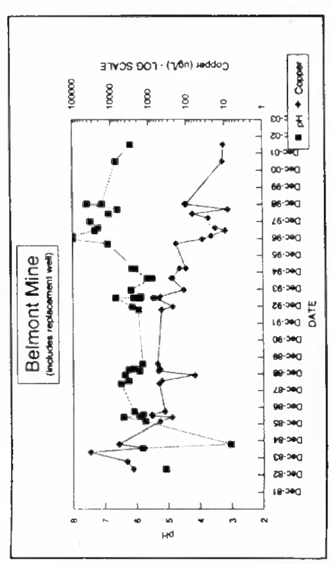

Granite Mountain Mine
(surface samples)
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic

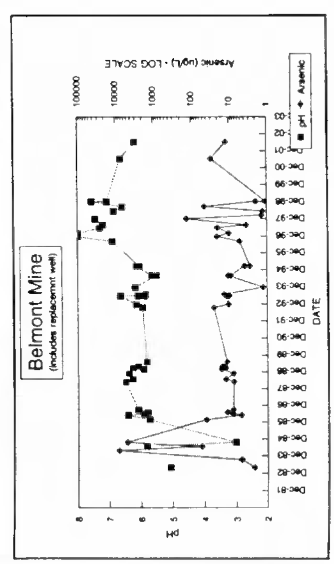

Steward Mine
(surface samples)
pH
DATE

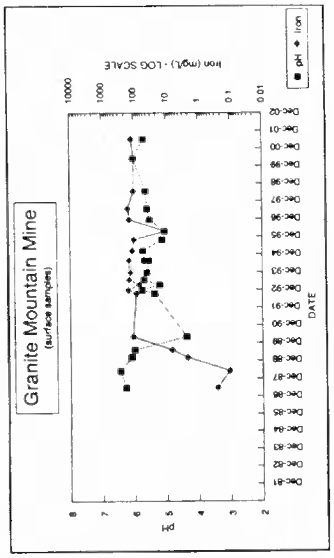

Steward Mine
(surface samples)
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper

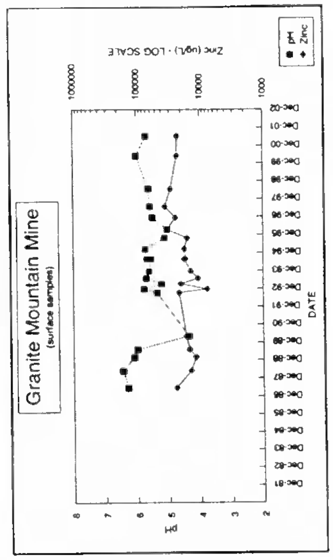

Steward Mine
(surface samples)
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic

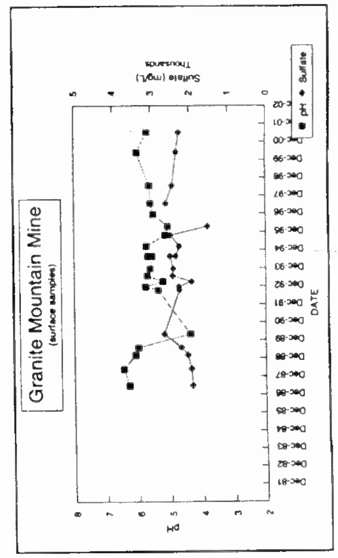

Belmont Mine
(includes replacement well)
pH
DATE

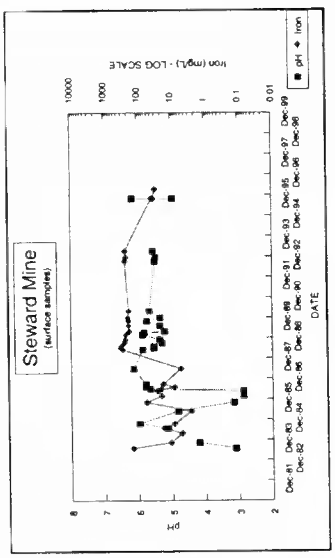

Belmont Mine
(includes replacement well)
pH
DATE
Copper (ug/L) - LOG SCALE
pH
Copper

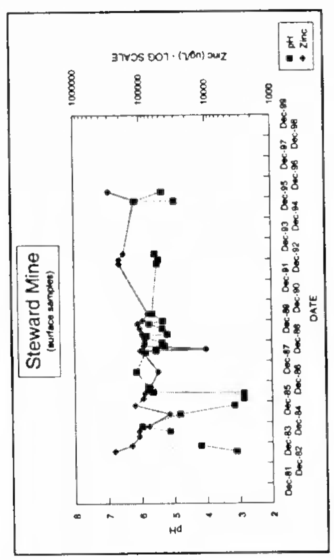

Belmont Mine
(includes replacement well)
pH
DATE
Arsenic (ug/L) - LOG SCALE
pH
Arsenic

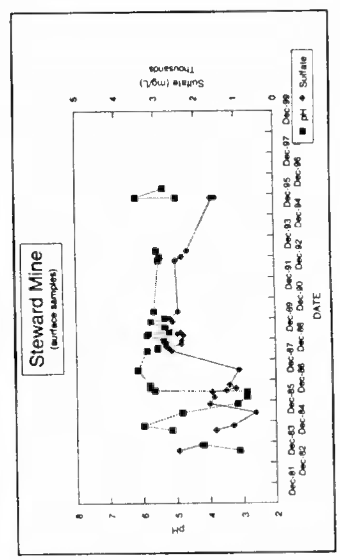

Granite Mountain Mine
(surface samples)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron

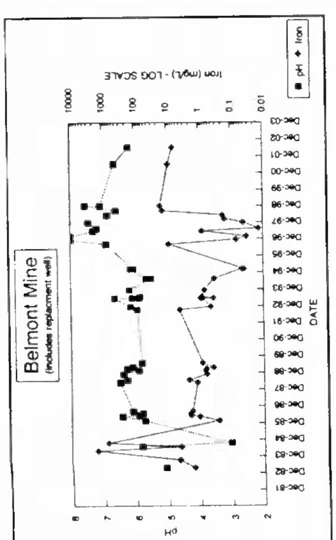

Granite Mountain Mine
(surface samples)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc

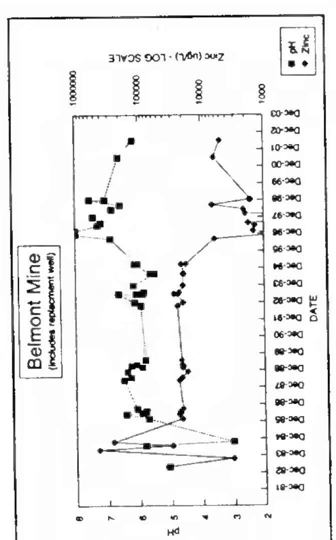

Granite Mountain Mine
(surface samples)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate

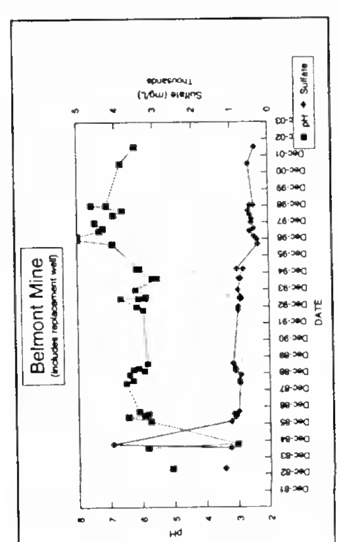

Steward Mine
(surface samples)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron


Steward Mine
(surface samples)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc


Steward Mine
(surface samples)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate


Belmont Mine
(includes replacement well)
pH
Iron (mg/L) - LOG SCALE
DATE
pH
Iron


Belmont Mine
(includes replacement well)
pH
Zinc (ug/L) - LOG SCALE
DATE
pH
Zinc


Belmont Mine
(includes replacement well)
pH
Sulfate (mg/L)
Thousands
DATE
pH
Sulfate