2003 Update of Water-Level Monitoring and Water-Quality Sampling
Butte Underground Mines and Berkeley Pit
Butte, Montana
1982 – 2003

Horseshoe Bend-Berkeley Pit Water Treatment Plant, MBMG Archives

prepared for

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

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Executive Summary

The Record of Decision and Consent Decree for the Butte Mine Flooding Operable Unit stipulates that a yearly update of data collected from the Post Remedial Investigation/Feasibility Study and Consent Decree 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 2003, combined with data collected since 1982, when ARCO suspended underground mine dewatering and mining in the Berkeley Pit.

Major new observations and developments discussed in this report are:

1. Montana Resources resumption of mining and its impact on water levels and monitoring activities.

2. Inflow of water from the Horseshoe Bend Drainage into the Berkeley Pit continued through mid-November 2003. This inflow continued the increased rate of rise of water levels in the Berkeley Pit and associated underground mines.

3. Completion of the Horseshoe Bend water treatment plant and the diversion of water away from the Berkeley Pit occurred the later part of November 2003.

4. 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 2003 was about 7 percent less than 2002 (231 vs. 247 acre-feet). With less water pumped during 2003, the water level rose between 0.8 and 1.5 feet throughout the system.

5. The annual Berkeley Pit model update was not updated this year due to limited changes in mining operations. The date projected in the 2002 report of 2018 when 5,410-foot water-level elevation would be reached at the Anselmo Mine was considered to still be a valid projection.

6. Water-quality changes seen in East Camp alluvial wells. Well LP-9 had a tremendous increase in metal concentrations since it was last sampled during the RI/FS (11 years ago).

Water-level and water-quality data are presented in the same order and manner as the previous reports (Duaime, T.E., 1998; Duaime, T.E., Metesh, J.J., 2000; Duaime, T.E., 2001; Metesh, J.J., Duaime, T.E., 2002; Duaime, T.E., Metesh, J.J., 2003; and Duaime, T.E., Metesh, J.J., 2004) 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.

The 2003 monitoring program reflected the monitoring and sampling activities outlined in the 2002 Consent Decree. Therefore, some monitoring sites have been deleted from the program, while others have been added.

List of Acronyms

EPA	U.S. Environmental Protection Agency
DEQ	Montana Department of Environmental Quality
ROD	Record of Decision
CD	Consent Decree
MBMG	Montana Bureau of Mines and Geology
BMFOU	Butte Mine Flooding Operable Unit
RI/FS	Remedial Investigation/Feasibility Study
BP/ARCO	British Petroleum/Atlantic Richfield Company
MR	Montana Resources
HSB	Horseshoe Bend
HSB Falls	Horseshoe Bend Falls
MCL	Maximum Contaminant Level
SMCL	Secondary Maximum Contaminant Level
CWL	Critical Water Level

2003 Consent Decree Update
Water-Level Monitoring and Water-Quality Sampling:
Butte Underground Mines and Berkeley Pit,
Butte, Montana

1982 – 2003

SECTION 1.0 SITE BACKGROUND

Butte, Montana has been a center of underground mining since the 1870s and handling ground water became a standard operation as underground mining expanded. The Anaconda Copper Mining Company began interconnecting selected mine levels in an effort to establish a common mine level for draining water to a central pump station, as early as 1901. Water was drained to these common levels through a combination of stopes, drifts, or diamond-drill drainage holes. Daly (1923) stated that up to 28 mines were dewatered this way. Prior to the 1966-1967 construction of a new pump station at the Kelley Mine, water was drained to the High Ore Mine where water was collected and pumped to the surface (Miller, 1973). 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 (fig. 1-1). When 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 begin filling with water, the Kelley pump station was removing up to 5,000 gallons per minute of water. Allowing water in the underground mines to rise resulted in a corresponding rise in water levels in the bedrock adjacent to the mines. Other contaminated surface water was diverted into the Berkeley Pit, which also started to fill with metal-laden water. Water levels in the underground mines rose over 1300 feet during the remainder of 1982 and over 800 feet in 1983.

The full nature of the influence that historic mine dewatering had on the local ground-water 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 and settlement agreements.

The Butte Mine Flooding Operable Unit (BMFOU) Remedial Investigation/Feasibility Study (RI/FS) began in 1990 and resulted in the 1994 Record of Decision (ROD) (EPA, 1994). The ROD included provisions for: (1) continued monitoring and sampling of both ground water and surface water, (2) diversion of the Horseshoe Bend Drainage (HSB) water away from the Berkeley Pit (to slow the pit filling rate), (3) incorporation of the HSB water in the Montana Resources (MR) mining operations for treatment, (4) construction of a water treatment plant if changes in mining operations (e.g. mine shutdown) prevent treatment of HSB water, and (5) establishment of a maximum level to which water in the underground mines and Berkeley Pit can rise, before a water treatment plant must be built and in operation.

The U.S. Environmental Protection Agency (EPA) and Montana Department of Environmental Quality (DEQ) began Consent Decree (CD) negotiations with British Petroleum/Atlantic Richfield Company (BP/ARCO) and the Montana Resources Group in the fall of 2001, culminating in an agreement being approved by the U.S. District Court in August 2002. The CD addressed all the current and future activities relating to the BMFOU and providing reimbursement to the EPA and DEQ for past costs associated with the site. Funding for the continuation of the long-term ground-water, surface-water, and Berkeley Pit/Continental Pit monitoring were included in the CD. The monitoring performed by the MBMG is under the direction of DEQ and EPA. BP/ARCO and the Montana Resources Group agreed in the CD to be responsible for all costs associated with the design, construction, operation, and maintenance of a water-treatment plant for treating HSB, Berkeley Pit, and other contaminated waters associated with the site. (Refer to the CD and the Explanation of Significant Differences to see the entire scope of activities addressed in the CD and an explanation of differences from items contained in the 1994 ROD.)

Figure 1-1. Photo showing precipitation plant, leach pads, and flume carrying water from underground mines.

Section 1.1 Introduction

The BMFOU 1994 ROD and subsequent 2002 CD specify that an annual review of water levels and water quality shall 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 seventh such report and focuses on notable changes and trends evident from the cumulative data.

For an overview of the history of mining on the Butte Hill and the Superfund processes that have followed since the EPA designated the flooding underground Butte Mines and Berkeley Pit a Superfund site in 1987, the reader is referred to the Butte Mine Flooding RI/FS, Butte Mine Flooding ROD, Butte Mine Flooding CD, and MBMG Open-File Report No. 376.

Monitoring activities continued in 2003 in the East Camp, West Camp and Outer Camp systems (fig. 1-2). 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 within the interconnected mine workings to separate the West Camp from the East Camp. The Outer Camp system consists of the western and northern extent of mine workings that were connected to the East Camp at some time, but were isolated many decades ago, with water levels returning to or near pre-mining conditions. By the time water levels in the East Camp underground mines reached the elevation of the bottom of the Berkeley Pit, more than 66 percent of the workings were already flooded. More than 90 percent of the underground mine workings have been inundated with water through 2003.

Section 1.2 Notable 2003 Activities and Water-Level and Water-Quality Observations

The five main activities and observations for 2003 are listed below:

1. Montana Resources' (MR) June 30, 2000 suspension of mining and milling operations continued through mid-2003. Plans were announced during the summer of 2003 to restart the Continental Pit and concentrator during the fall of the year. As a result, water was pumped from the Continental Pit to allow mining to resume. Water was also pumped to the Yankee Doodle Tailings Dam to provide make-up water for the concentrator.
2. The Horseshoe Bend (HSB) water treatment plant was completed and brought on-line during November 2003. Water that was flowing into the Berkeley Pit from the HSB drainage was diverted to the treatment plant. Treated water was then sent to the concentrator for use in the milling process. The reduction in water discharging to the Berkeley Pit appeared to slow the pit water-level rise.
3. The Continental Pit was dewatered for mining operations and monthly water-quality sampling of this site was discontinued.

4. West Camp pumping rates were less than previous years, which resulted in a slight water-level increase throughout the West Camp system.
5. East Camp alluvial well LP-9 was sampled for the first time in many years as part of the CD monitoring. Results showed the water to be highly contaminated, which differs from results collected during the RI/FS investigation.

Section 1.3 Precipitation Trends

Precipitation during 2003 continued to be less than average. Total precipitation was 9.67 inches compared to the long-term average of 12.76 inches. This is a deficiency of 25 percent and is the fifth consecutive year of below-average moisture. Table 1.3.1 contains monthly precipitation totals from 1982 through 2003; fig. 1-3 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 (12.70 inches vs. 12.76 inches). Figure 1-4 shows departure from normal precipitation from 1895 through 2003.

Table 1.3 Butte NOAA precipitation statistics, 1982-2003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL AVERAGE
Mean	0.52	0.48	0.83	1.05	1.94	2.17	1.51	1.34	0.96	0.71	0.64	0.54	12.70
Std. Dev.	0.36	0.29	0.39	0.64	0.78	1.29	1.18	0.88	0.68	0.52	0.39	0.41	
Maximum	1.40	1.26	1.84	2.57	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	0.89	0.50	0.00	0.15	0.07	0.00	0.15	0.11	
Number of years precipitation greater than mean													6.00
Number of years precipitation less than mean													16.00

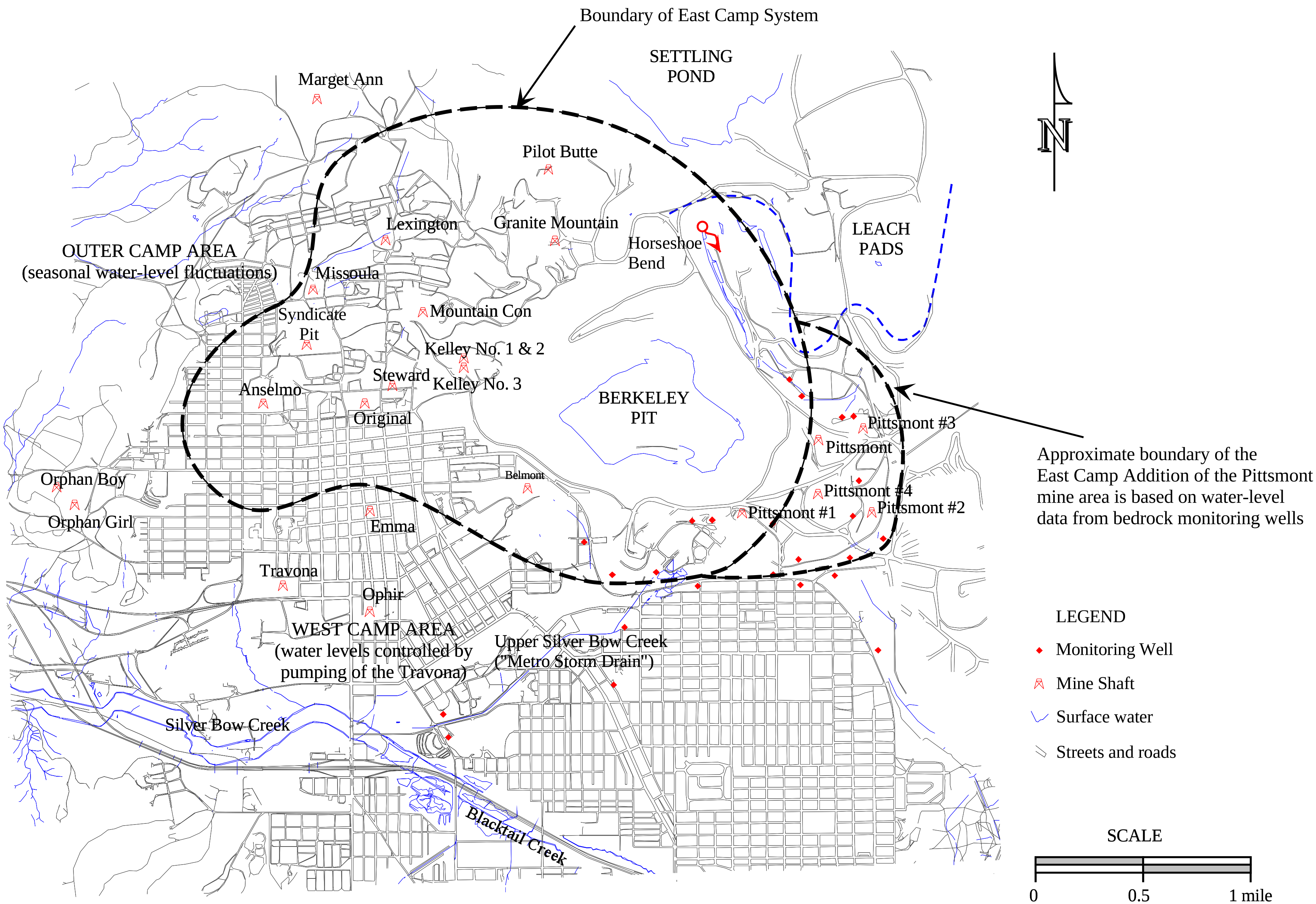


Figure 1-2. The mines of the Butte hill are presently considered in three groups: the East Camp, which includes the Berkeley Pit and the area east; the West Camp in the southwest part of the hill; and the Outer Camp, which includes the outlying mines.

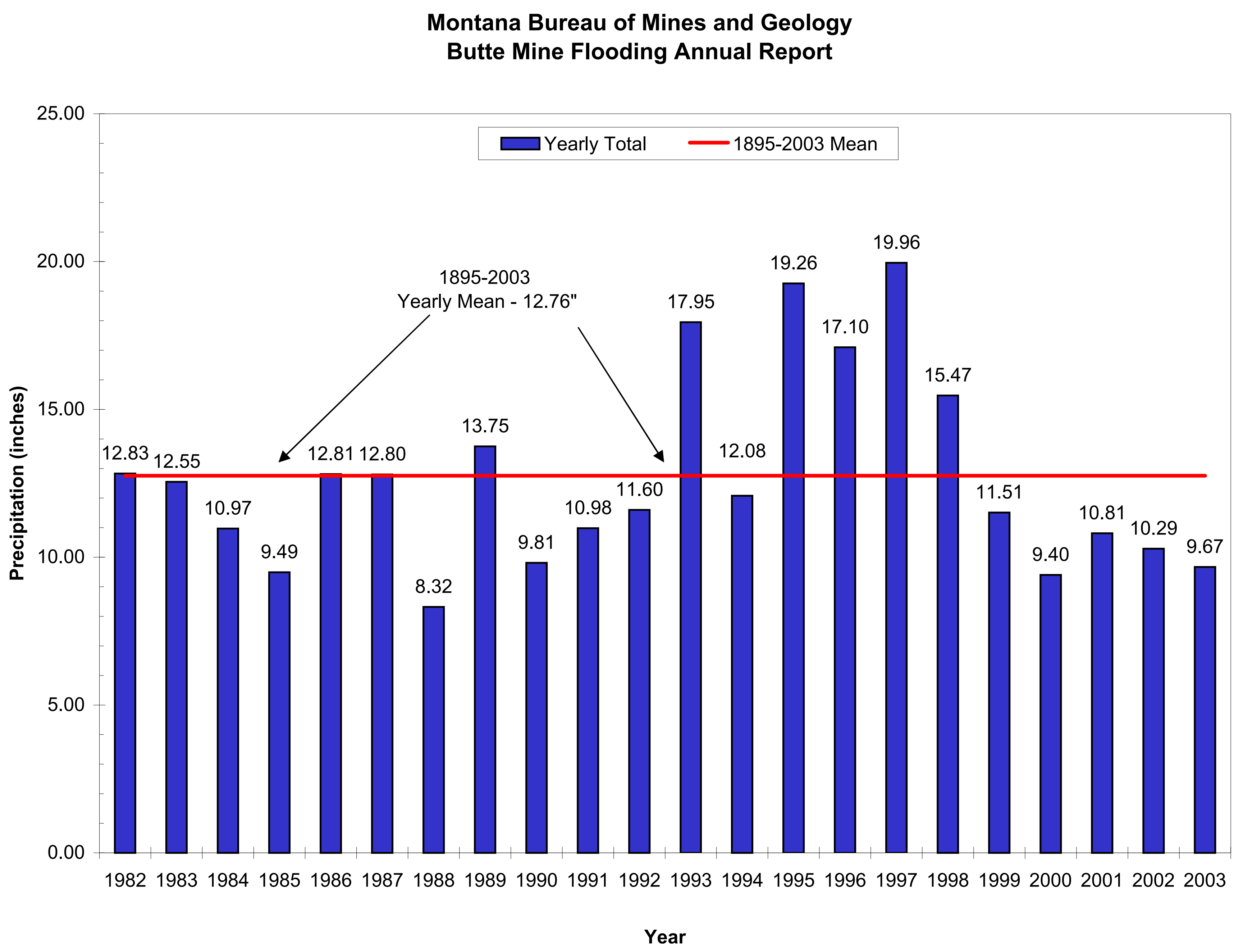


Figure 1-3. Yearly precipitation totals, 1982-2003, showing 1895-2003 yearly mean.

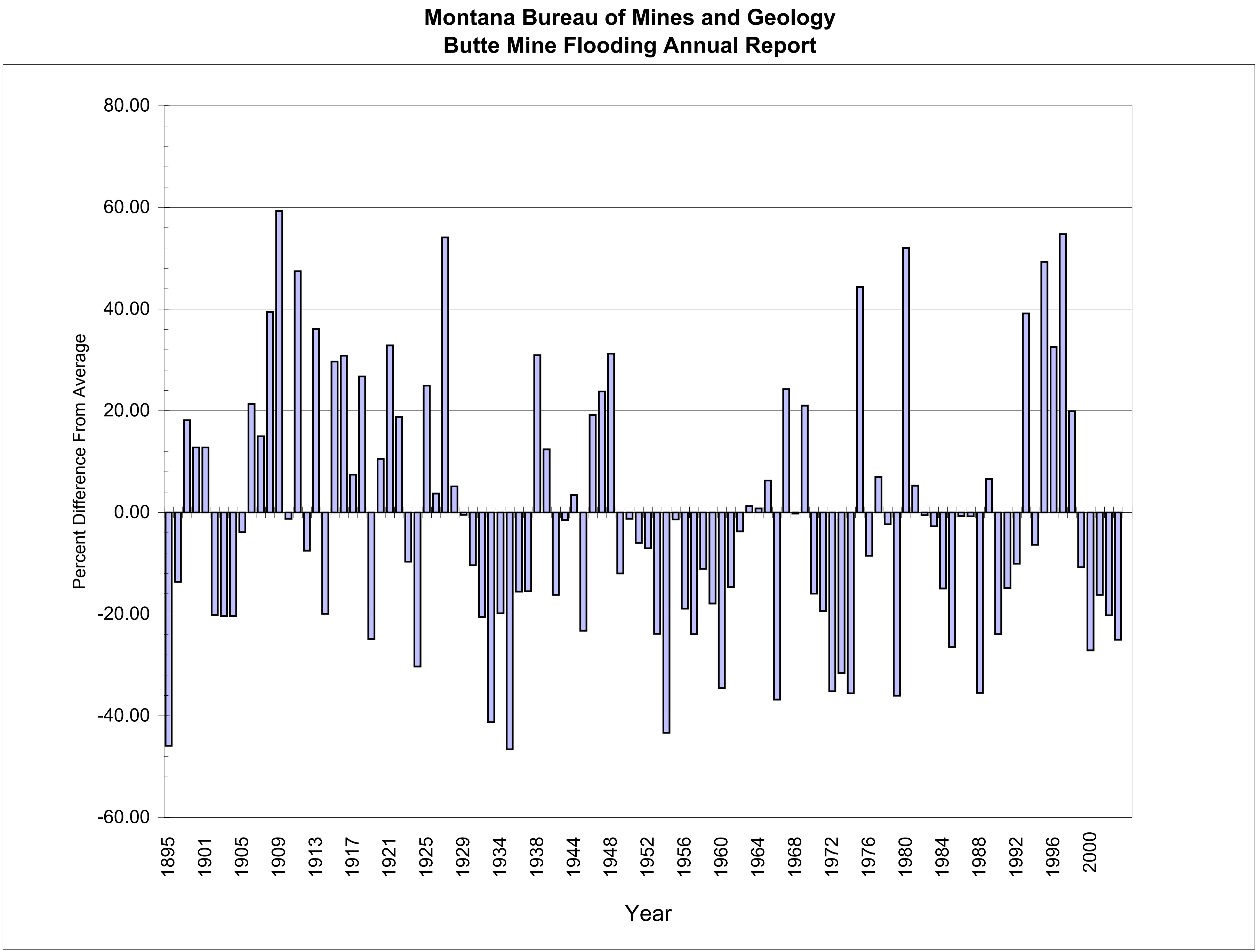


Figure 1-4. Percent precipitation variation from normal, 1895-2003.

SECTION 2.0 EAST CAMP SYSTEM

The East Camp System is comprised of that portion of the bedrock aquifer affected by underground mine dewatering in 1982 and the overlying shallow alluvial aquifer (figure 2-1). The East Camp Monitoring System consists of the Anselmo, Belmont, Granite Mountain, Kelley, Steward, Lexington and Pilot Butte Mines, and the Berkeley Pit. It also includes the bedrock system adjacent to the East Camp mines and the shallow East Camp alluvial system. 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 groups of wells with each group representing sites where wells were installed or monitored during different studies that have been incorporated in the BMFOU-CD monitoring program. From these groups, 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 program, water-quality sampling does not occur at each East Camp monitoring well and takes place only once or twice per year.

Water-level conditions and water-quality characteristics vary throughout the alluvial system. Wells within or adjacent to historic mining activities show trends relating to the influence of those activities. Sites outside historic mining areas reflect conditions more typical of the regional hydrogeology.

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 lists the annual water-level changes for these sites.

There was a noticeable change in 2003 water-level trends for all of these wells, with wells AMC-5 and AMC-6 exhibiting the greatest change. The water levels rose in all of these wells, with the exception of well AMC-10, which remained dry. This is the first time this has happened since 1997. While there were small monthly water-level increases earlier in the year, the major increases occurred from August through the remainder of the year. These increases coincide with MR's start-up of mining and are not related to precipitation events. However, the exact relationship between water-level increases and start-up activities is not well defined. It does not appear that any one or two activities are responsible for water-level changes, but a combination of several factors contributed to the change. Several of the start-up activities that might have combined to influence water levels were: 1) pumping of water to the Yankee Doodle Tailings Dam to provide a reservoir of make-up water for the concentrator facility; 2) filling with water and pressure testing the concentrator clarifier tanks and pipelines; and 3) filling the concentrator pond with water.

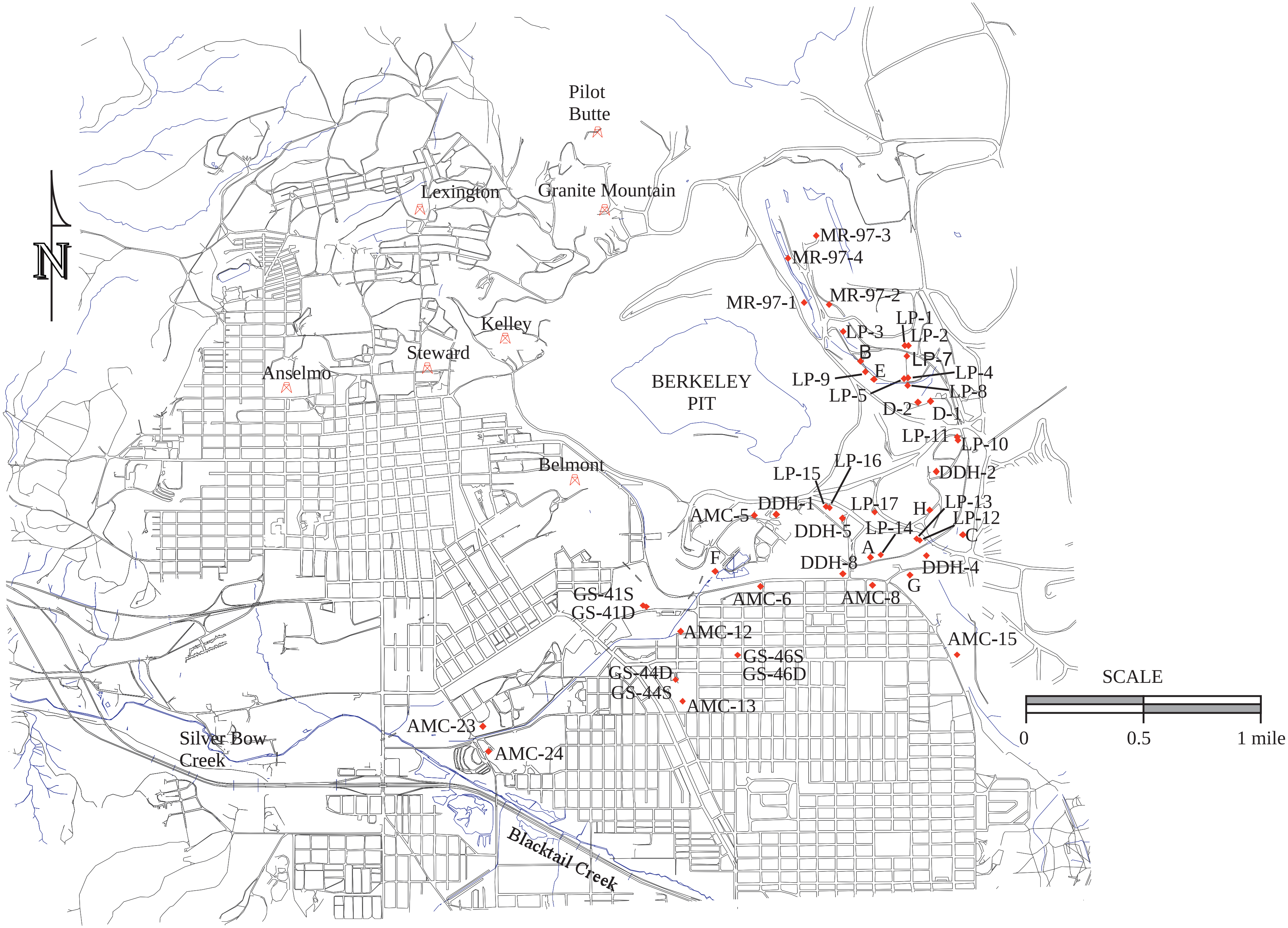


Figure 2-1. East Camp monitoring sites.

Precipitation had very little effect on well-water levels and where it did influence water levels, that influence was very short lived.

Well AMC-5 is located in the storage yard associated with the Butte Concentrator, while wells AMC-6 and AMC-8 are located south of the active mine area and the Butte Concentrator facility (fig. 2-2). Well AMC-12 is located southwest of these wells. Hydrographs for wells AMC-5 and AMC-12 (fig. 2-3) and AMC-6 and AMC-8 (fig. 2-4) 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.

Wells AMC-5, AMC-6 and AMC-8 exhibited a water-level rise throughout most of 2003. These increases in water level are much different from trends seen for many years. There is no apparent relationship between precipitation trends and increased water levels. The total 2003 rise in water level in wells AMC-5 and AMC-6 of 6.9-ft and 3.5-ft respectively is the largest yearly increase since 1986, which coincidently is the same year that MR resumed mining operations following ARCO's 1983 complete shutdown of their Butte operations.

Table 2.1.1 AMC-series wells, annual water-level changes, in feet.

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-12	AMC-13	AMC-15
1983	-23.75	-2.30	-4.90	DRY	0.20	0.60	-5.80
1984	-4.50	-2.55	-3.75	DRY	-1.80	-1.10	-3.40
1985	-3.40	-3.90	-3.00	DRY	-2.45	-1.85	-2.80
1986	8.70	3.90	-0.90	DRY	1.90	1.00	-2.10
1987	0.10	0.40	1.50	DRY	0.60	0.10	0.00
1988	0.20	-0.40	0.30	DRY	-0.10	-1.00	0.80
1989	-2.30	-0.80	-0.90	DRY	-0.20	-0.10	0.10
1990	0.20	0.10	0.30	DRY	1.10	0.00	-0.10
1991	0.00	0.30	0.80	DRY	-0.60	0.30	-0.30
1992	0.40	-0.40	0.50	DRY	-0.30	0.00	-0.10
1993	0.40	0.70	0.80	DRY	1.10	1.00	-0.40
1994	0.64	0.53	0.91	DRY	-0.19	-0.50	0.96
1995	0.64	1.01	0.51	DRY	1.23	1.13	0.97
1996	-0.05	0.62	2.14	DRY	0.74	0.69	2.60
1997	1.80	1.47	2.24	DRY	1.20	0.70	2.80
1998	-1.52	0.42	1.15	DRY	0.18	0.09	0.58
1999	-1.56	-2.03	-2.45	DRY	-1.56	-1.09	-1.50
2000	-2.46	-2.56	-3.88	DRY	-1.77	-1.17	-3.73
2001	-1.89	-1.92	-3.03	DRY	-0.55	-0.36	-2.34
2002	-0.89	-1.25	-1.77	DRY	-0.98	-0.73	-1.65
2003	6.97	3.50	0.97	DRY	0.53	0.03	0.37
Net Change	***-22.27***	***-5.16***	***-12.46***	***0.00***	***-1.72***	***-2.26***	***-15.04***

Well AMC-12 water-level variations were similar to those of 2001 and 2002; however, the overall trend changed from downward to upward. Water levels increased in the spring with increased precipitation and then declined through the fall (fig. 2-3), a trend similar to the past two years.

Figure 2-2. AMC well location map.

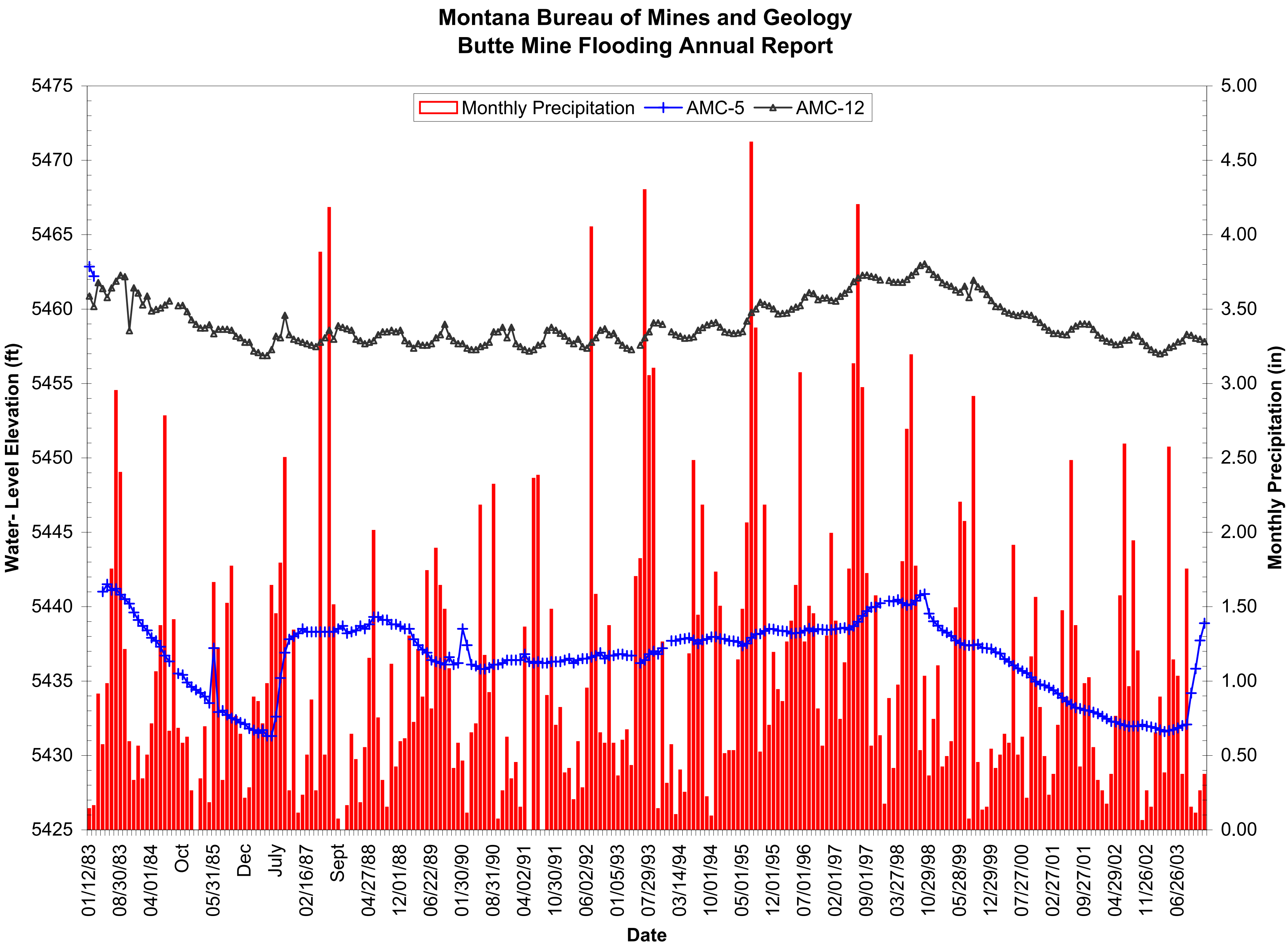


Figure 2-3. Water-level hydrographs for AMC-5 and AMC-12 wells.

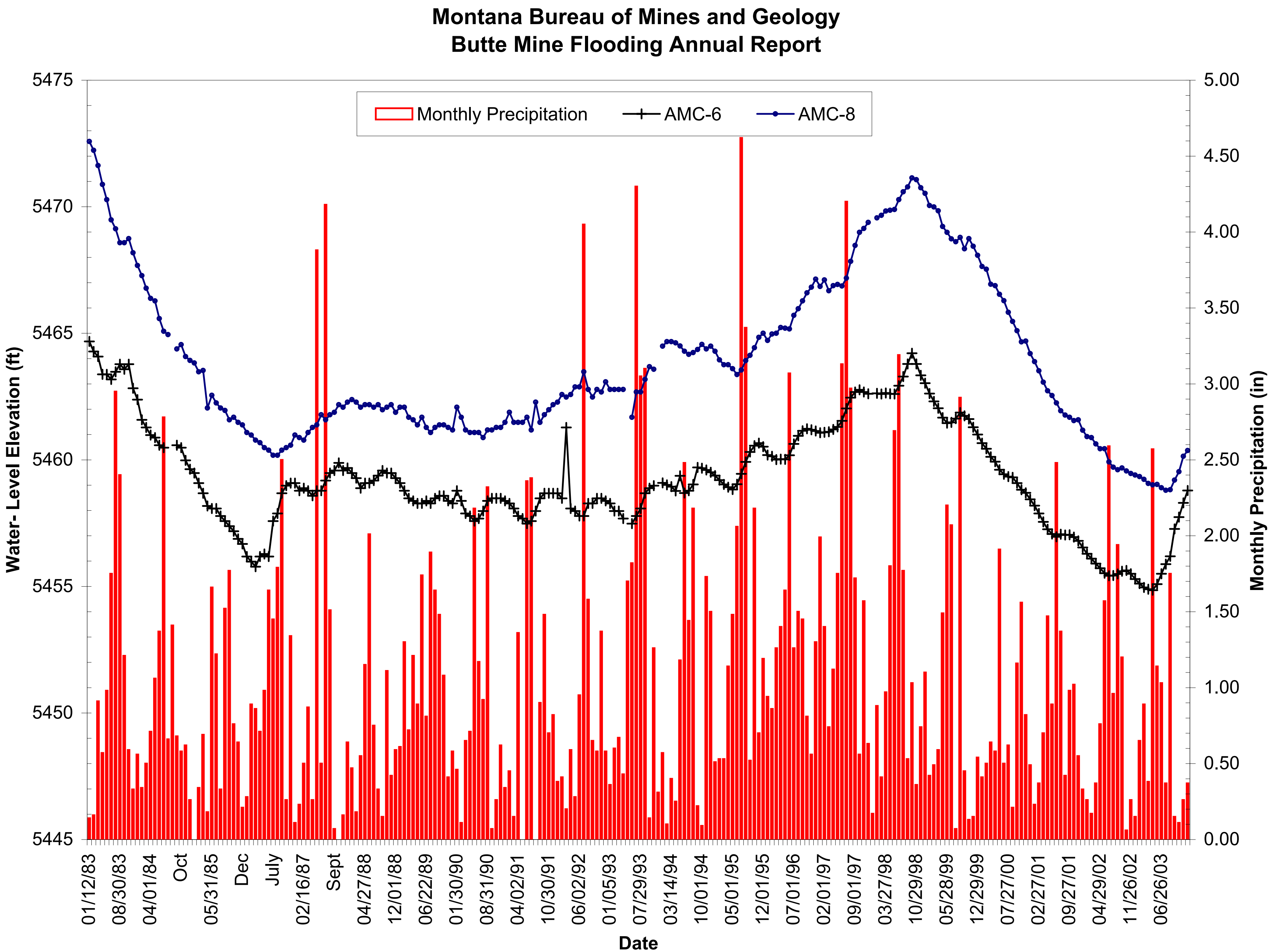


Figure 2-4. Water-level hydrographs for AMC-6 and AMC-8 wells.

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 (fig. 2-5a). Water levels began to rise in the spring and continued throughout the summer, before starting to decline in the fall. This trend is similar to that of prior years.

Well AMC-15 is located on the west side of the Hillcrest waste dump (fig. 2-2) in an area where reclamation has taken place. Water in this well is much deeper (90 feet) 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 influence of the recent below-normal precipitation is shown by the steep decline in water levels the past three years (fig. 2-5b), when this well did not show any significant response to precipitation. The water-level decline began leveling off in the later part of 2002, then rose almost one-half foot from September through December 2003.

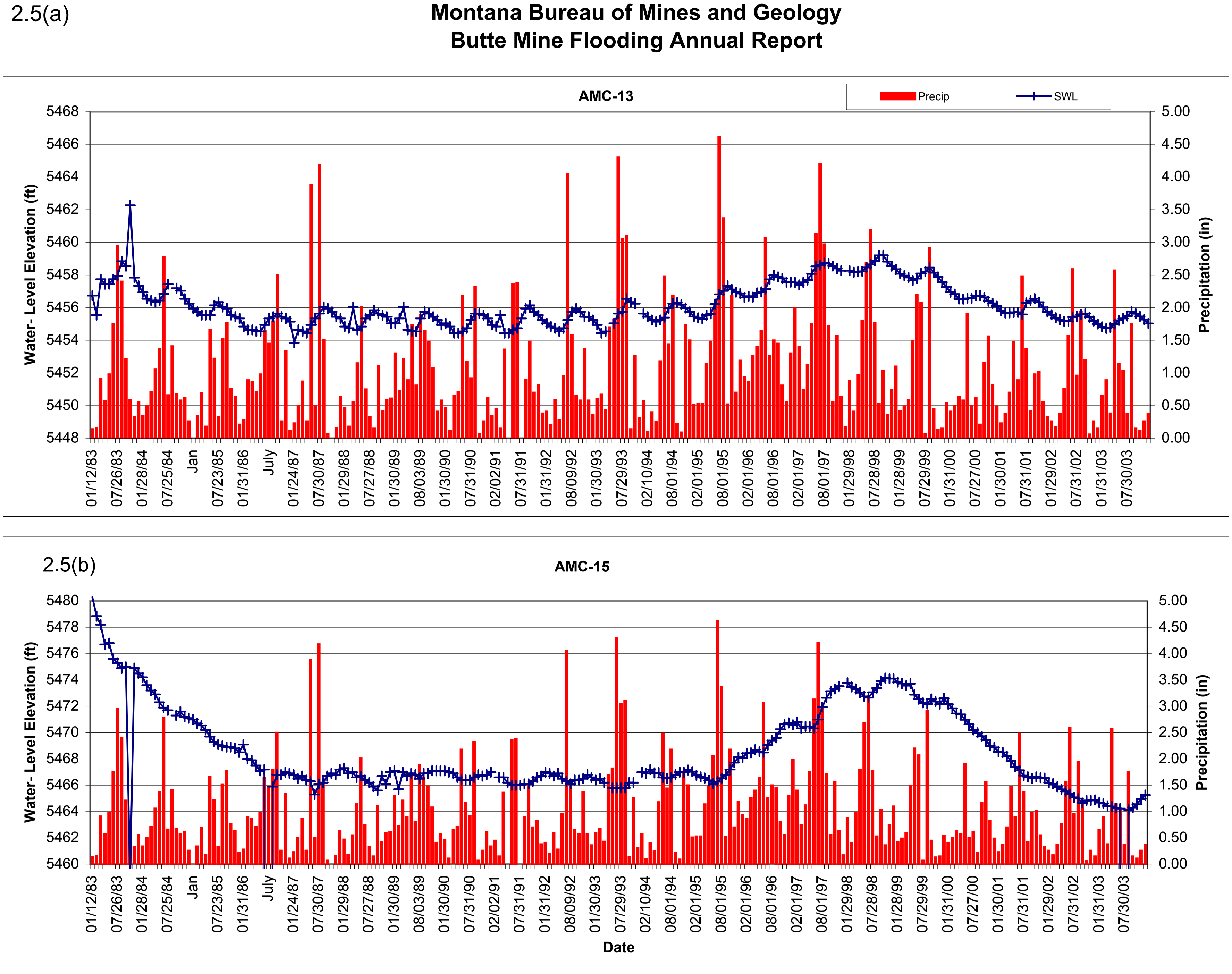
Section 2.1.1.1 AMC-Series Wells Water Quality

Concentration trends of the 2003 data collected from the AMC-series wells are summarized in Table 2.1.1.1. Well AMC-5, just south of the Berkeley Pit, has exceeded MCLs and SMCLs throughout the period of record. The concentrations of most of the dissolved metals have shown a slight downward trend; however, the concentrations of arsenic, cadmium, and sulfate have been increasing the last several years.

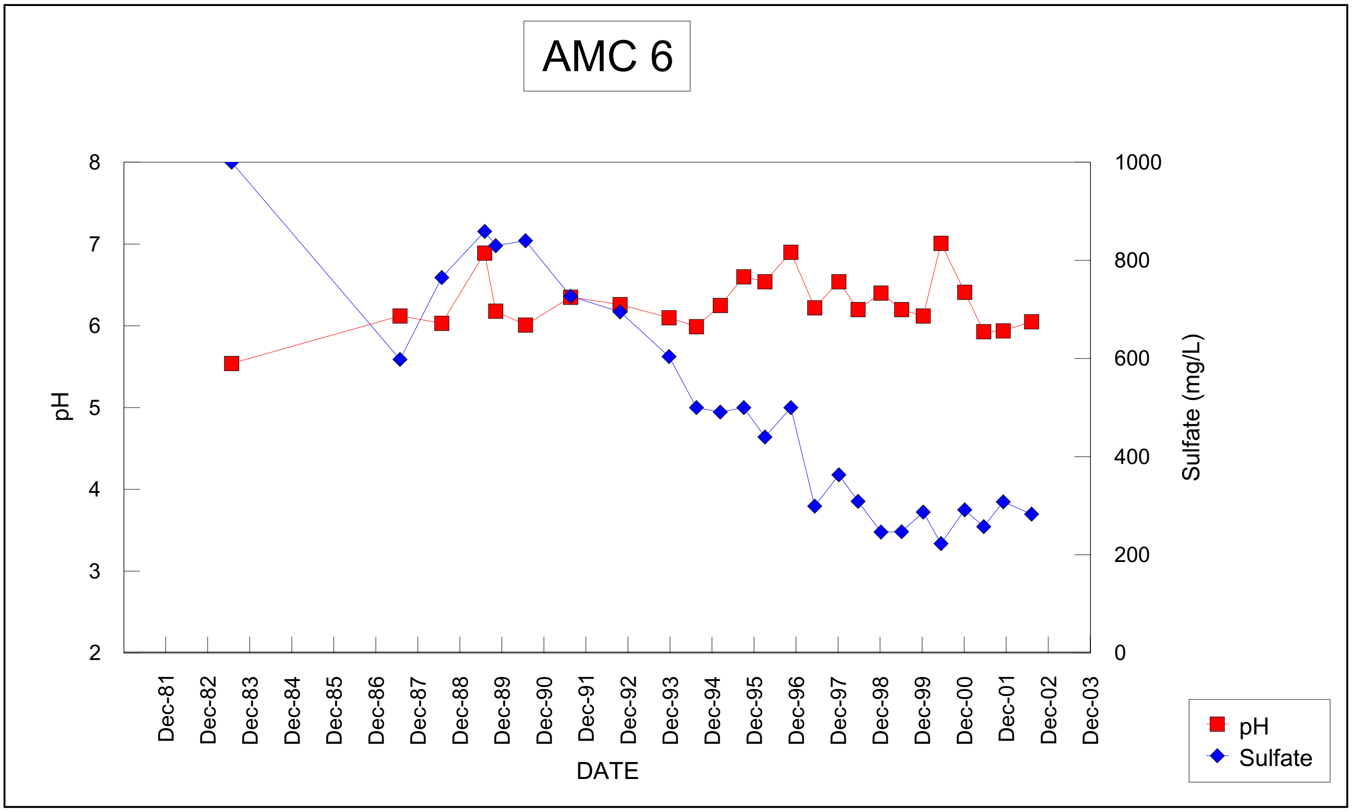
Wells AMC-6 and AMC-8 are just south of the Berkeley Pit and generally coincide with the ground-water divide. Concentrations of most dissolved constituents are generally higher in the down-gradient well, AMC-6, but well AMC-6 has shown decreasing concentrations throughout the period of record. For example, cadmium has decreased from over 200 to less than 20 μg/L; sulfate has decreased from over 1000 to less than 250 mg/L in the 20-year period of record (fig. 2-6). AMC-8 has exhibited a steady but small increase in the concentrations of some dissolved constituents including zinc and cadmium and a steady but small decrease in the concentrations of others. However, a notable trend is the steady increase in the concentration of sulfate which exceeded 450 mg/L in 2003 (fig. 2-6).

Table 2.1.1.1 Exceedances and trends for AMC-series wells, 2003.

Well Name	Exceedances	Concentration Trend	Remarks
AMC-5	Y	Variable	Sulfate exhibits upward trend
AMC-6	Y	Downward	Slight downward trend continues
AMC-8	Y	Variable	Increasing sulfate continues
AMC-12	Y	Variable	Sulfate and cadmium have decreased over record
AMC-13	Y	Variable	Not sampled in 2003
AMC-15	Y	Variable	Only sulfate exceeds SMCL; net change is small



Figures 2-5. Water-level hydrographs for AMC-13 (a), and AMC-15 (b) wells.



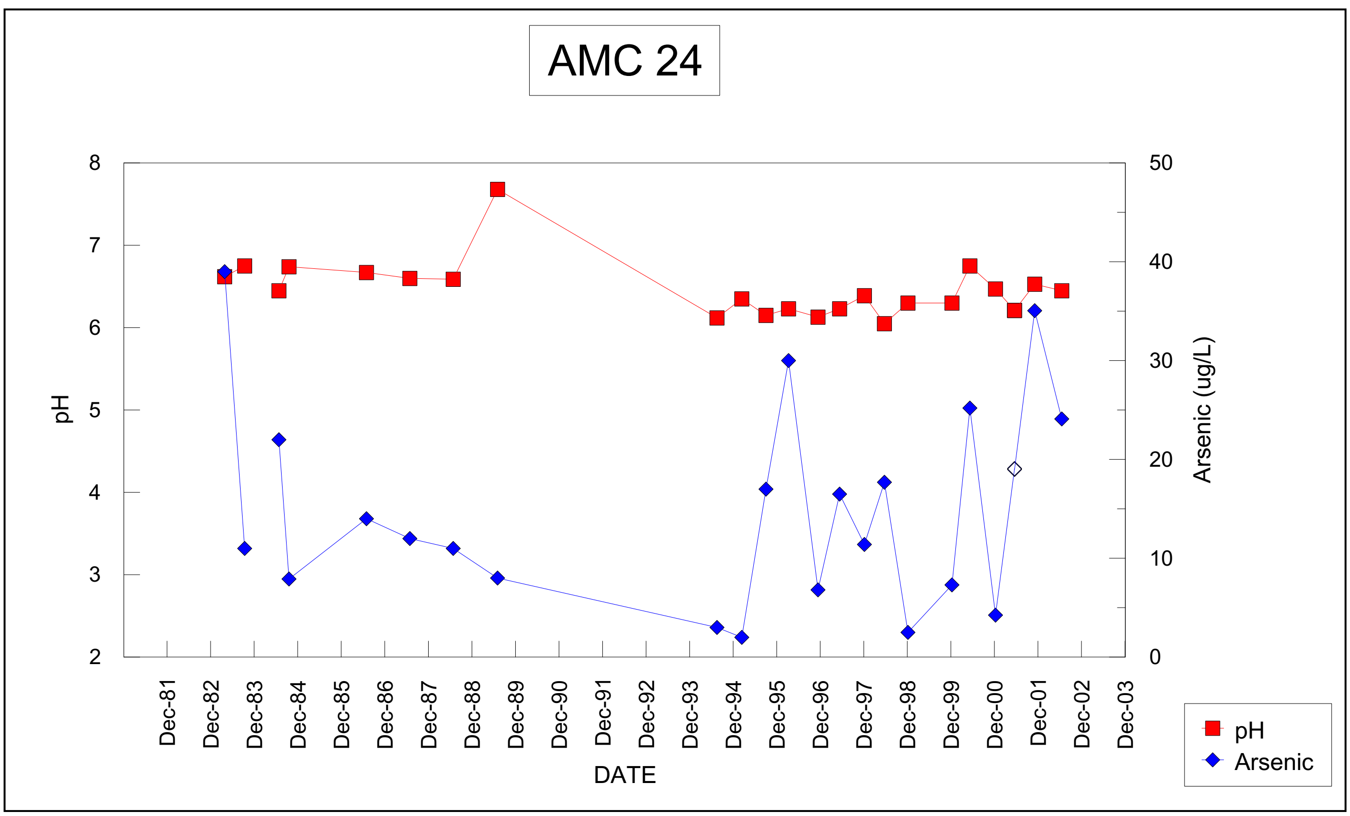


Figure 2-6. Sulfate concentrations for AMC-6 and arsenic concerations for AMC-24.

Well AMC-15 showed little change in concentrations in the most recent data. Only sulfate exceeds the SMCL in this well (329 mg/L). Zinc concentrations in the AMC-series wells range from 57,200 μg/L in AMC-5 near the Berkeley Pit to about 30 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 concentrations range from 12,600 μg/L in AMC-5 to less than 5 μg/L in AMC-15.

Section 2.1.2 LP-Series Wells

The locations of the LP series monitoring wells are shown on figure 2-7. As discussed in Duaime and others (1998), these wells were installed in 1991 as part of the BMFOU RI/FS study. Water-level monitoring and sampling of the LP-series wells continued throughout 2003. Table 2.1.2 contains a summary of annual water-level changes for these 17 sites. Well LP-11 was plugged and abandoned in 2001; well LP-03 was plugged and abandoned in 2002 to make room for the HSB water-treatment plant. Two other wells (LP-06 and LP-07) remain dry. Water levels declined in eight of the remaining 13 wells during 2003. Water levels experienced a net decline in all 17 of these wells, ranging from 2.80 feet to 43 feet in wells LP-14 and LP-08, respectively. Monitoring data through 2003 indicated that water levels in wells located to the north of the Pittsmont Waste Dump (LP-01 through LP-09) continued to decline more rapidly than in wells to the east and south of the Pittsmont Dump. These declines were not as great, however, as in previous years. As a matter of fact, well LP-02 had a water-level rise of 1.6 feet during 2003. This is only the second time since monitoring began that the water level rose at this site. The water-level rise in this well was first noticed during the late summer of 2003, which coincides with various MR start-up activities. However, no single event relating start-up activities and this water-level rise was found. It is possible that several activities might have been responsible for this increase.

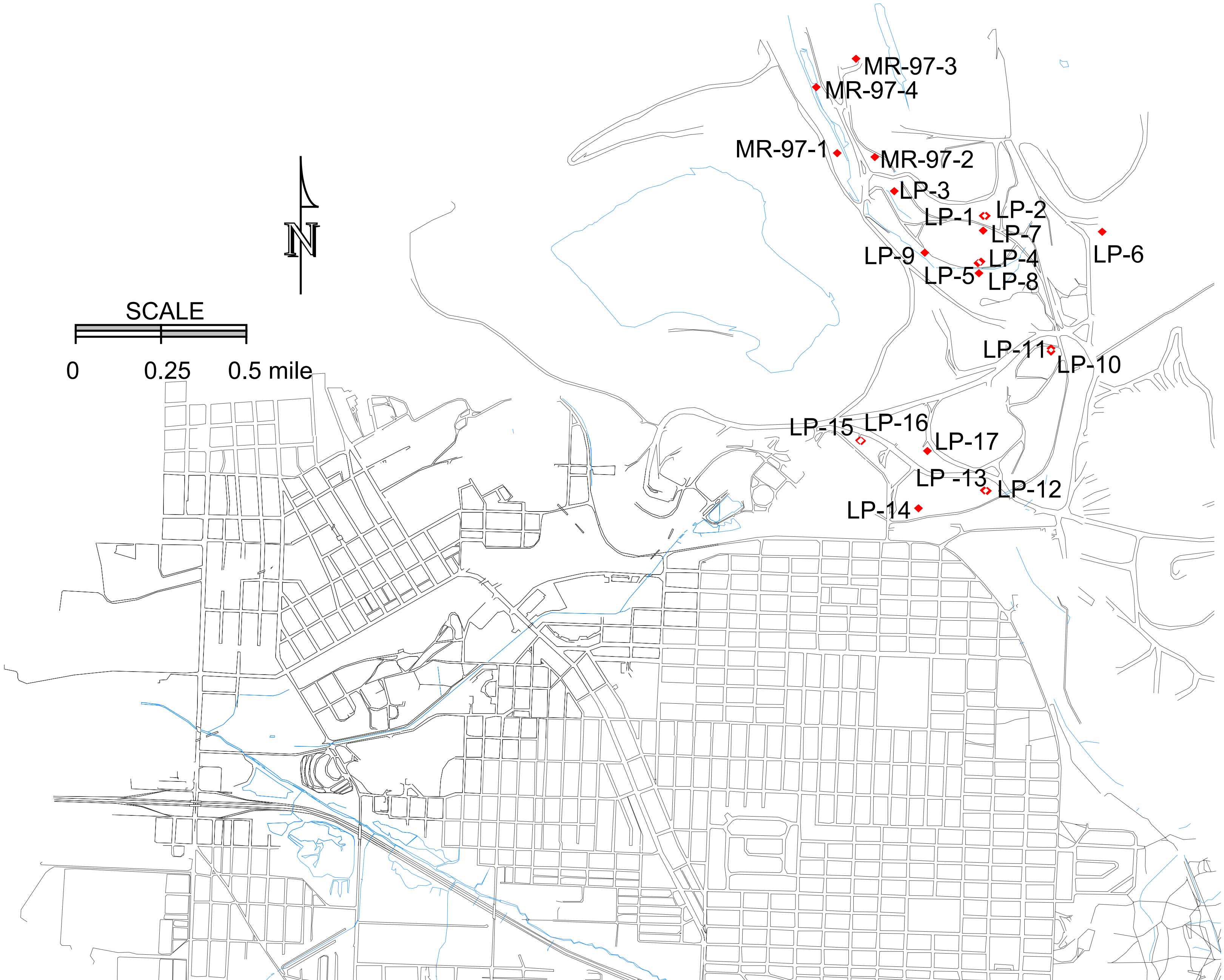


Figure 2-7. LP series and MR97 wells location map.

Table 2.1.2 Annual water-level change in LP-series 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	-1.46	-	-	-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	-0.20	-3.10	-14.03	-13.28
2001	-5.13	-4.73	-9.51	-8.88	-5.47	Dry	Dry	-12.10	-3.04
2002	-5.21	-3.91	-2.01*	-6.03	-4.86	Dry	Dry	-4.11	-3.46
2003	-2.29	1.60	P&A*	-1.75	-2.00	Dry	Dry	-0.04	-1.15
Net Change	**-27.36**	**-24.74**	**-31.45**	**-31.82**	**-30.33**	**-3.79**	**-16.64**	**-43.00**	**-34.53**

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	-1.47	-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
2002	-0.15	P&A*	-1.83	-1.21	-1.65	-0.68	-0.86	-0.67
2003	-2.75	P&A*	-1.74	-0.26	0.46	1.08	0.89	0.09
Net Change	**-7.50**	**-5.38**	**-5.82**	**-3.70**	**-2.80**	**-6.25**	**-8.95**	**-4.22**

* Plugged and abandoned.

The net water-level declines in the areas adjacent to wells LP-06 and LP-07 are greater than those shown in Table 2.1.2, as both of these wells are currently dry. The water levels in these areas have declined below the screened intervals of nearby monitoring wells.

The water-level decline noted in some of these wells in 1999 following MR's deactivation of the leach pads continued, however, the amount of the decline was much less for 2003. 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, from precipitation events. A portion of the water-level decline could have been associated with the 2000-2003 mine suspension and the drying out and reclamation activities within the Yankee Doodle Tailings Dam.

Figures 2-8 through 2-10 show hydrographs from seven representative wells, along with monthly precipitation totals. Wells LP-01 and LP-02 are located to the north of the site near the base of various leach pads and screened in two different intervals. Well LP-01 is screened deeper than well LP-02. The wells are screened at depths of 129 to 159 feet and 177 to 197 feet, respectively, and are completed in the deeper portion of the alluvial aquifer. Water-level trends were mostly downward in these two wells during the first half of 2003 (figure 2-8), however, the water level in well LP-02 rose more than 3.5 feet in October, then declined slightly during the remainder of 2003. This water-level rise is not related to precipitation events; however, other minor increases during the year appear to be related to precipitation.

Minor water-level fluctuations were also noted in the deeper screened well (LP-01), but the changes were not as significant. While LP-02 had a net water-level increase for 2003 (based primarily on the October 2003 rise), the water level in well LP-01 had a net decline. These water-level variations are noticeable on the graphs for both of these wells (figure 2-8). It is not unusual that well LP-02 showed greater variations in water levels than LP-01 since its screened interval is shallower. Water-level changes from such things as precipitation or filling of the Yankee Doodle Tailings Dam with water for concentrator start-up would show up in the shallower screened well (LP-02) first.

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 were completed at different depths also. Well LP-04 is screened from 125 to 145 feet below ground surface, while well LP-07 is screened from 90 to 95 feet below ground surface. Based upon these well-completion depths, well LP-07 would be considered complete in the upper portion of the alluvial aquifer, while well LP-04 would be considered complete in the deeper portion of the alluvial aquifer. Water levels declined in well LP-04 during 2003 (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 screened interval, 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 way in all three of these wells until beginning to rise in September 2003 and continuing through the end of the year. Wells LP-15 and LP-16, located near one another, were completed as a nested pair. Well LP-15 was screened from a depth of 215 to 235 feet below ground surface and well LP-16 was screened from 100 to 120 feet below ground surface. Water-level changes are similar in all three wells regardless of completion depth. The water levels had a net increase for 2003, which is in contrast to the declines seen the previous four years.

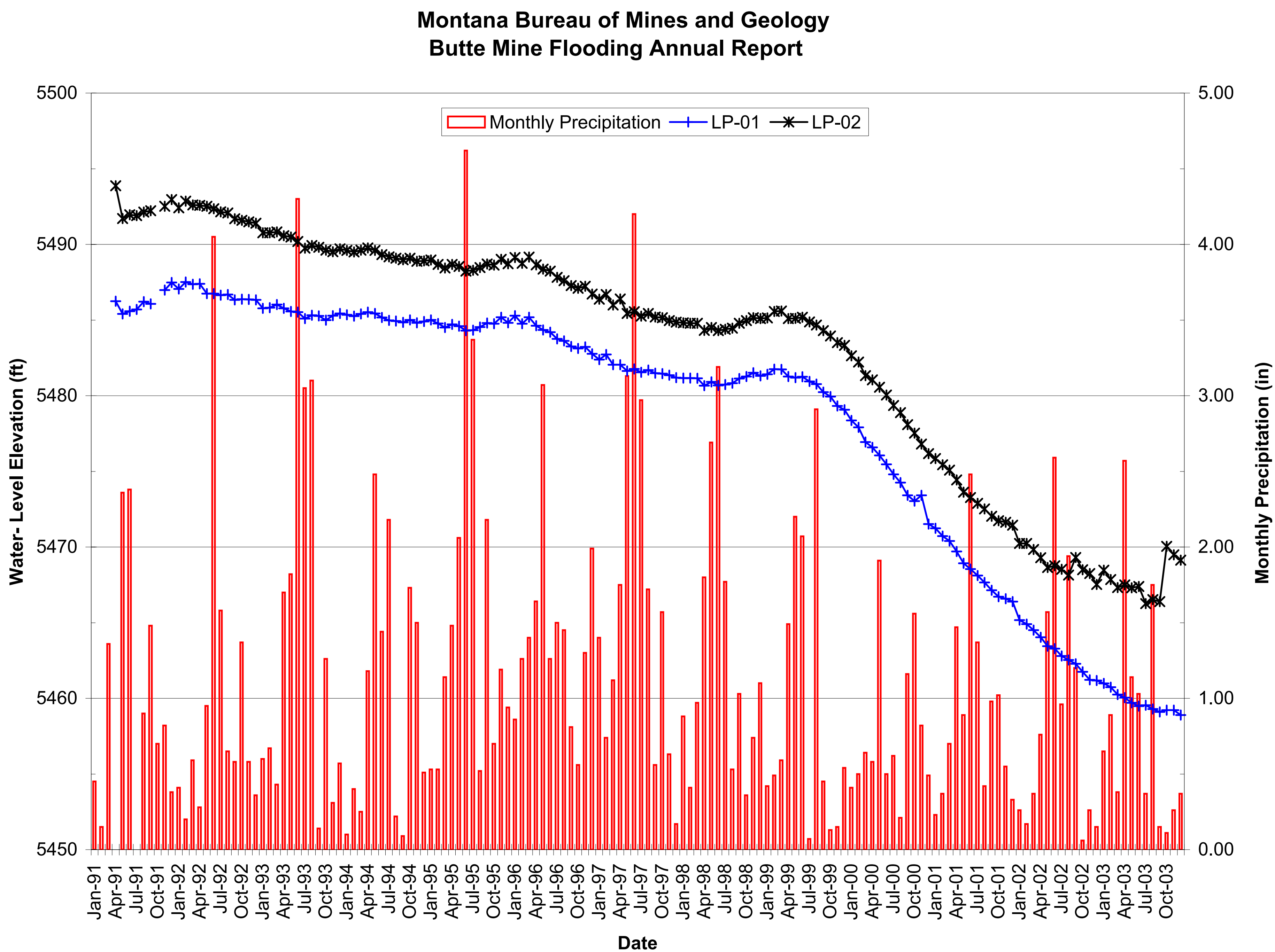


Figure 2-8. Water-level hydrographs for LP-01 and LP-02 wells.

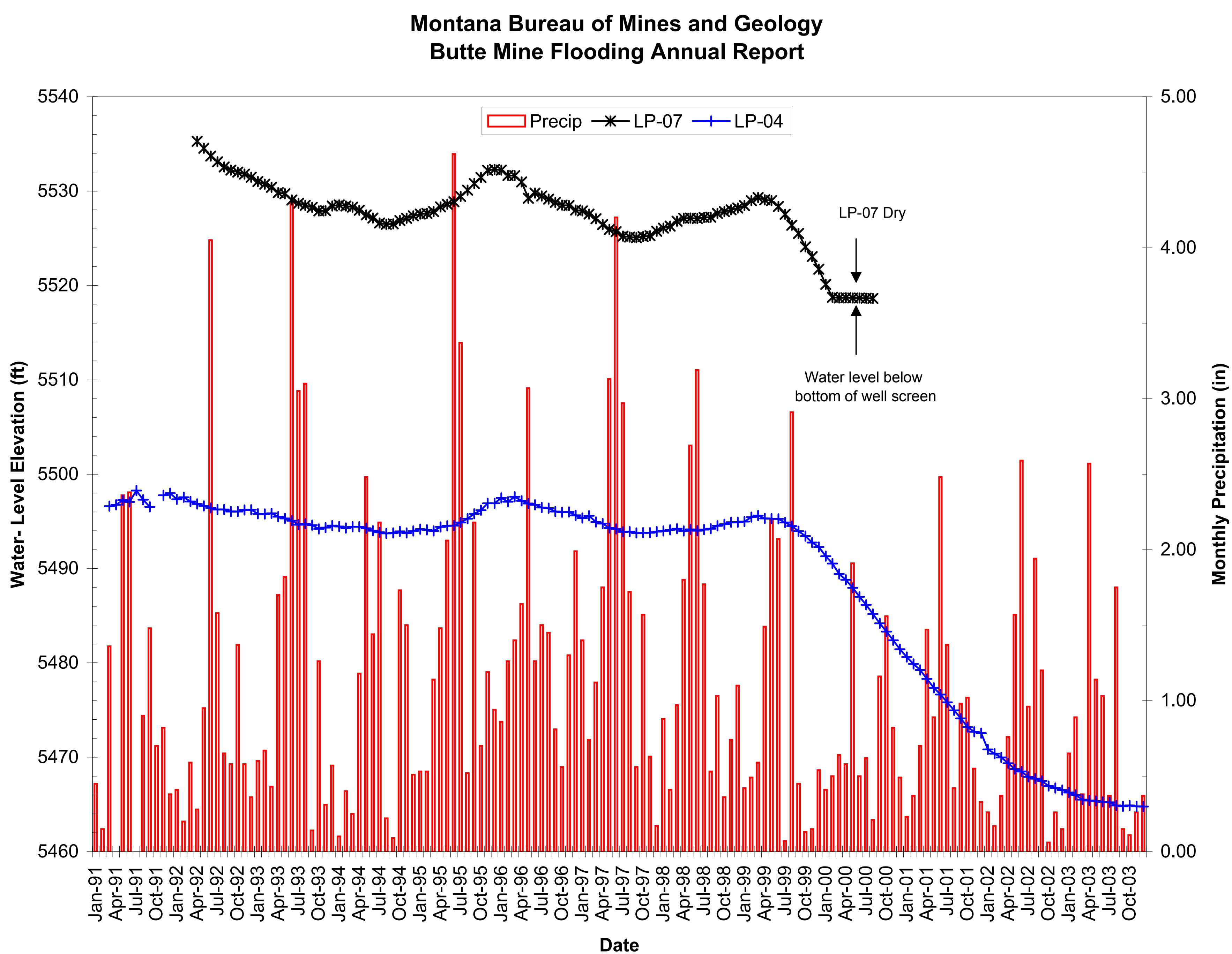


Figure 2-9. Water-level hydrograph for LP-04 and LP-07 wells.

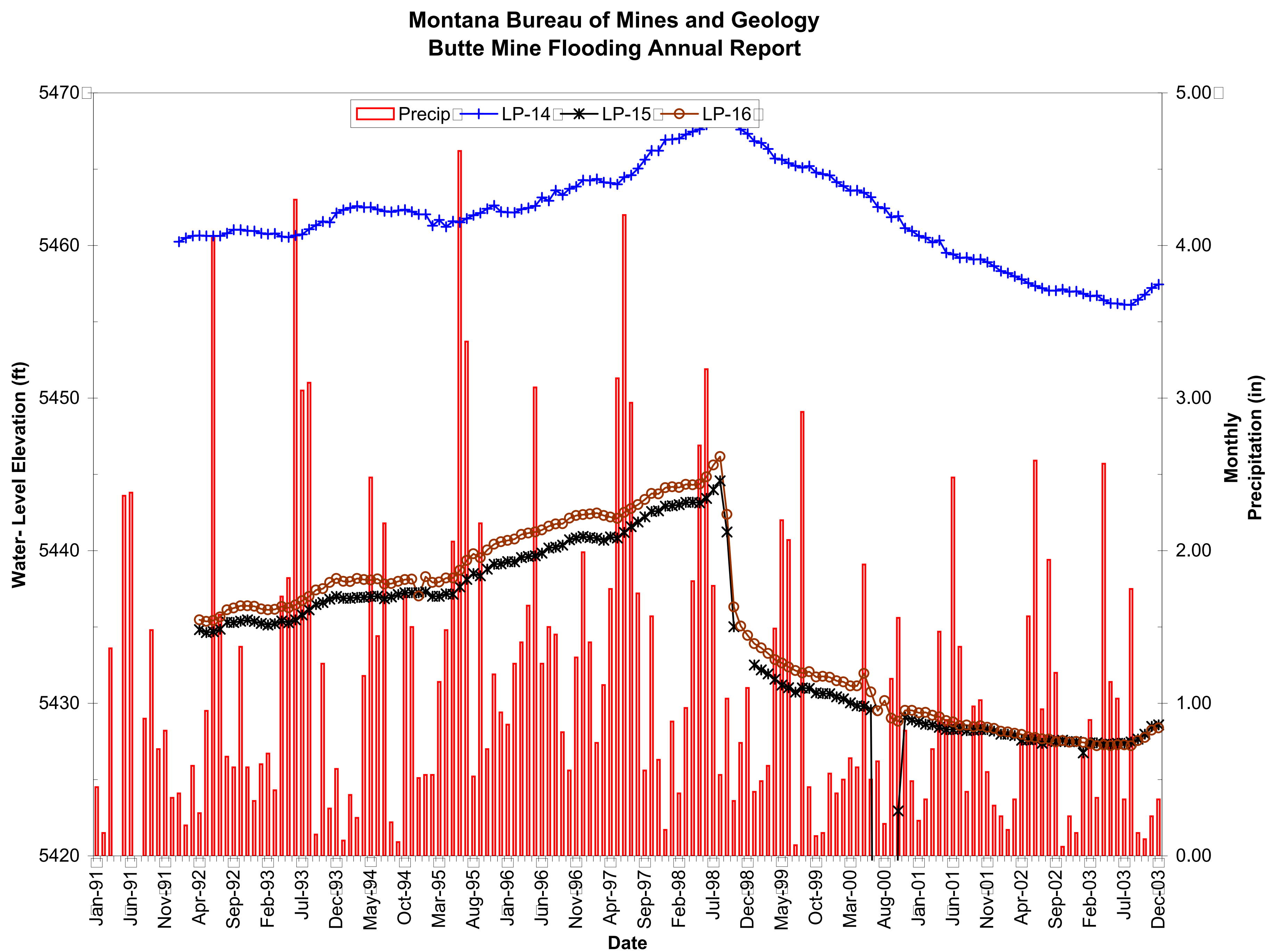


FIgure 2-10. Water-level hydrograph for LP-14, LP-15, and LP-16 wells.

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 has not operated since the fall of 2000.

The general observation made in the last several 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 overall trend toward lower water levels seen since 1999 continued in 2003. Water levels in these LP-series wells were either controlled by the operation and subsequent dewatering of the leach pads, operation of the Yankee Doodle Tailings Dam, the depressed water levels in the Berkeley Pit, or a combination of all three. The influence of precipitation is minimal at most, on any of these wells.

An alluvial aquifer potentiometric map (fig. 2-11) constructed using December 2003 water levels, shows how alluvial waters are flowing towards the Berkeley Pit from the areas 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.

Section 2.1.2.1 LP-Series Wells Water Quality

Current water-quality monitoring of the LP-series wells is restricted to those wells east and south of the Pittsmont Dump (fig. 2-7) with one exception; Well LP-09, located just south of the leach pad area. Water-quality trends in 2003 showed some changes in several wells; these are summarized in Table 2.1.2.1. Well LP-9 was sampled in August of 1992 and then not sampled again until April of 2003. A comparison of the data indicates large increases in the concentration of most dissolved constituents. Most notable are the concentrations of aluminum (from <100 to 50,000 μg/L), arsenic (from 4.4 to 43 μg/L), cadmium (from 510 to 14,600 μg/L), and zinc (from 165,000 to 1,870,000 μg/L). In general, the concentrations of dissolved metals increased by nearly an order of magnitude and approached those values seen in the pregnant solution of the up-gradient leach pads.

Table 2.1.2.1 Exceedances and trends for LP series wells, 2003

Well Name	Exceedances (1 or more)	Concentration Trend	Remarks
LP-9	Y	Upward	Large increases since 1992
LP-10	N	None	No significant changes in 2003
LP-12	Y	None	No significant changes in 2003
LP-13	Y	None	No significant changes in 2003
LP-14	Y	Variable	Increase in sulfate concentration continues
LP-15	Y	None	Net change is small for most analytes
LP-16	Y	Variable	Downward sulfate trend continues
LP-17	Y	Variable	Slight upward trend in concentrations

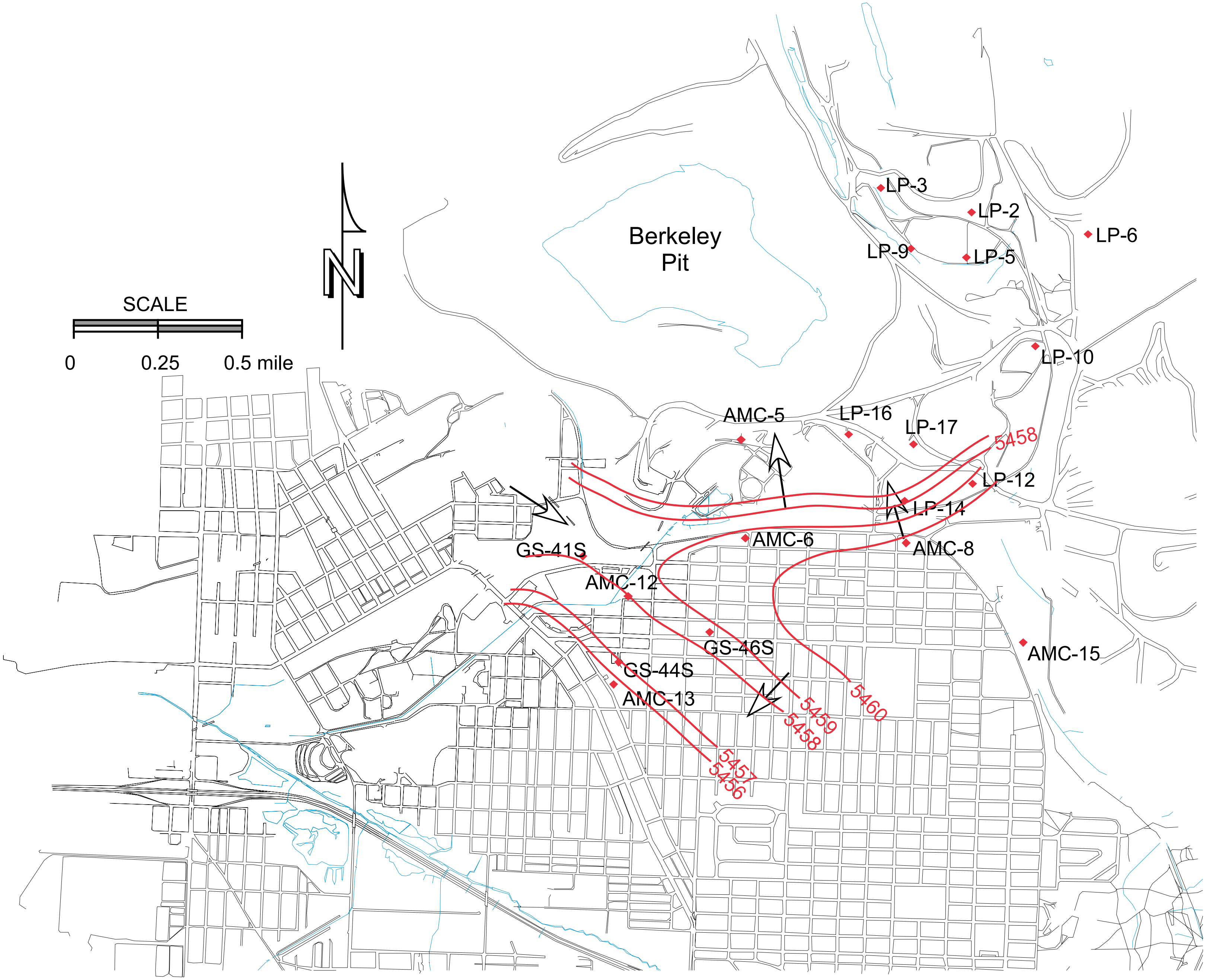
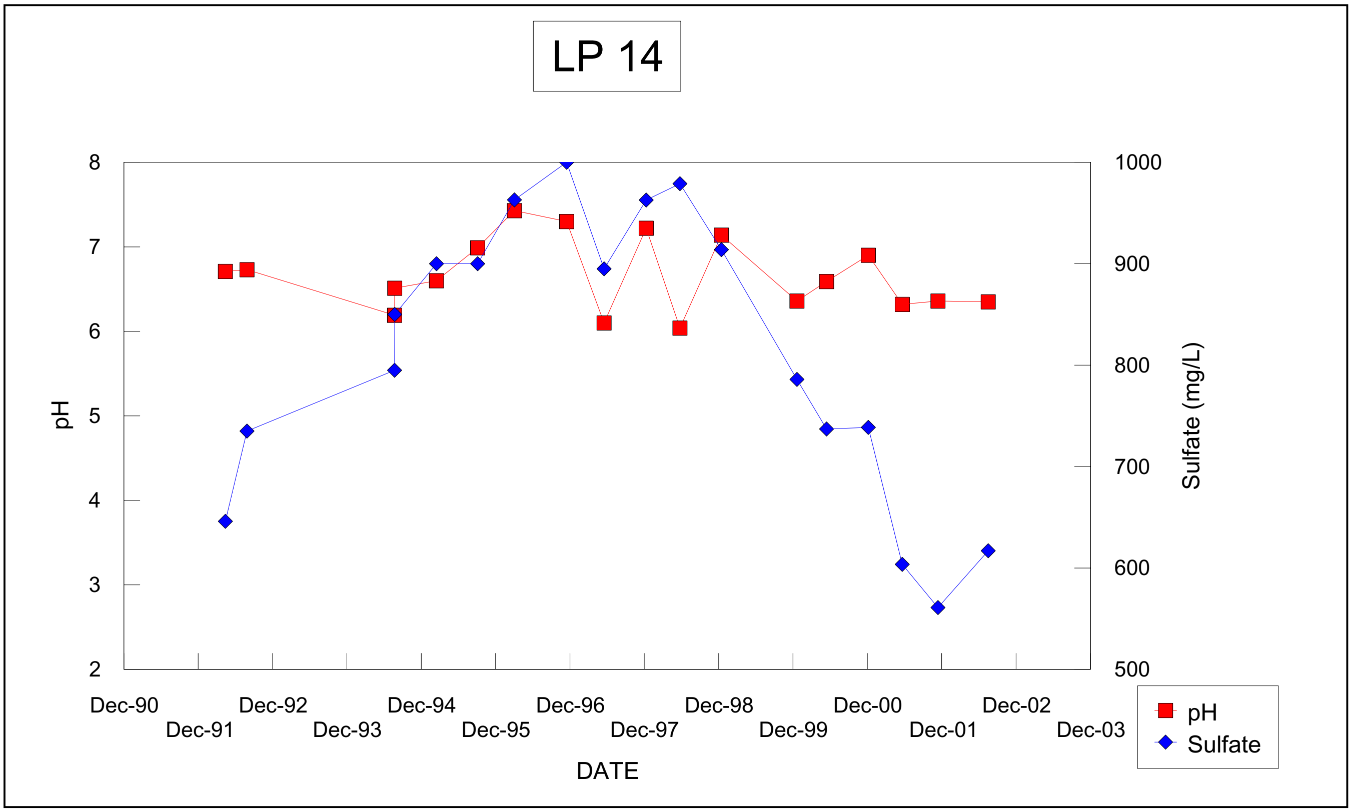


Figure 2-11. Alluvial aquifer potentiometric map for December, 2003; arrows indicate direction of ground-water flow implied by contours (contour interval is 1 foot).



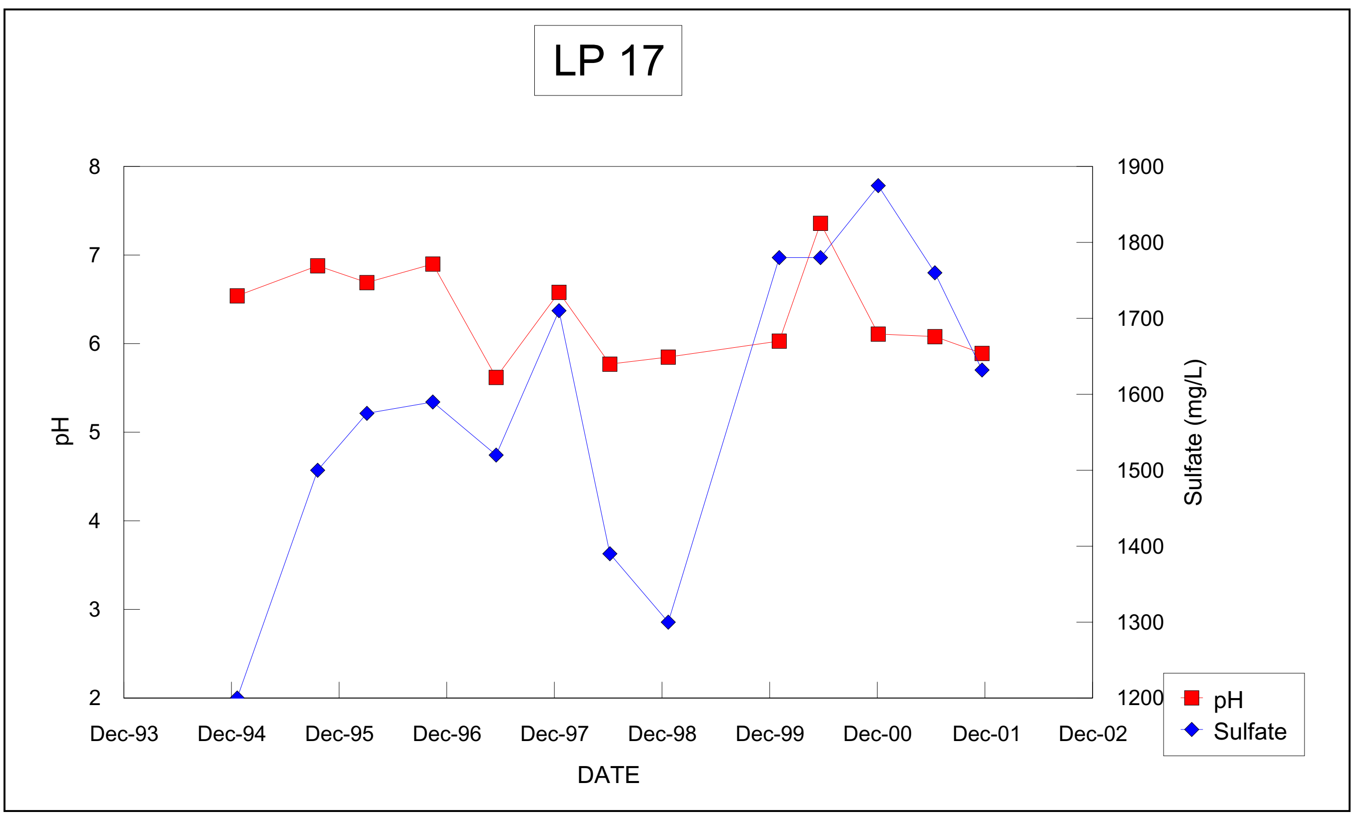


Figure 2-12. Sulfate concentrations for LP-17 and LP-14.

Well LP-14 demonstrated another reversal of trend in the sulfate concentration; what had been a downward trend through 2000 has been an upward trend since that time (fig. 2-12). Well LP-14 had been exhibiting trends similar to that of LP-16, but no longer is. LP-16 continued to be variable with respect to the concentration of dissolved constituents, but overall is exhibiting a downward trend in sulfate (fig. 2-12).

Well LP-17 has been the well with the highest concentration of most dissolved constituents in the past few years. With the sampling of LP-9, however, that is no longer the case. Well LP-9 exhibited the highest concentration of arsenic (43.4 μg/L), zinc (1,870,000 μg/L), cadmium (14,600 μg/L) and many other dissolved constituents. Well LP-17 had the highest concentration of copper (25,200 μg/L). Wells LP-15 and LP-10 had the lowest concentration of most dissolved constituents; sample results from Well LP-15 indicate copper was less than 4 μg/L.

Section 2.1.3 Precipitation Plant Area Wells

Wells MR97-1, MR97-2, MR97-3, and MR97-4 (fig. 2-7) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Table 2.1.3.1 lists annual and net water-level changes for these wells. Water-level changes appear to correspond to water levels and/or flow in these ditches and ponds. Variations in water levels occurred in well MR97-1 (fig. 2-13) when MR began to discharge water from their Berkeley Pit copper recovery project (Spring 1999) 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. Other changes were also 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 MR97-2 and MR97-3, which are adjacent to collection ditches (fig. 2-14 and 2-15).

Water-level increases were seen again following MR’s summer 2000 suspension of mining. Water from the HSB drainage that had been pumped to the Yankee Doodle Tailings Dam since April 1996 was allowed to flow into the pit following the June 2000 mine shut-down. What is somewhat surprising is the HSB discharge water used the same drainage channel that the discharge water from the pit copper recovery project had been using, but the flow of water was only about one-third as great. If anything, with the decreased flow in the channel, less water would be available for ground water recharge and water levels would be expected to either stabilize or drop. Instead, they rose before gradually declining over the next year.

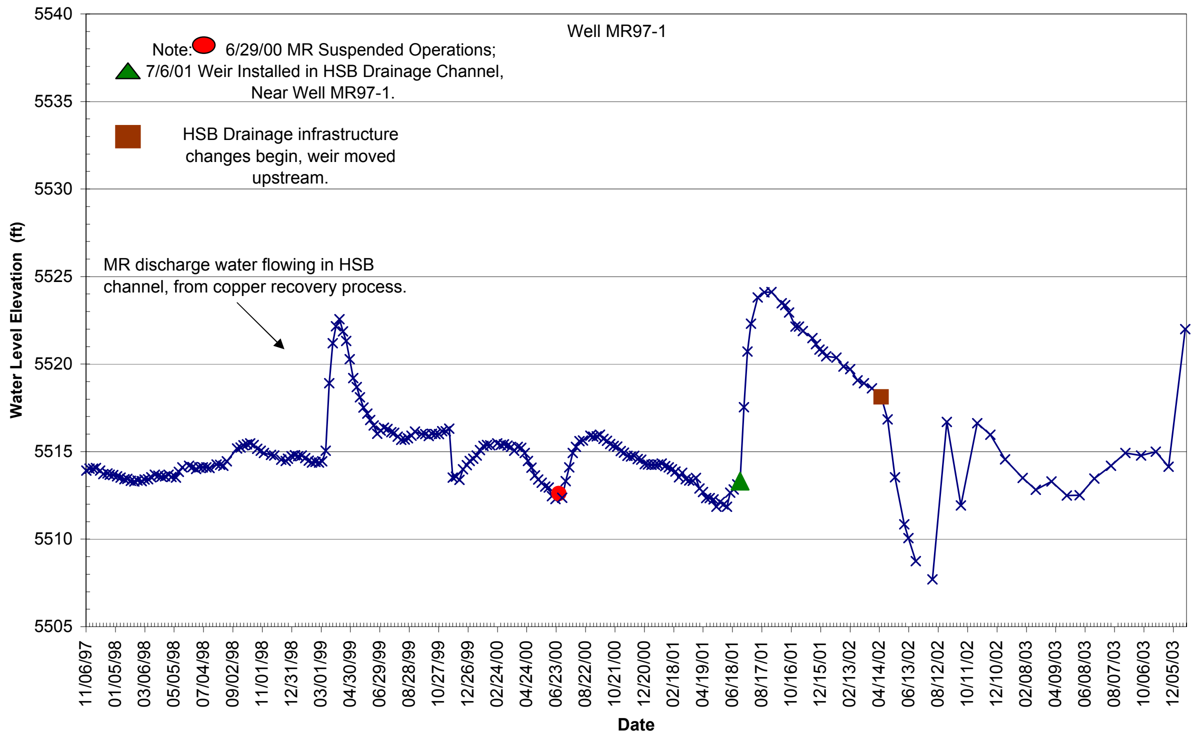


Figure 2-13. Water-level hydrographs for well MR97-1

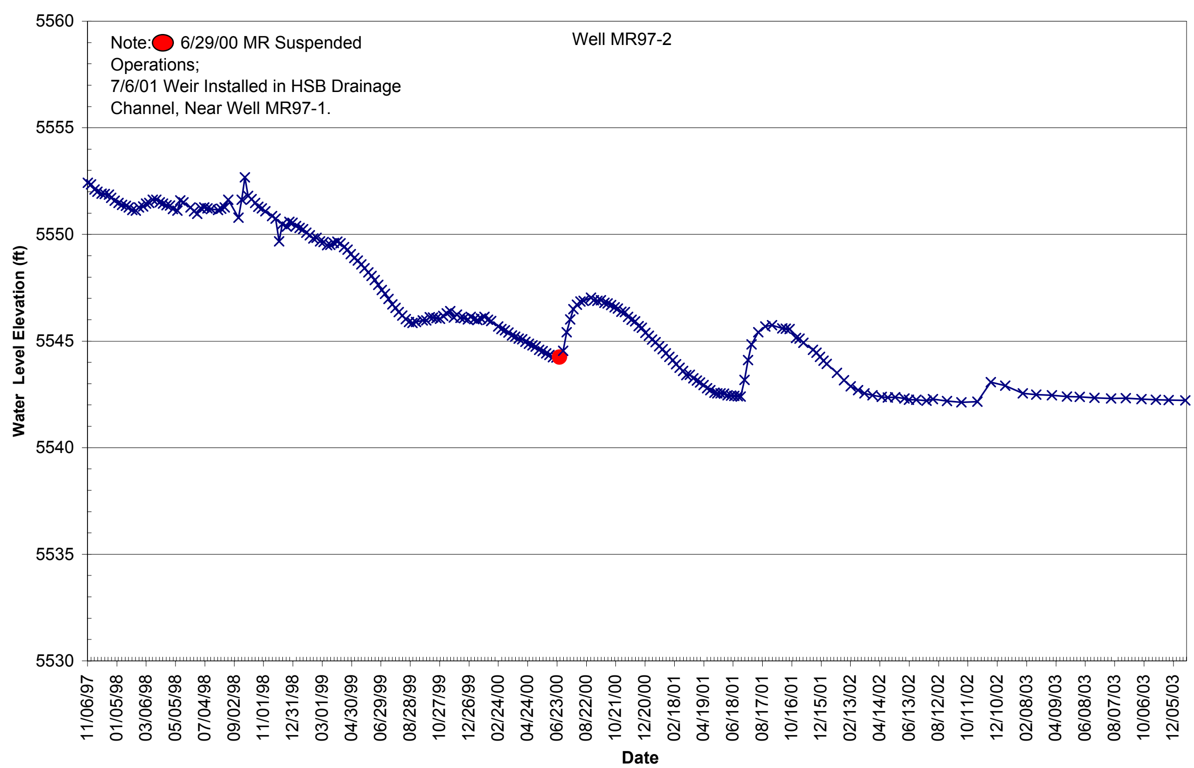


Figure 2-14. Water-level hydrographs for well MR97-2.

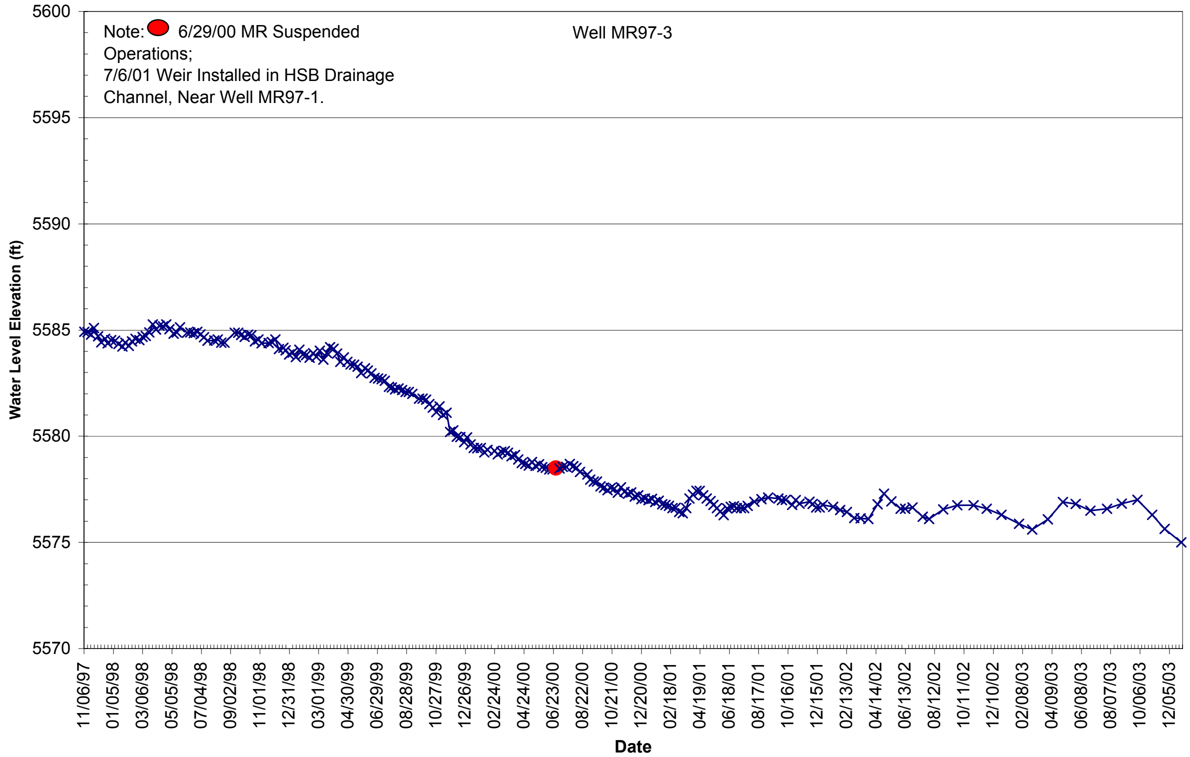


Figure 2-15. Water-level hydrographs for well MR97-3.

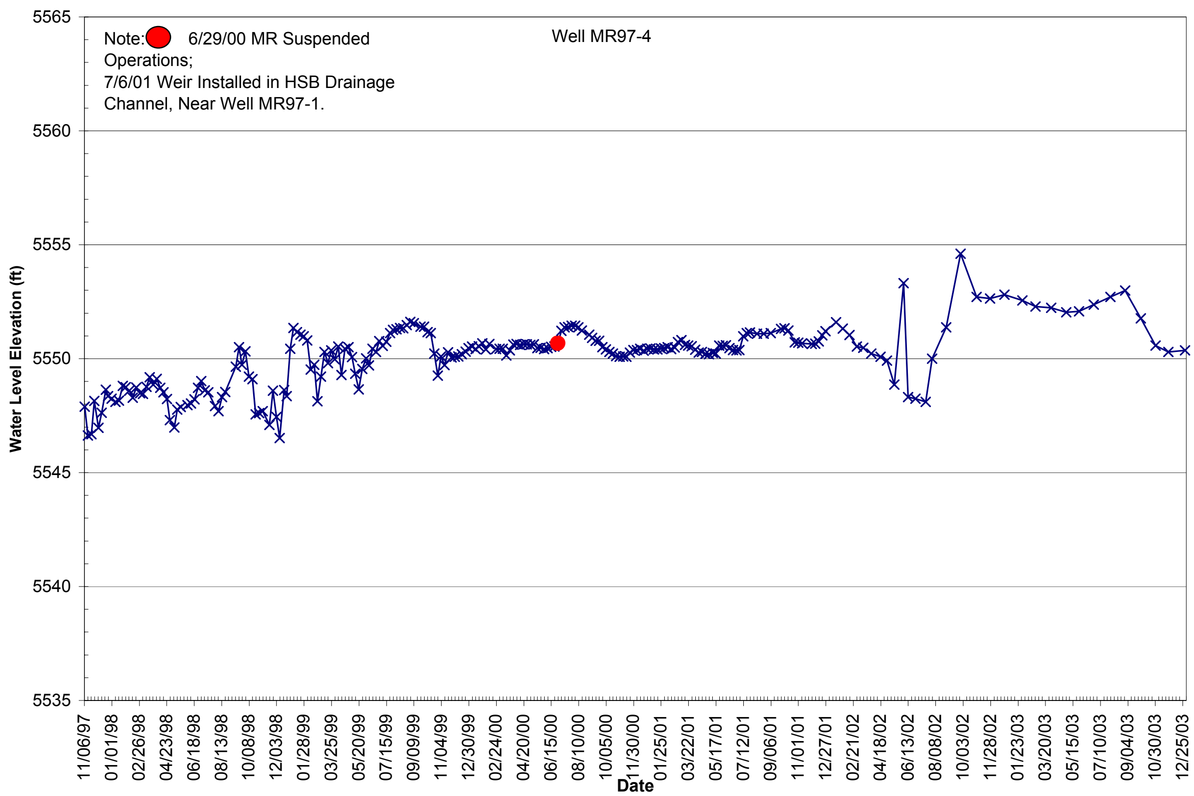


Figure 2-16. Water-level hydrographs for well MR97-4.

Table 2.1.3 Annual water-level changes in MR97-series wells.

Year	MR97-1	MR97-2	MR97-3	MR97-4
1997	-0.25	-0.84	-0.40	0.34
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
2002	-5.88	-1.02	-0.47	1.60
2003	7.43	-0.70	-1.29	-2.45
Net Change	**8.07**	**-10.21**	**-9.91**	**2.47**

Similar variations were observed in well MR97-1 during July 2001 and again in 2002, when a weir was installed (2001) and then relocated (2002) in the channel. The weir that was installed in 2001 was relocated upstream of the outlet that was historically referred to in MR's precipitation-plant operations as Pond 4. The weir was relocated as part of infrastructure changes relating to the HSB water treatment plant construction. The area occupied by Pond 4 was excavated and enlarged, then lined with lime rock during construction activities. The weir's relocation resulted in a drop in water levels in well MR97-1 because the weir and the accompanying impounded water were moved upgradient of this well. Water levels showed some minor fluctuations during early 2003, before rising several feet and then leveling off, until a substantial rise occurred during December 2003. The December rise coincides with the resumption of MR's copper-recovery project and the corresponding flow of discharge water in a drainage ditch near well MR97-1.

Water-level increases were also seen in wells MR97-2, MR97-3, and MR97-4 following MR's suspension of mining (fig. 2-14, 2-15, and 2-16). The response in water levels in well MR97-2 (fig. 2-14) was very similar to that seen in well MR97-1. A similar increase was seen in well MR97-2 following the 2001 weir installation. Water levels were stable at this site during 2003 and did not show the same fluctuations as noted in well MR97-1.

The water level in well MR97-3 showed only a minor response to the 2001 and 2002 construction activities. However, water levels rose the first part of 2003, before leveling off for the next 5 to 6 months and then falling the last several months of the year (fig. 2-15). This MR-series well is the furthest away from the HSB drainage channel and appears to be the least responsive to operational changes and flows in the discharge channel.

Water-level changes in well MR97-4 (fig. 2-16) were similar to those seen in well MR97-3, except the decline in water levels began earlier in 2003 and were greater. Since this well is closer to the precipitation-plant facilities and HSB ponds and drainage ditches, it is possible that changes in operational flows in this area are responsible for the water-level declines observed the later part of 2003. Changes would be more pronounced in this well than in well MR97-3.

Water levels have declined more than 9 feet in the two wells (MR97-2 and MR97-3) 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 and relocation, have affected ground-water levels in the area.

No water-quality samples were collected from this group of wells in 2001, 2002, or 2003. 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

Monthly water-level monitoring of the six GS wells continued throughout 2003. The locations of these wells are shown on fig. 2-17. Table 2.1.4 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. Water-levels had a net increase in all six wells during 2003, which is the first net rise since 1998.

Table 2.1.4 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	0.17	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	-20.7
2001	-0.28	-0.41	-0.22	-0.38	-1.78	-0.92
2002	-0.82	-0.81	-0.94	-0.82	-1.18	-1.18
2003	0.19	0.26	0.27	0.17	-081	0.77
Net Change	**-0.19**	**-0.14**	**0.05**	**0.00**	**-0.03**	**-0.11**

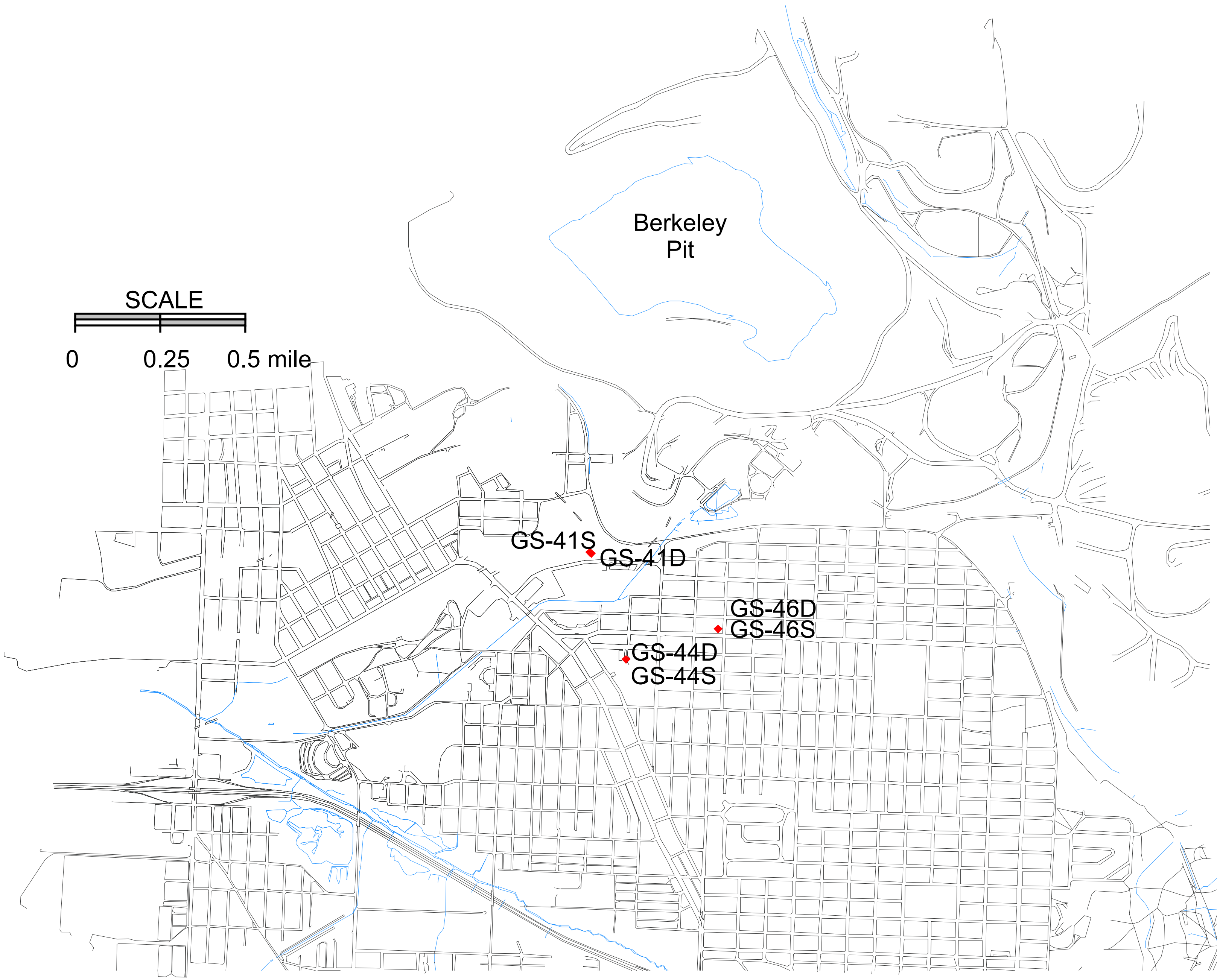


Figure 2-17. GS wells location map.

Figures 2-18 through 2-20 are water-level hydrographs with monthly precipitation totals shown for well pairs GS-41, GS-44, and GS-46. The seasonal variations 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.

Water-level changes in wells GS-41S and GS-41D were similar once again during 2003 (fig. 2-18) and the influence of precipitation was very noticeable. Water levels rose about 0.2 feet in these two wells during 2003—the first rise in six years.

Wells GS-44S and GS-44D had similar water-level changes throughout 2003 (fig. 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 rose about 0.2 feet for 2003. This is the first water-level rise in five years.

Overall, water-level trends were similar during 2003 in wells GS-46S and GS-46D (fig. 2-20) and followed the trends discussed previously for wells GS-41 and GS-44. Water levels rose more than 0.75 feet in both wells during 2003. These increases are 3 to 4 times those in the other two pairs of wells, however, the seasonal trends are the same as those in the other GS-series wells. The net water-level increase is the first in five years

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 has the potential to move upwards in the aquifer and possibly discharge into a surface-water body, such as Silver Bow Creek.

The net water-level increase in all six of these wells is surprising following 5-6 years of decline, considering the continued below normal precipitation trends. The 2003 annual precipitation totals were less than the totals for either 2001 or 2002.

2.1.4.1 GS-Series Wells Water Quality

Water-quality samples were collected during both sample events from these wells as part of the 2003 BMFOU monitoring. These were the first water-quality data collected from these wells for several years. Water quality in GS-41S reflects its proximity to the Parrot tailings area; concentrations of dissolved constituents are extremely high. Only arsenic, which has increased from less than 40 to nearly 80 μg/L has exhibited a notable trend in this well. Well GS-41D, which has slightly better (but still extremely poor) water quality, exhibits little change in the concentration of dissolved constituents.

Well GS-44S, at the north end of Clark's Park, was last sampled in 2001; the concentration of several dissolved constituents exceeded MCLs. In the 2003 samples, the concentrations of several dissolved

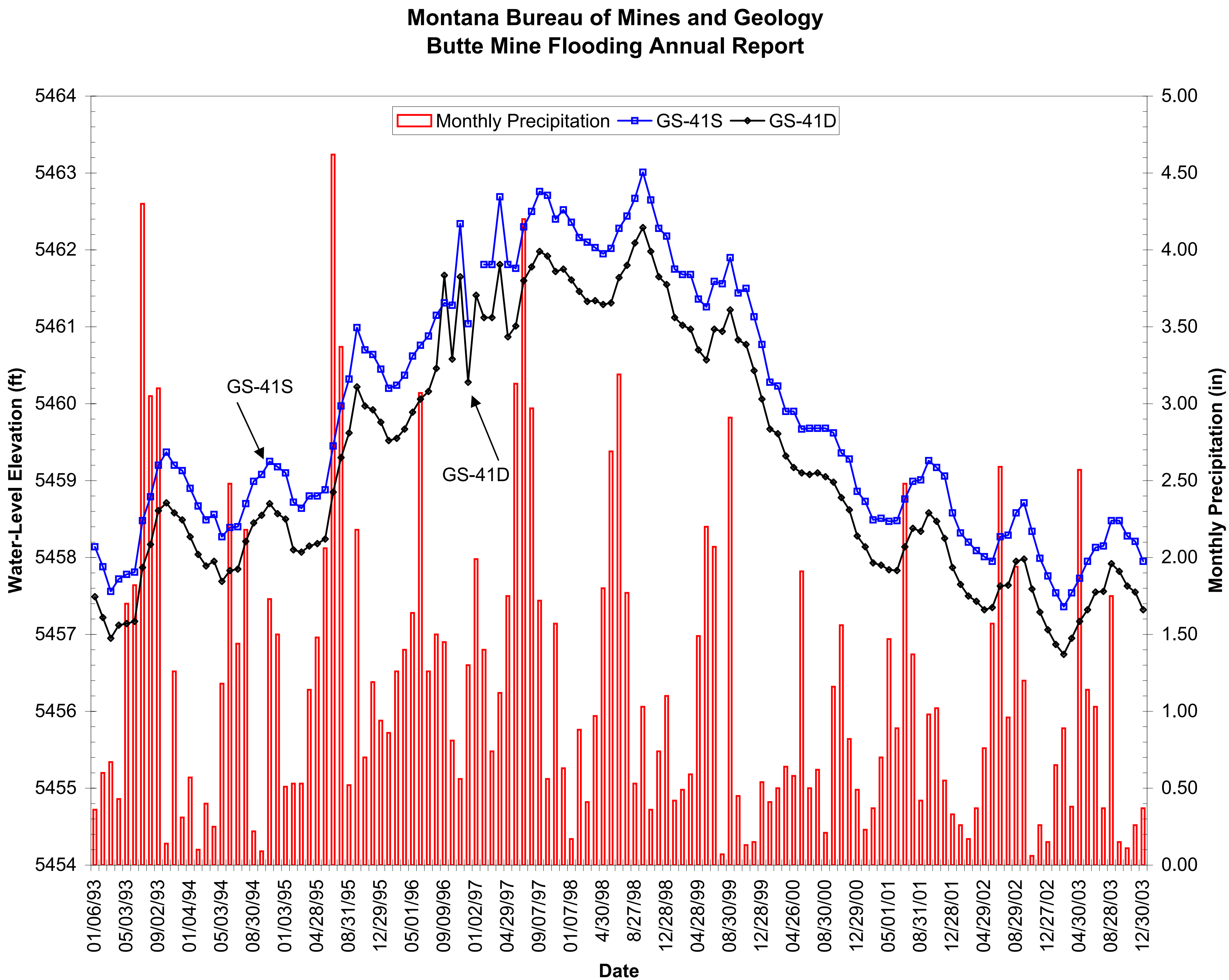


Figure 2-18. Water-level hydrographs for GS-41S and GS-41D wells.

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Butte Mine Flooding Annual Report

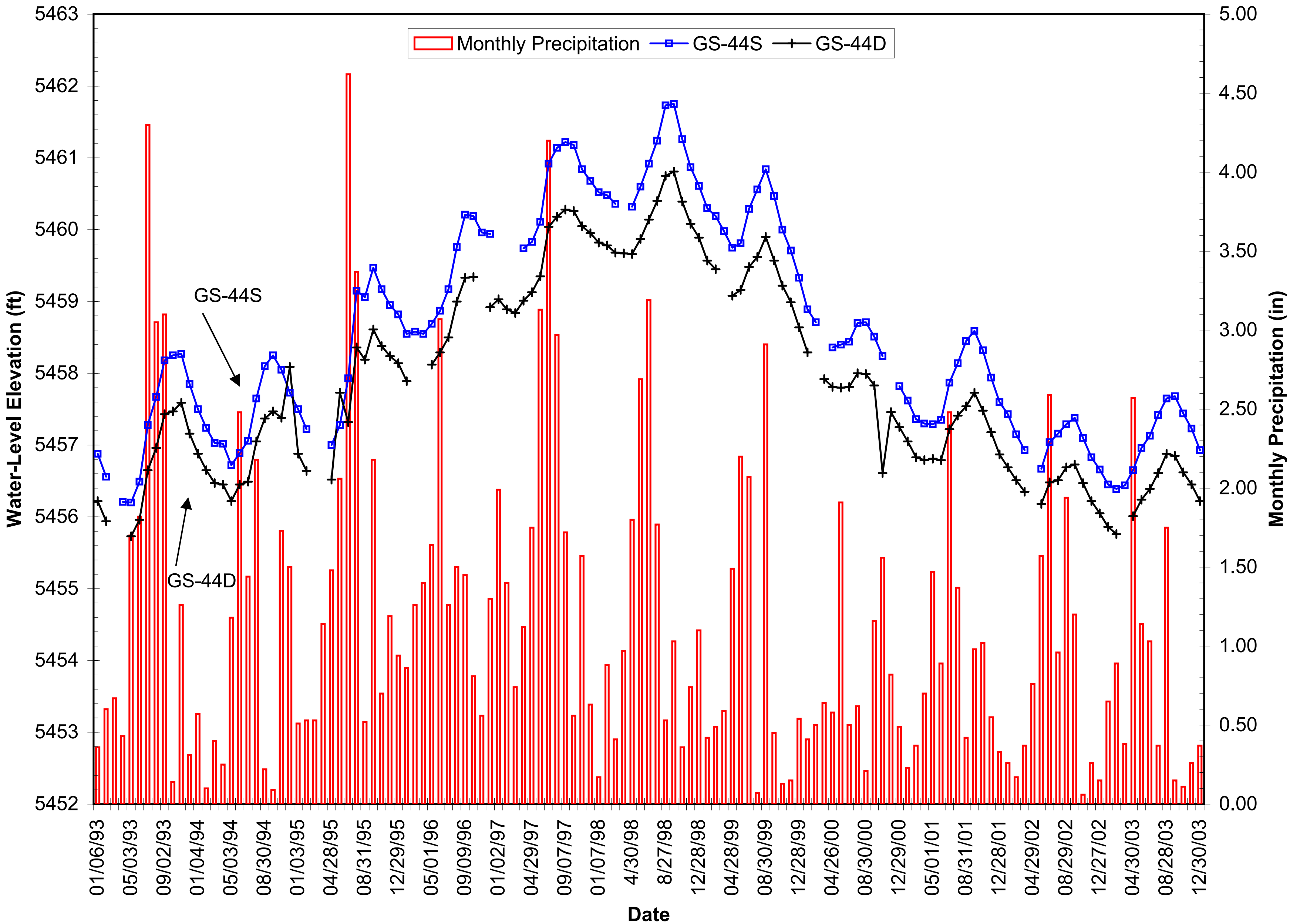


Figure 2-19. Water-level hydrographs for GS-44S and GS-44D wells.

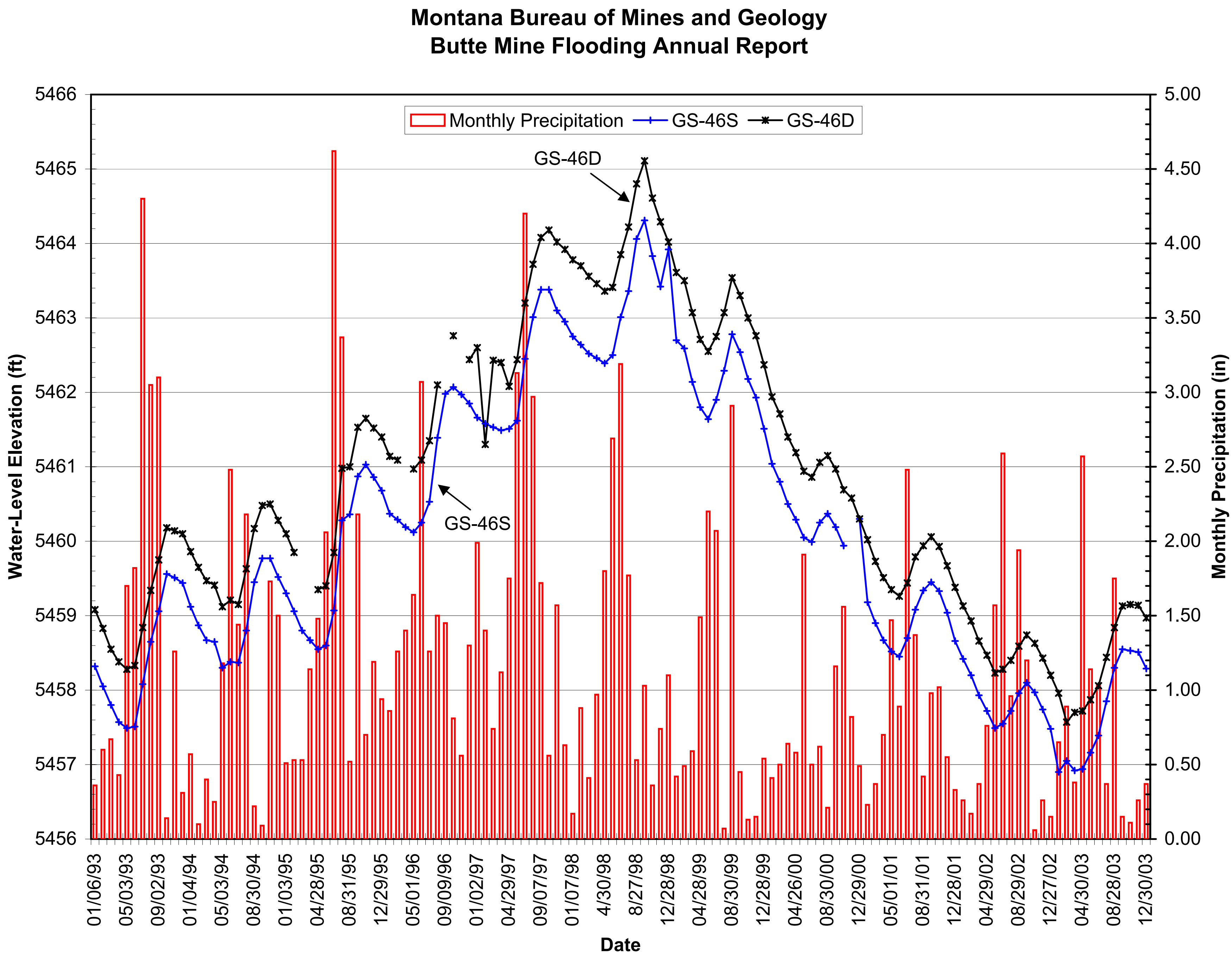


Figure 2-20. Water-level hydrographs for GS-46S and GS-46D wells.

metals, particularly cadmium and zinc, have decreased to below the MCL for the first time in the 14-year period of record. The deeper well, GS-44D, continues to exhibit concentrations greater than MCLs, but overall concentrations have decreased by as much as 50 percent over the period of record and several are approaching the MCL. The concentration of zinc, for example, was over 23,000 μg/L in 1989 and the concentration of zinc in 2003 was about 7,200 μg/L; the drinking water MCL is 5,000 μg/L. Wells GS-46S and D, northeast of Clark's Park exhibit good water quality and show little or no trend.

Section 2.2 East Camp Underground Mines

Monitoring of water levels in the seven East Camp underground mines continued. Their locations are shown on figure 2-21. During the year 2003, water levels rose between 13 and 14 feet in the mines, which is similar to the rise in 2002, with some exceptions. The Berkeley Pit water level rose 13.8 feet, which is about 2.5 feet less than last year (Table 2.2). Figure 2-22 shows the annual water level changes graphically for these sites. The net 2003 water-level change between the mine shafts and Berkeley Pit was more comparable than the several prior years.

Figure 2-23 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 2003, several changes are noticeable (figure 2-24). The stoppage of HSB drainage water from entering the pit in 1996 resulted in a flattening of the line, while the 2000 addition of this same water resulted in an increased slope of the line. The 3-foot water-level change (rise) following the 1998 Berkeley Pit landslide is very noticeable. The HSB water treatment plant, which came on-line during late November 2003, did not have any significant influence on 2003 water levels.

Figure 2-25 shows monthly water-level changes in the Berkeley Pit through 2003. The addition of HSB drainage water continued through late November 2003. Water-level changes seen over the last 6 months of 2000, following the addition of HSB drainage water, continued through 2003. A similar trend was seen in all the East Camp underground mines. Water levels remain highest in the sites furthest 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.

Figure 2-26 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. Based upon volume estimates of the underground mines and December 2003 water-level elevations, over 90 percent of the underground mine workings are flooded.

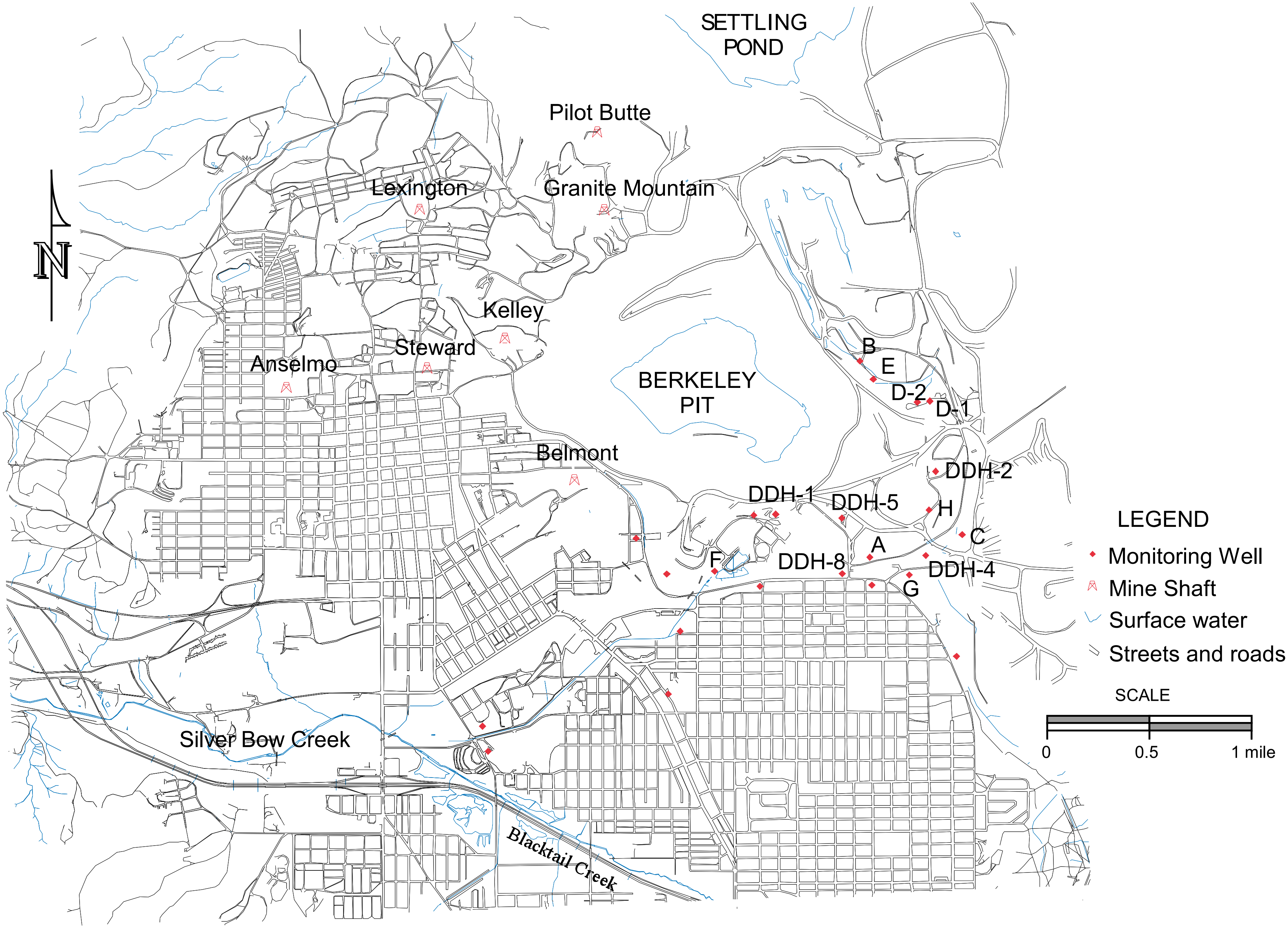


Figure 2-21. East Camp mines and bedrock wells location map.

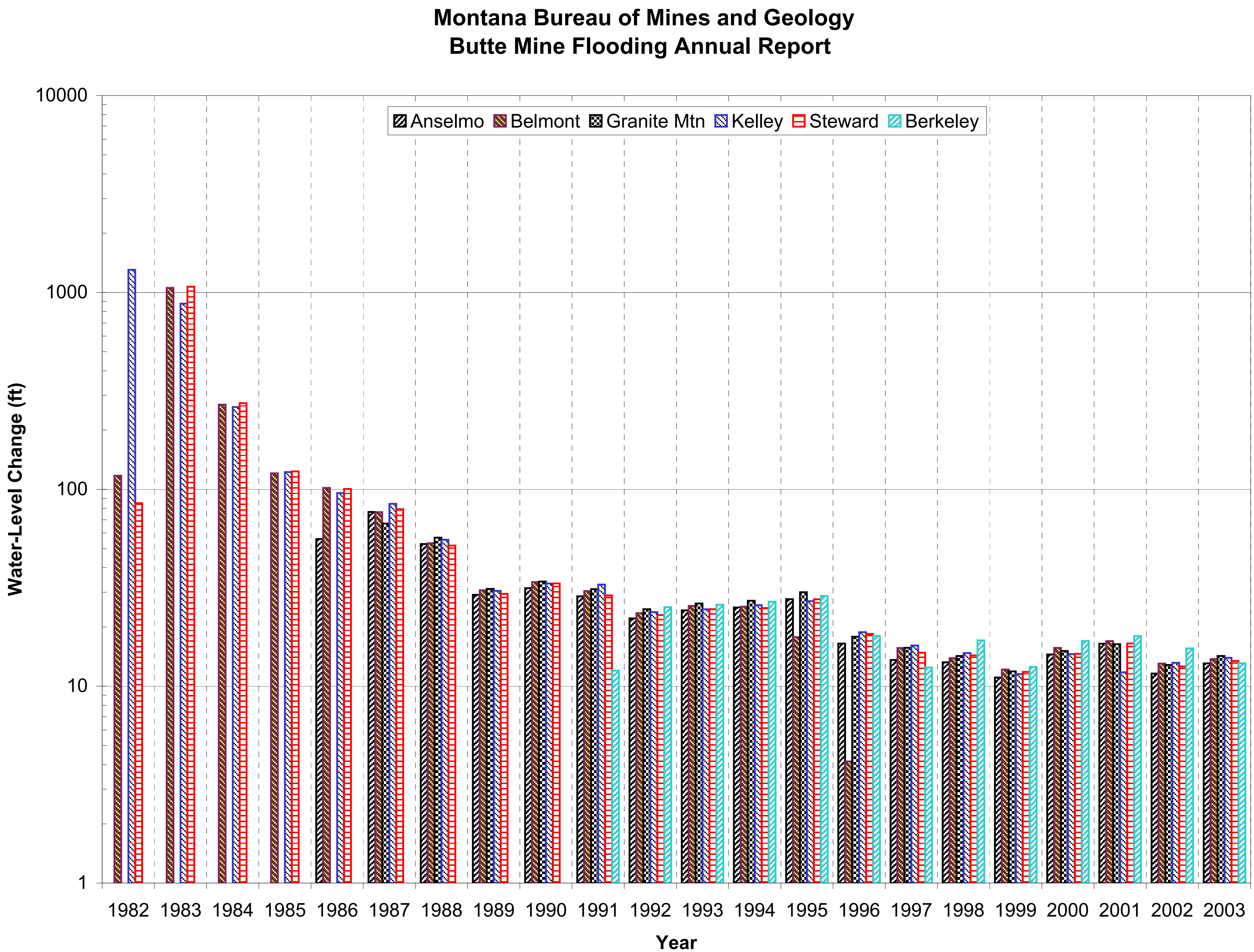


Figure 2-22. East Camp mines annual water-level changes.

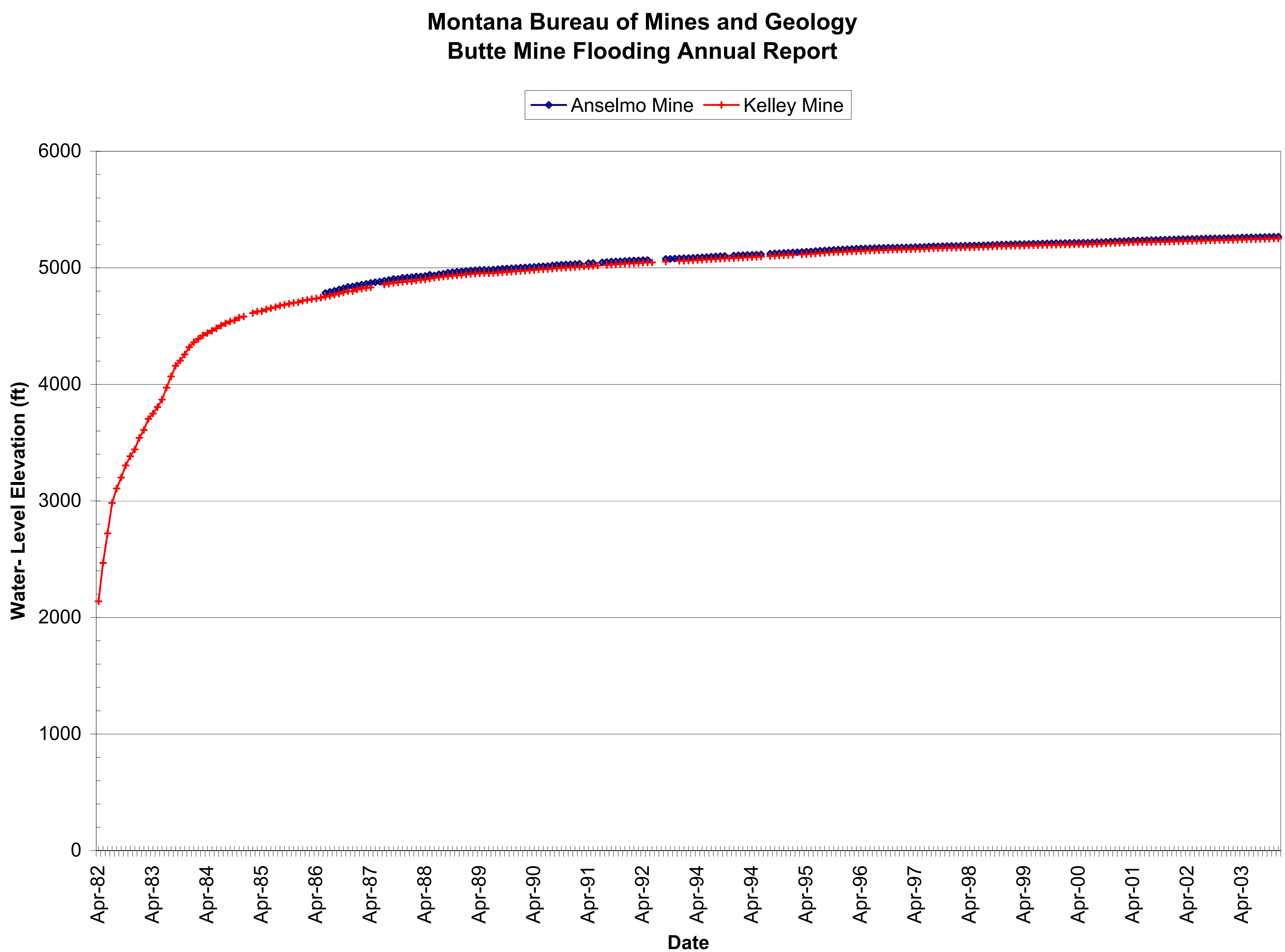


Figure 2-23. Water-level hydrographs for the Anselmo Mine and Kelley Mine.

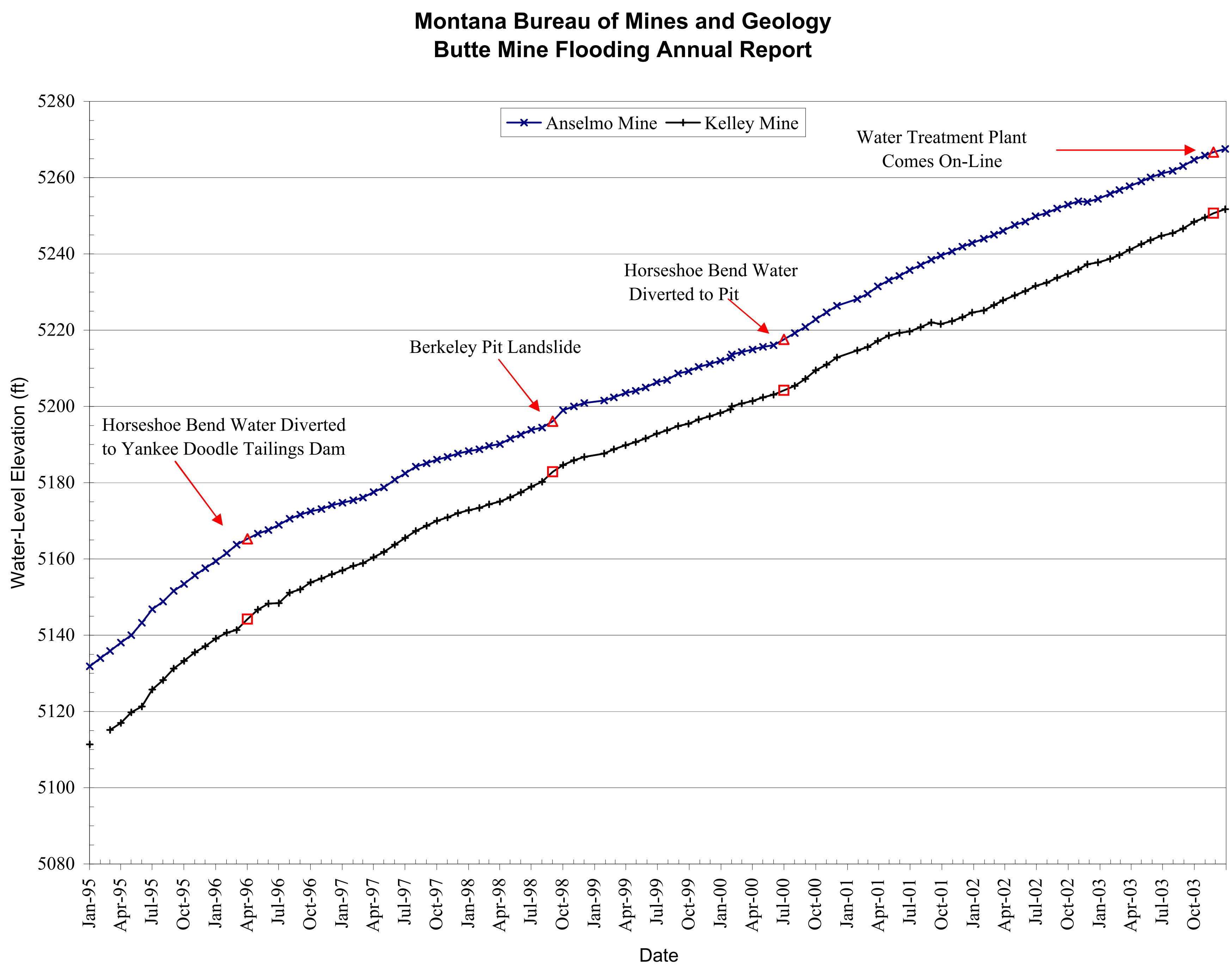


Figure 2-24. Water-level hydrograph, 1995-2003, Anselmo Mine and Kelley Mine.

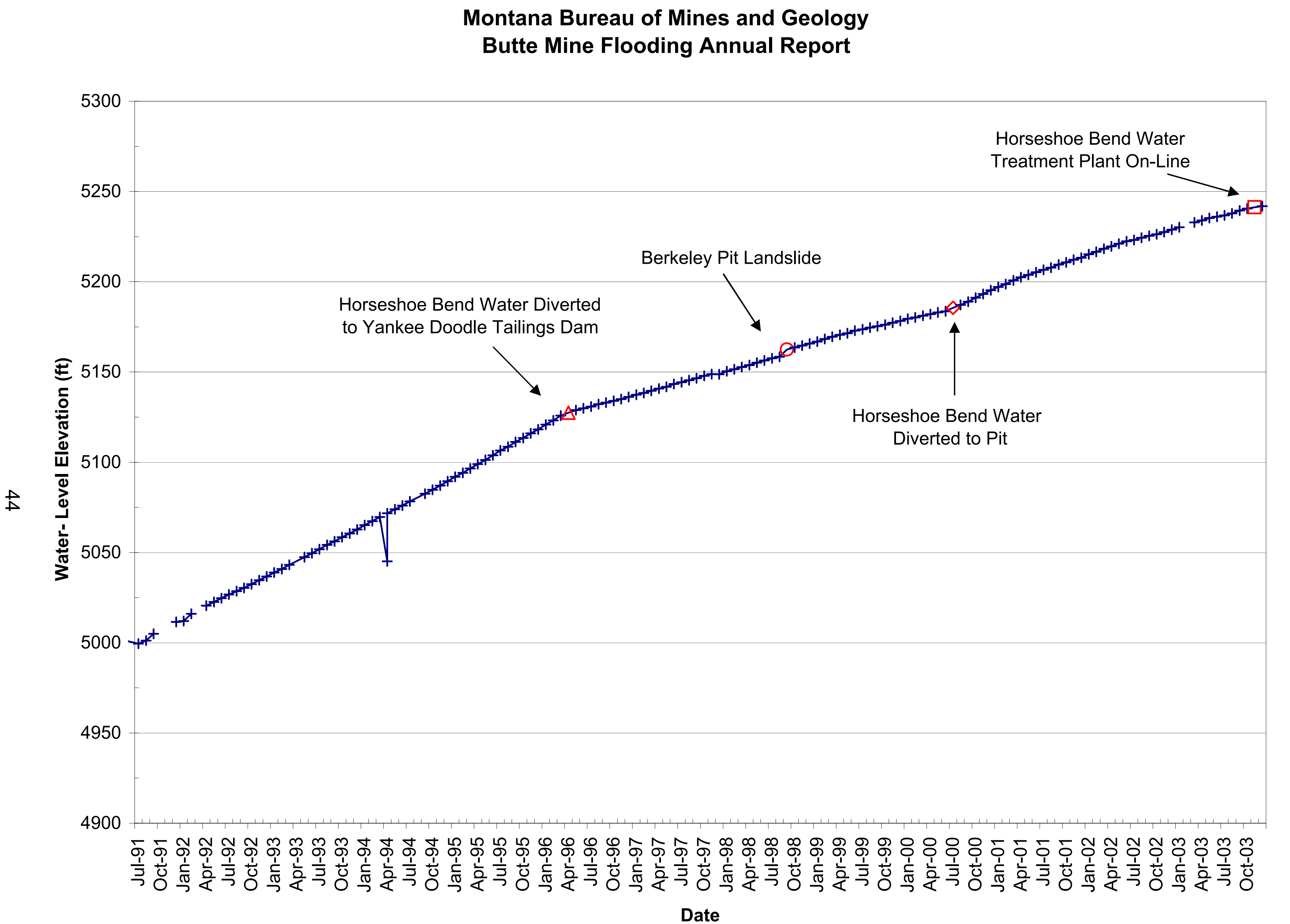


Figure 2-25. Water-level hydrograph for the Berkeley Pit.

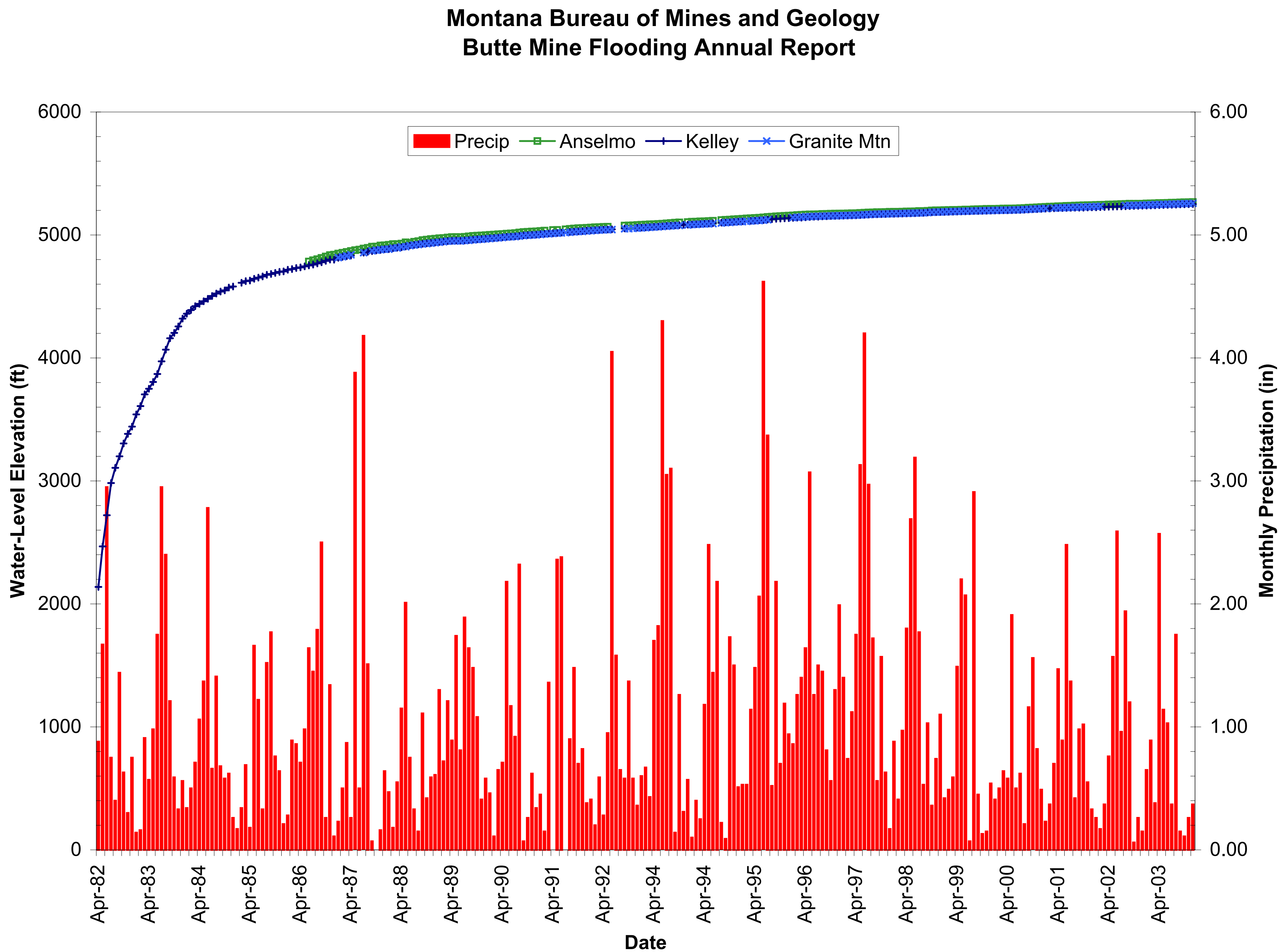


Figure 2-26. Water-level hydrographs for selected East Camp mines, with monthly precipitation.

Table 2.2. Annual water-level changes in East Camp mines, in feet

Year	Berkeley Pit	Anselmo	Kelley	Belmont [1]	Steward	Granite Mountain	Lexington[2]	Pilot Butte
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		
10- Year Change	***12.00***	***276.00***	***2,898.00***	***1,888.00***	***1,875.00***	***220.00***	***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
2002	15.56	11.60	13.15	13.02	12.60	12.82	12.08	11.33
2003	13.08	13.05	13.94	13.74	13.44	14.23	2.75	14.05
Grand Total Change*	***242.38***	***483.70***	***3,113.20***	***2,084.90***	***2,092.21***	***446.27***	***91.23***	***100.14***

[1] Mine shaft collapsed in 1995; a replacement well was drilled adjacent to the mine, into mine workings, in 1997. Since the well was drilled into the Belmont Mine workings it is assumed that this water level is reflective of the Belmont Mine.
[2] No water-level measurements since February 2003, due to obstruction in shaft at 366 ft below surface.
*Total change is the measured change in water level. Access or obstructions have prevented continuous water-level measurements at some sites.

Section 2.2.1 Water Quality

As noted in the 2002 report, water quality in the East Camp mines has been steady or slightly improving until 2002 when several of the shafts exhibited significant departure from previous trends. Data from several shafts indicate large changes in concentrations of chemical constituents in the water. The collection of several additional samples in 2003 confirms the changes and reduces the likelihood of analytical or sampling error.

Most notable is the increase in the concentration of metals, arsenic, and sulfate in the Kelley shaft. Dissolved copper is one of the few constituents that has decreased in concentration; arsenic, iron, sulfate, aluminum and several other constituents increased by about an order of magnitude in the July 2002 sample and have remained high since. Data collected in 2003 show the sustained increases in the concentrations of several dissolved constituents including arsenic, iron, and zinc (fig. 2-27); also notable is the lack of increase in copper. In fact, changes in concentrations and the concentration trends are common in all of the East Camp shafts over the past two years:

Anselmo: iron, aluminum, and arsenic concentrations have increased 2 to 3 orders of magnitude to near or above historic concentrations; zinc and cadmium show large (order of magnitude) fluctuations (fig. 2-28). Copper concentrations remain very low (<20 μg/L).

Steward: the trend of concentrations of most constituents in the Steward shaft has been upward throughout the period of record. This trend has changed for zinc and copper (fig. 2-29).

Kelley: iron, sulfate, arsenic, and aluminum have increased to near historic concentrations; copper concentration remains very low

Section 2.2.2 RI/FS Bedrock Monitoring Wells

Monitoring of the 9 RI/FS and ROD-installed bedrock wells continued. Monitoring well locations are shown on fig. 2-21. Water levels continue to rise in wells A, C, D-1, D-2, G, and J at rates similar to those in the East Camp Mine system. Water levels in well E continue to follow patterns identified in earlier reports, while water levels in well F increased over one-foot, which is the first net rise in 5 years. Table 2.2.2 contains yearly water-level changes and fig. 2-30 shows these changes graphically.

The monitoring program contained in the 2002 CD specified that water levels be monitored on a continuous basis in bedrock wells A, B, C, and G. Water-level transducers were installed in each of these wells and set to collect water-level data every hour. This detailed level of monitoring allows recording of changes in water levels not seen when only one water-level measurement is taken monthly.

Figures 2-31 and 2-32 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 levels 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 through 2003. 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 (fig. 2-33). The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

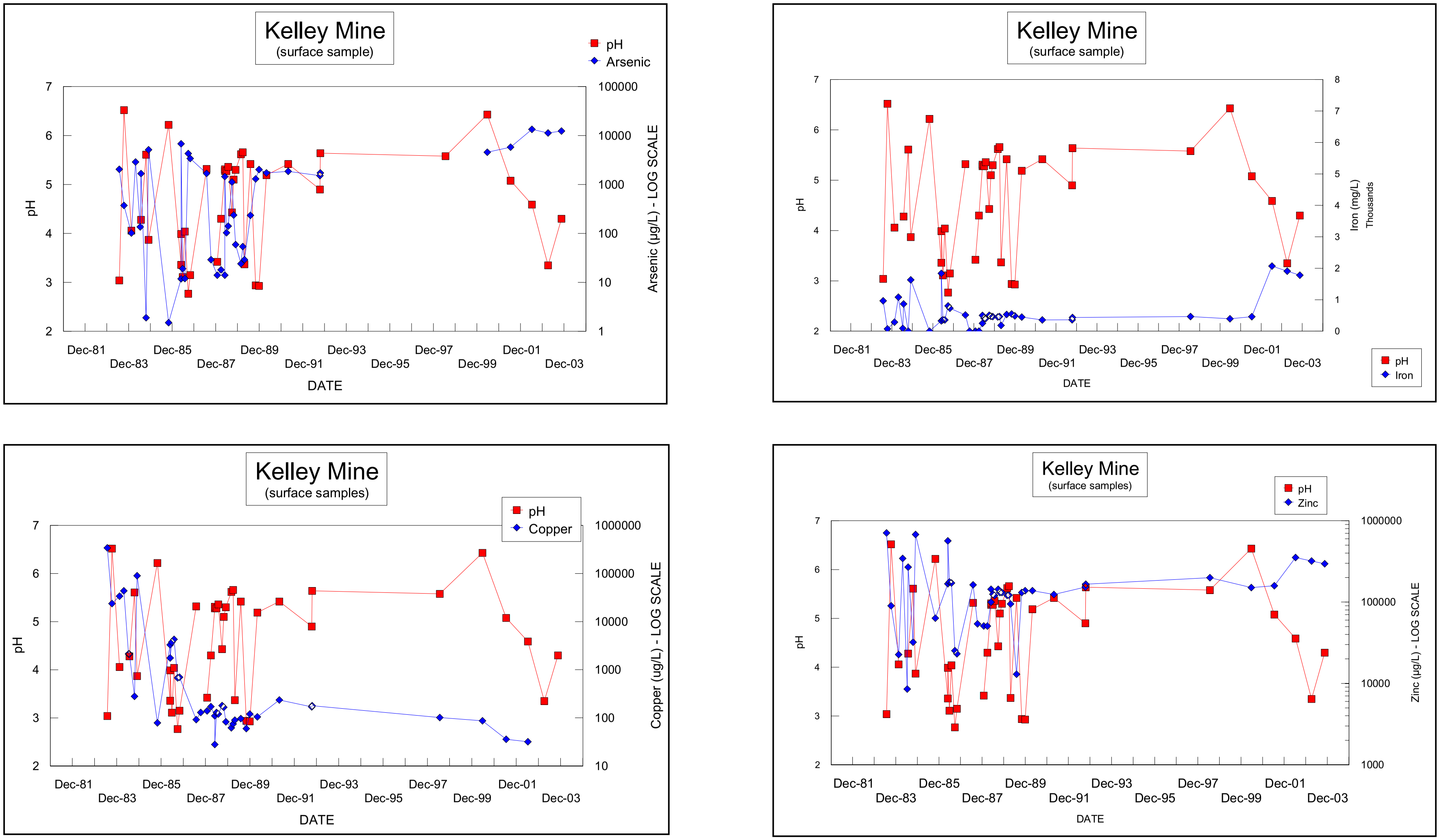


Figure 2-27. The concentration of most dissolved constituents in Kelley Mine waters remained high in 2003; the exception is copper which continued to decrease.

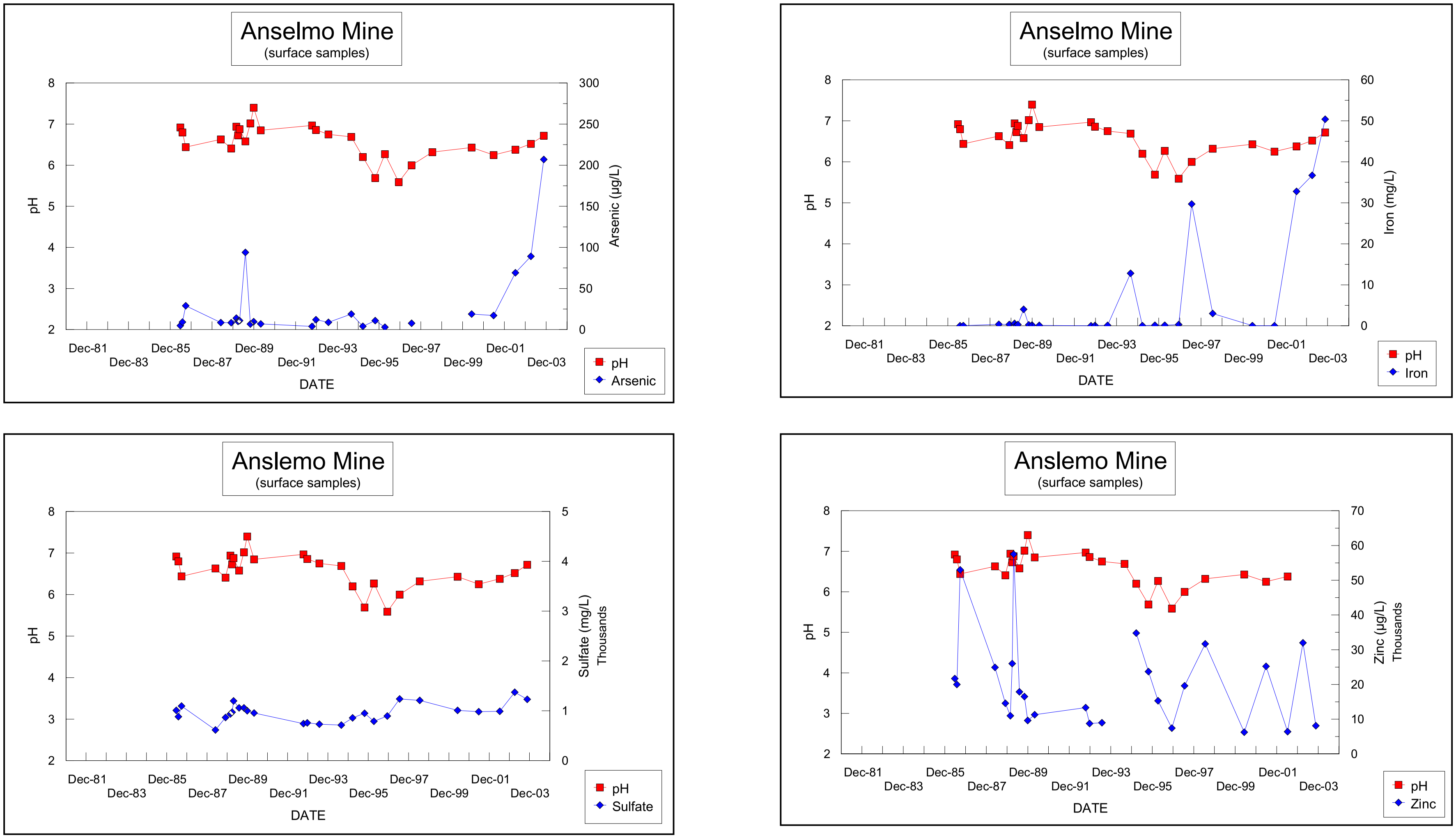
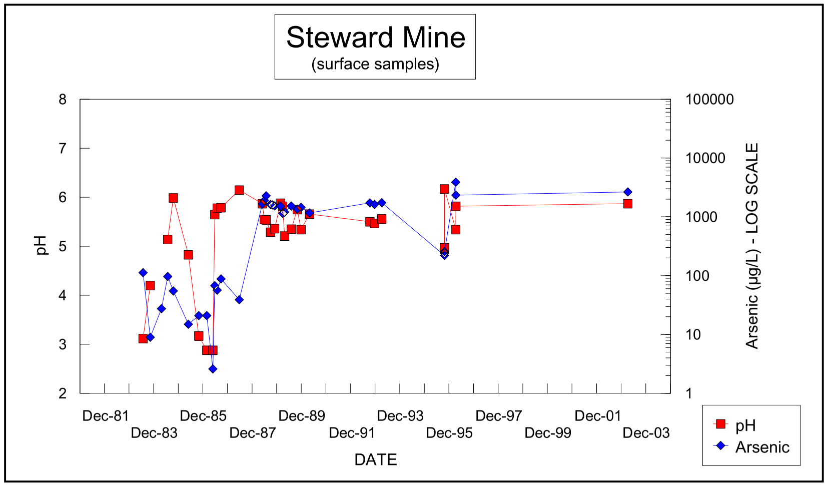
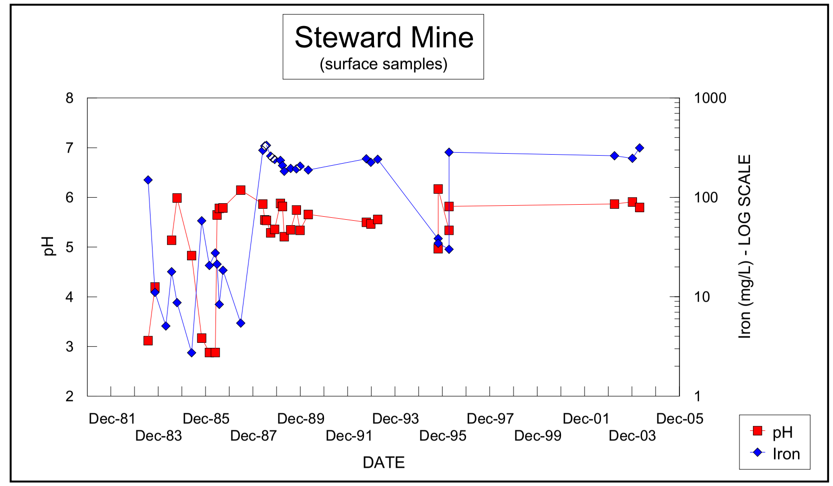
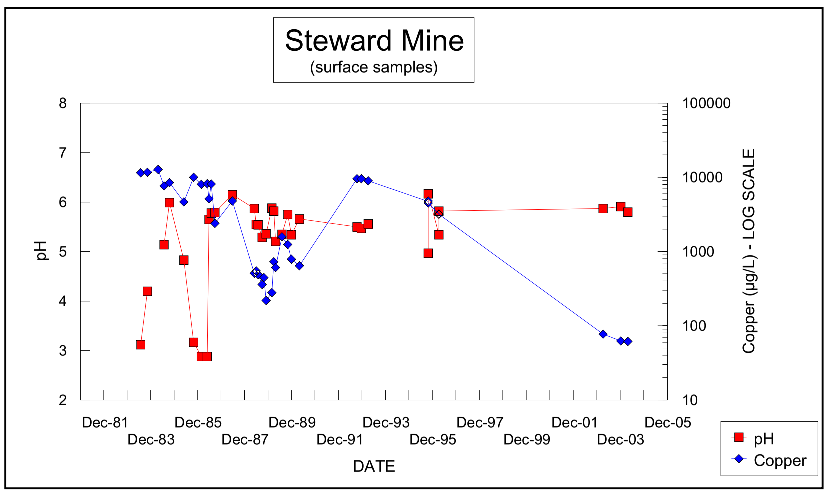


Figure 2-28. The concentration of arsenic and iron have increased dramatically in the Anselmo shaft. Sulfate concentrations increase slighltly and zinc fluctuates by an order of magnitude.







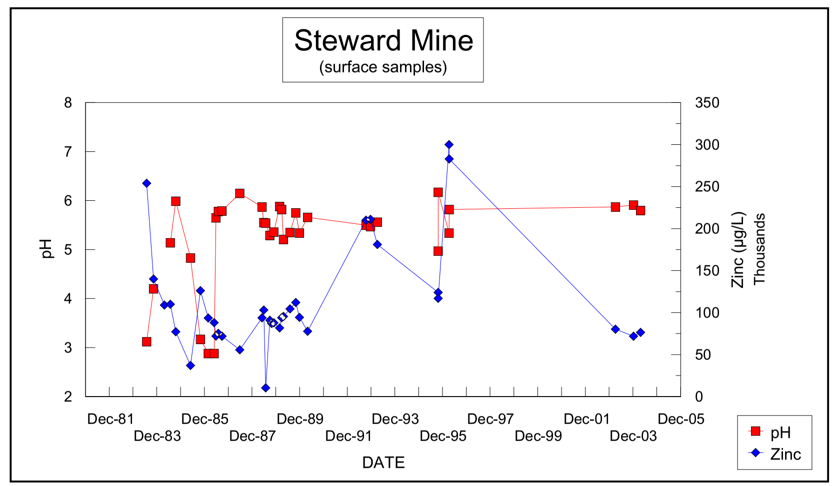


Figure 2-29. The concentrations of most dissolved constituents have increased in the Steward shaft over the period of record. Copper and zinc, however, have decreased to near historic levels.

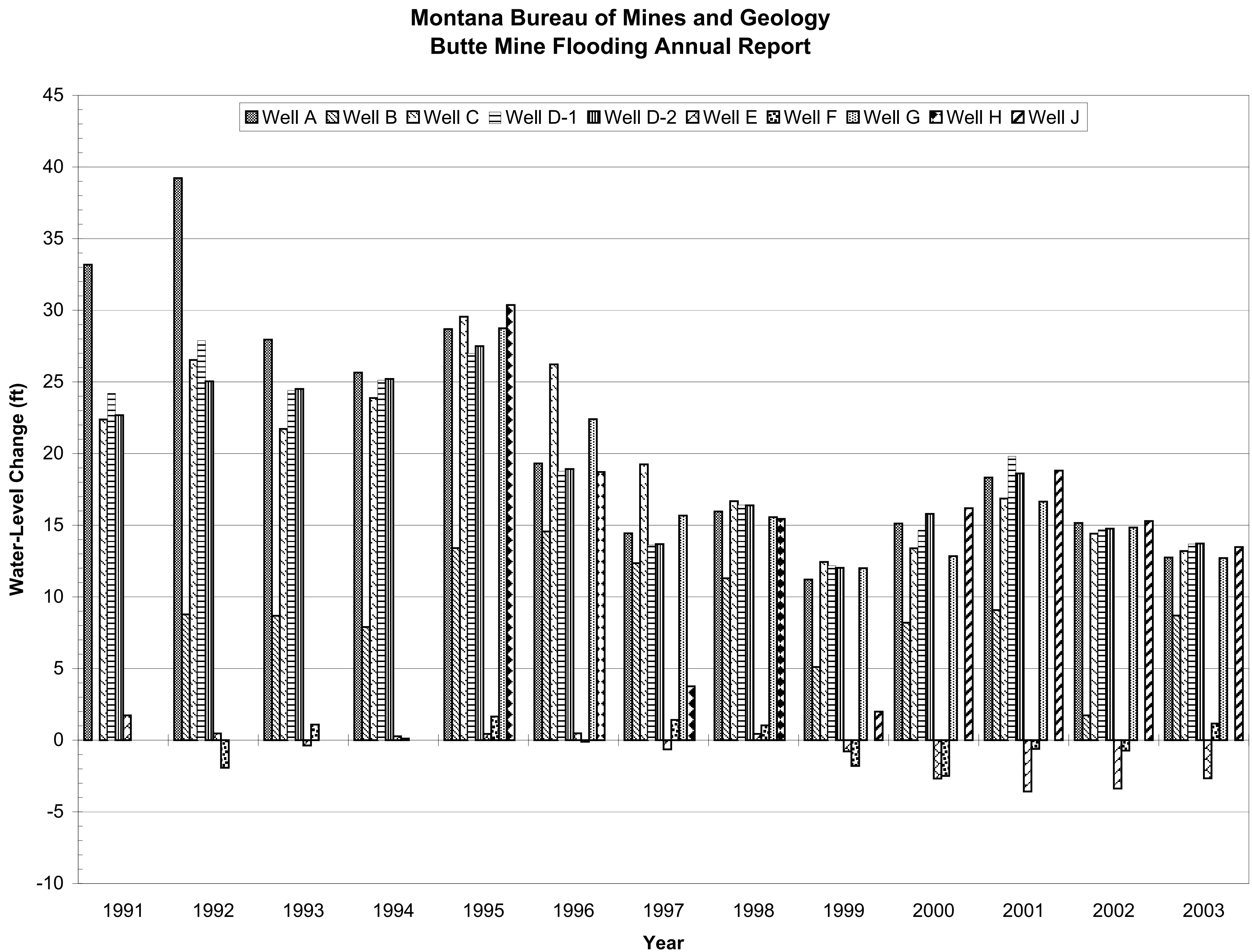


Figure 2-30. RI/FS bedrock wells annual water-level change.

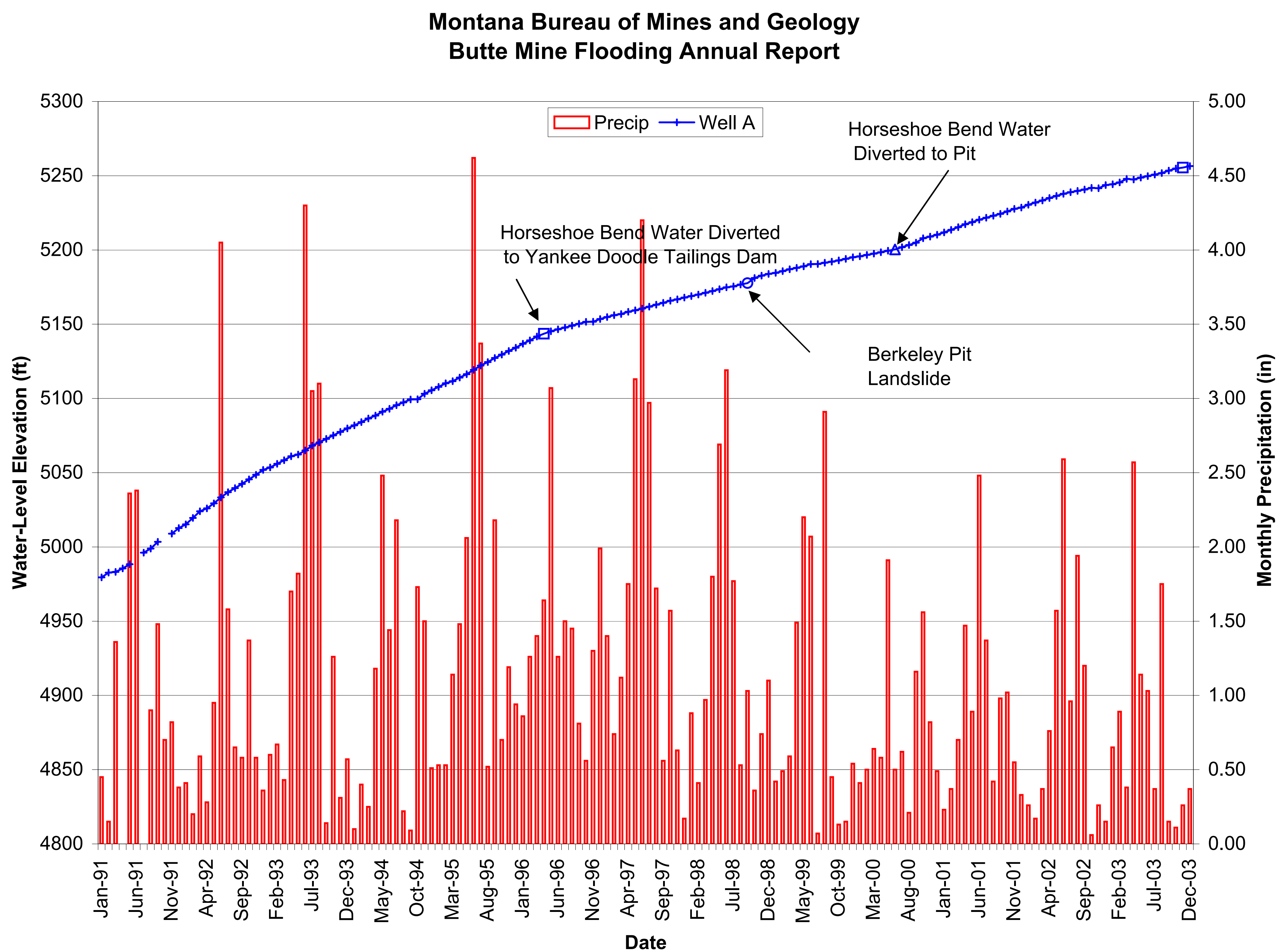


Figure 2-31. Water-level hydrograph for bedrock well A.

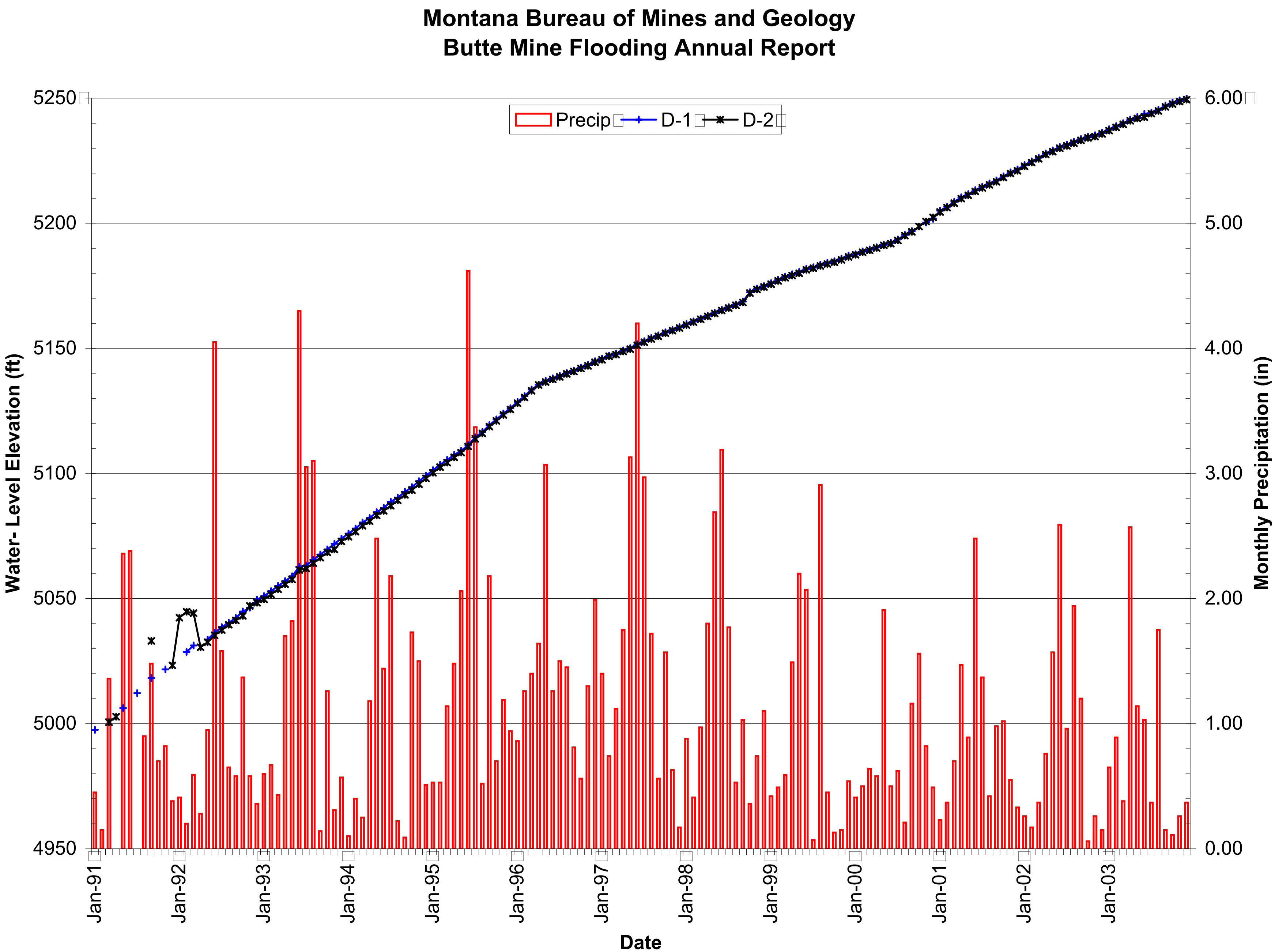


Figure 2-32. Water-level hydrographs bedrock wells D-1 and D-2.

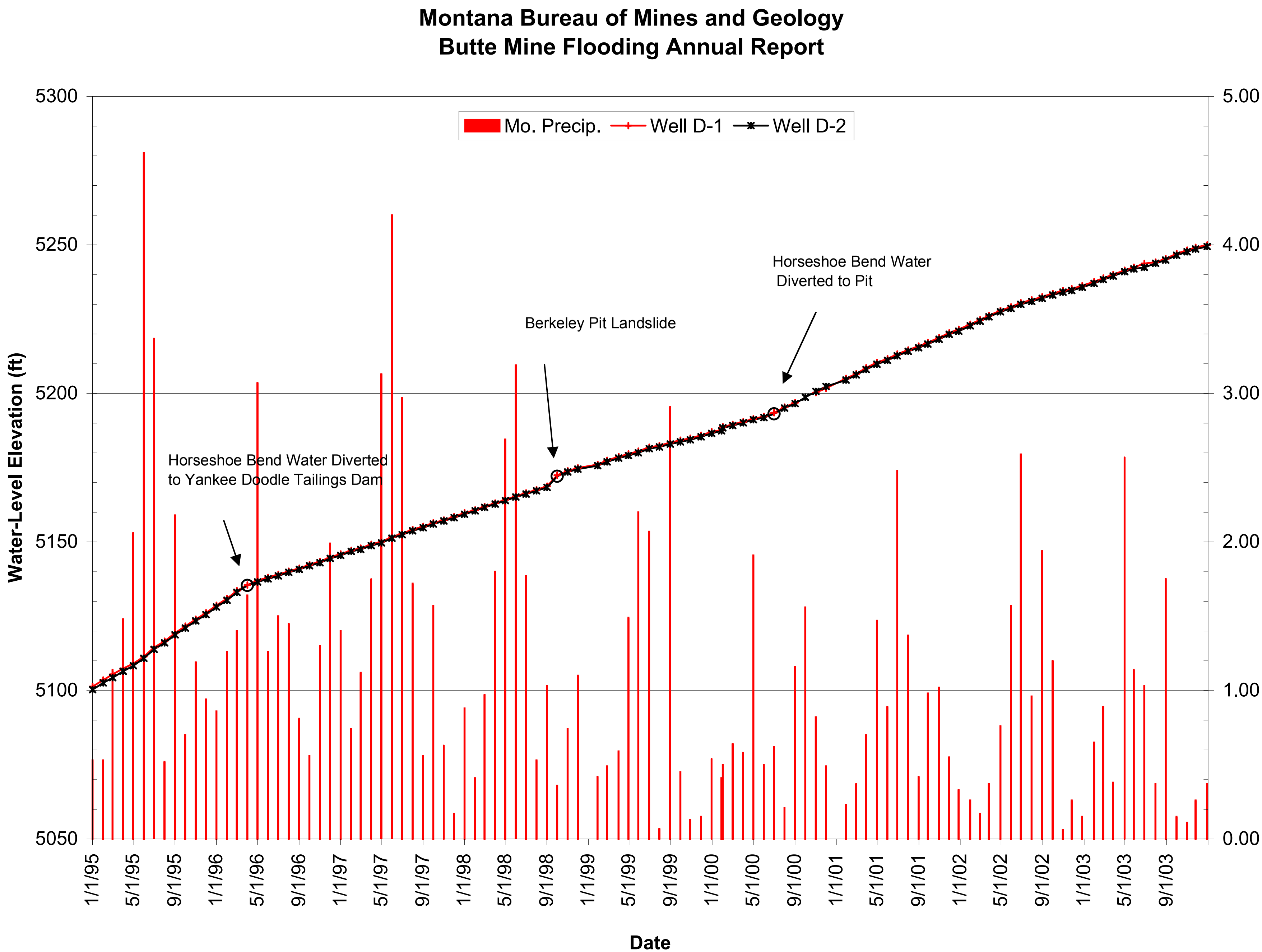


Figure 2-33. Water-level hydrographs, 1995-2003, wells D-1 and D-2.

Table 2.2.2 RI/FS bedrock well annual water-level change, in feet

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
2002	15.16	1.73	14.41	14.69	14.76	-3.37	-0.73	14.84	P&A	15.29
2003	12.75	8.70	13.20	13.69	13.72	-2.66	1.16	12.71	P&A	13.48
Total Change*	**276.97**	**109.80**	**256.51**	**252.44**	**248.84**	**-10.25**	**-1.21**	**151.41**	**68.29**	**65.76**

Year	DDH-1	DDH-2	DDH-4	DDH-5	DDH-6
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	21.07	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**	**235.60**	**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
2002	14.63	14.80	13.14	P&A	13.64
2003	13.05	13.90	NA	P&A	14.49
Total Change*	**317.05**	**288.68**	**276.05**	**240.42**	**320.53**

*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 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 fig. 2-34. 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 closely 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 was about one-half the rate of that of the above bedrock wells and Berkeley Pit over a number of years, until November 2002. Due to a water-level decline during November and December, the 2002 rate of water-level rise was only 11 percent of that of the Berkeley Pit. The 2003 water-level increase was closer to two-thirds that of the other bedrock wells. Hydrographs for wells A and B, showing monthly water-level elevations, are shown on fig. 2-35.

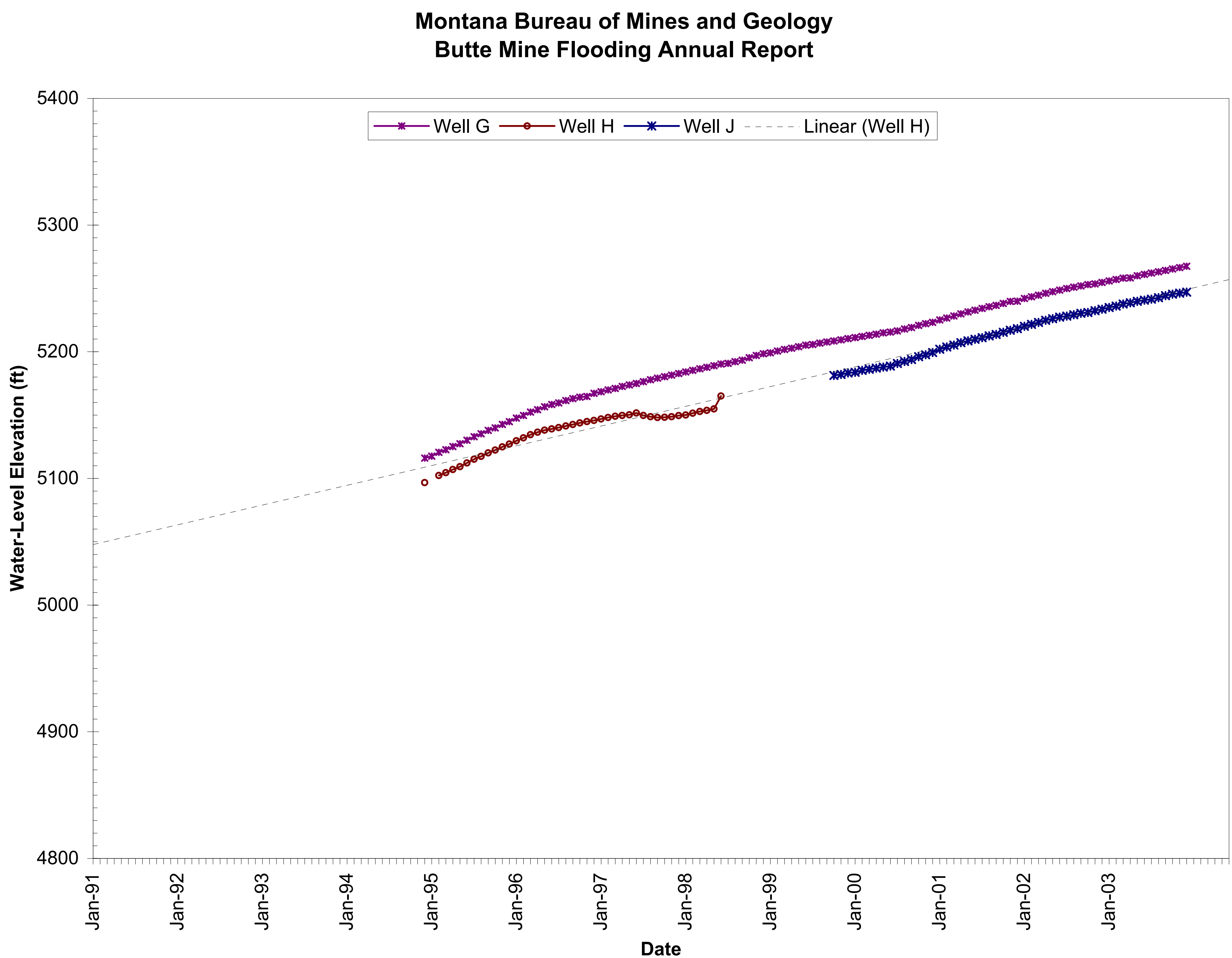


Figure 2-34. Water-level hydrographs for bedrock wells G, H, and J.

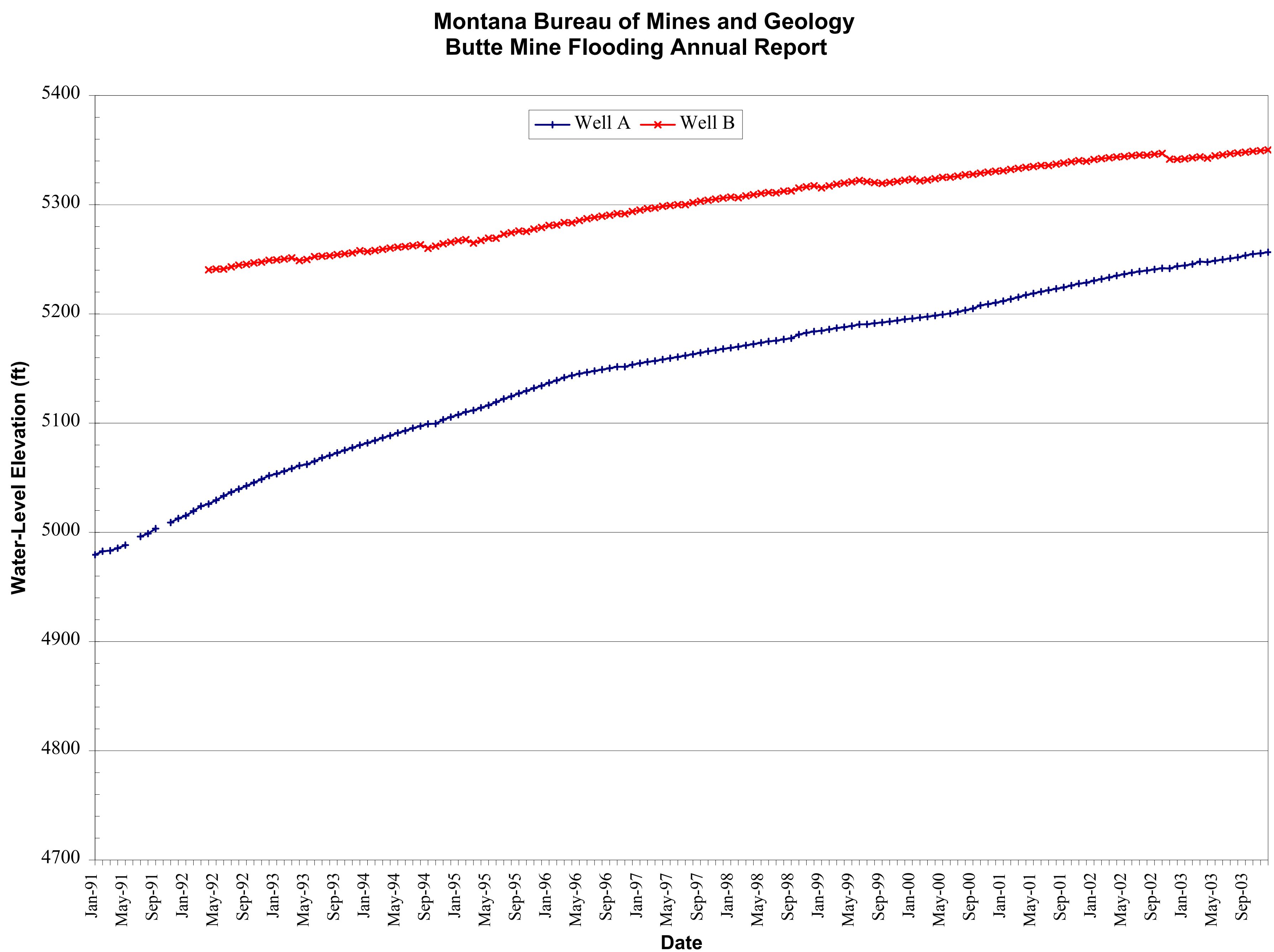


Figure 2-35. Water-level hydrograph for bedrock wells A and B.

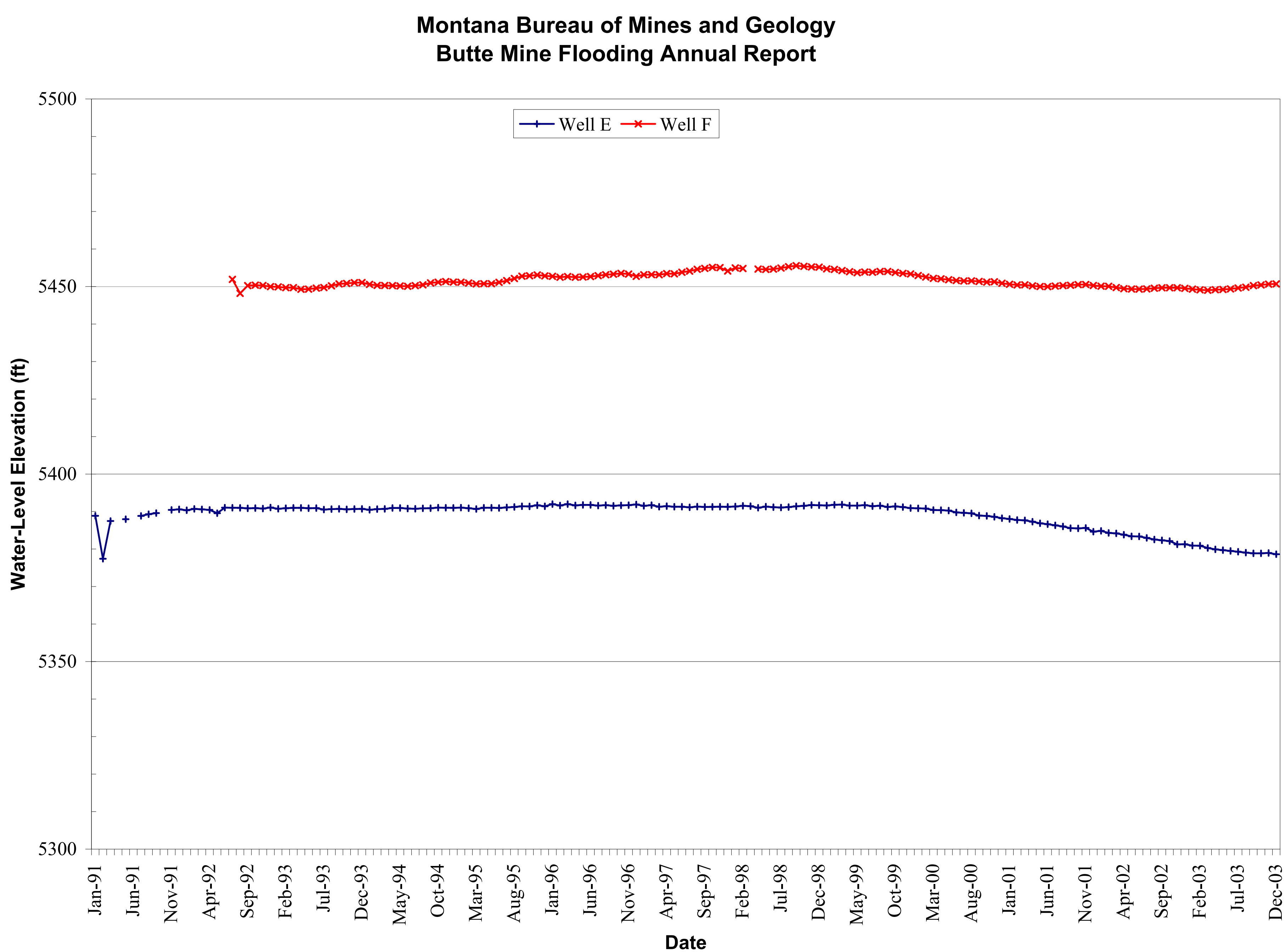


Figure 2-36. Water-level hydrograph for bedrock wells E and F.

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (fig. 2-36). Water levels in these two wells 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. The potentiometric-surface map (fig. 2-37) for the East Camp bedrock aquifer shows the flow of water from all directions is towards the pit.

Section 2.2.2.1 RI/FS Bedrock Well Water Quality

Only a few of the East Camp bedrock wells have shown notable changes in water quality over the past 2 or 3 years. What appeared in the 2002 data to be large changes in concentration may have been sampling or analytical errors. The concentrations of nearly all of the constituents in the wells for which a large change was noted returned to the previous levels. For example, in well D-2 arsenic apparently decreased from about 45 μg/L in 2001 to less than detection limits (5.3 μg/L) in 2002, but returned to a concentration of 35.9 μg/L in 2003. Similarly, zinc concentrations in well D-2 decreased from 6,040 μg/L in 2001 to less than the detection limit of 10.5 μg/L in 2002, and increased to 5,800 μg/L in the 2003 sample (fig. 2-38). The authors noted this possibility in the 2002 report.

Table 2.2.2.1 summarizes the water-quality trends over the past few years. As noted in previous reports, the status of wells B and D-1 changed with respect to MCLs due to the change in the water-quality standard of arsenic from 18 to 10 μg/L. In most wells, there was little change in the concentration of dissolved constituents. The exception is Well J, which has been showing upward trends in the concentration of zinc, cadmium, and several other metals.

Table 2.2.2.1 Exceedances and recent trends for East Camp Bedrock wells, 1989 through 2003; arsenic MCL changed from 18 to 10 μg/L.

Well Name	Exceedances* (1 or more)	Concentration Trend	Remarks
A	Y	None	arsenic (MCL), sulfate (SMCL)
B	Y	None	arsenic (MCL), sulfate (SMCL)
C	N	None	sulfate (SMCL)
D-1	Y	Variable	arsenic (MCL), sulfate (SMCL)
D-2	N	None	sulfate (SMCL)
E	Y	Variable	sulfate (SMCL), arsenic (MCL)
F	Y	None	arsenic (MCL), sulfate (SMCL)
G	N	None	sulfate (SMCL)
J	Y	Upward	very poor quality water

* excludes sulfate

Section 2.2.3 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, and DDH-8 ranged from 13.05 to 14.49 feet in 2003. The rates of rise are consistent with those of the other bedrock wells

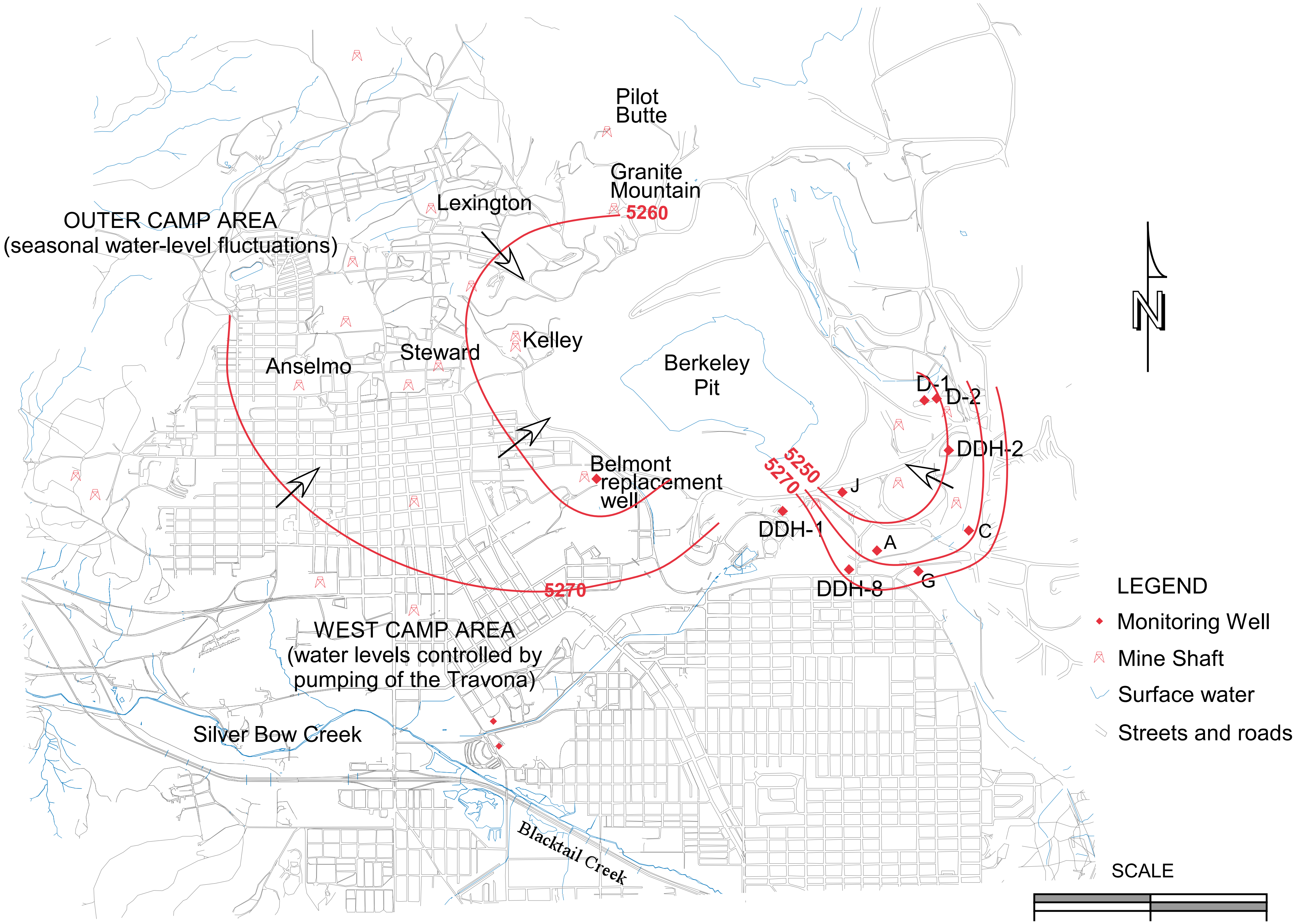
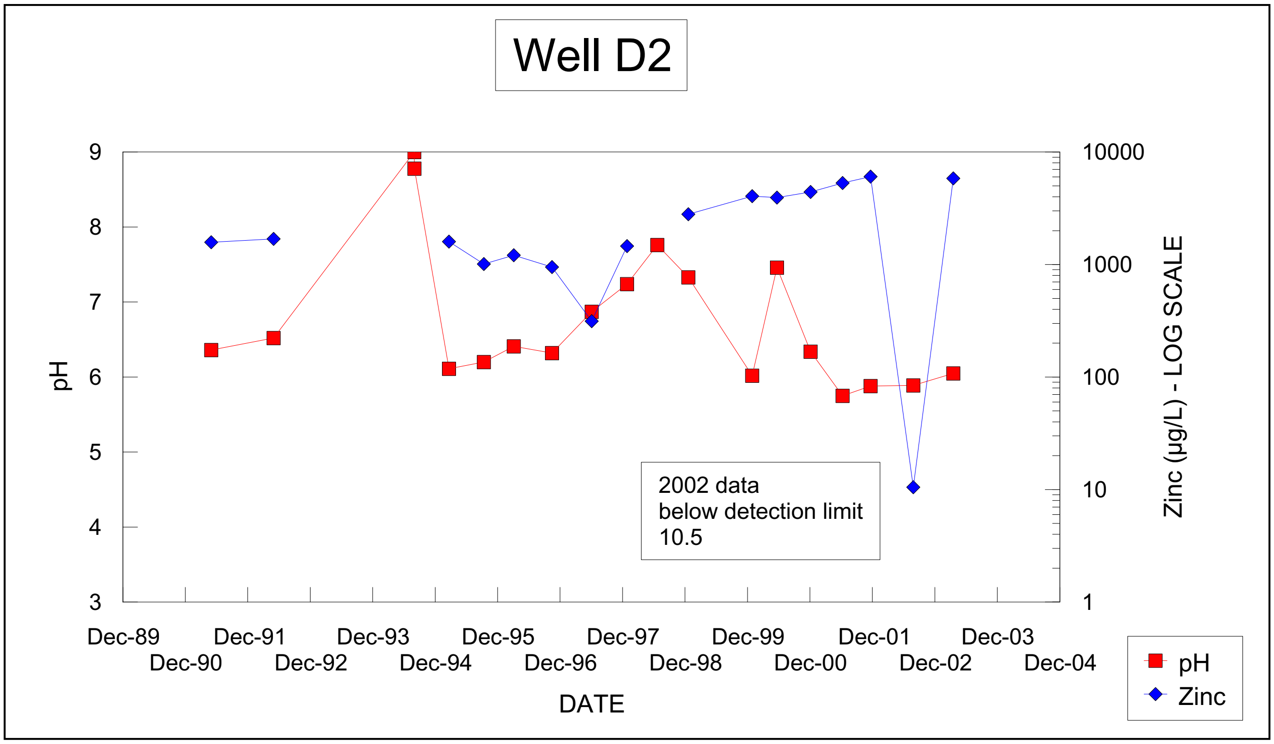


Figure 2-37. Potentiometric map for the East Camp bedrock aquifer, December, 2003; arrows indicate direction of ground-water flow (contour interval is 10 ft).



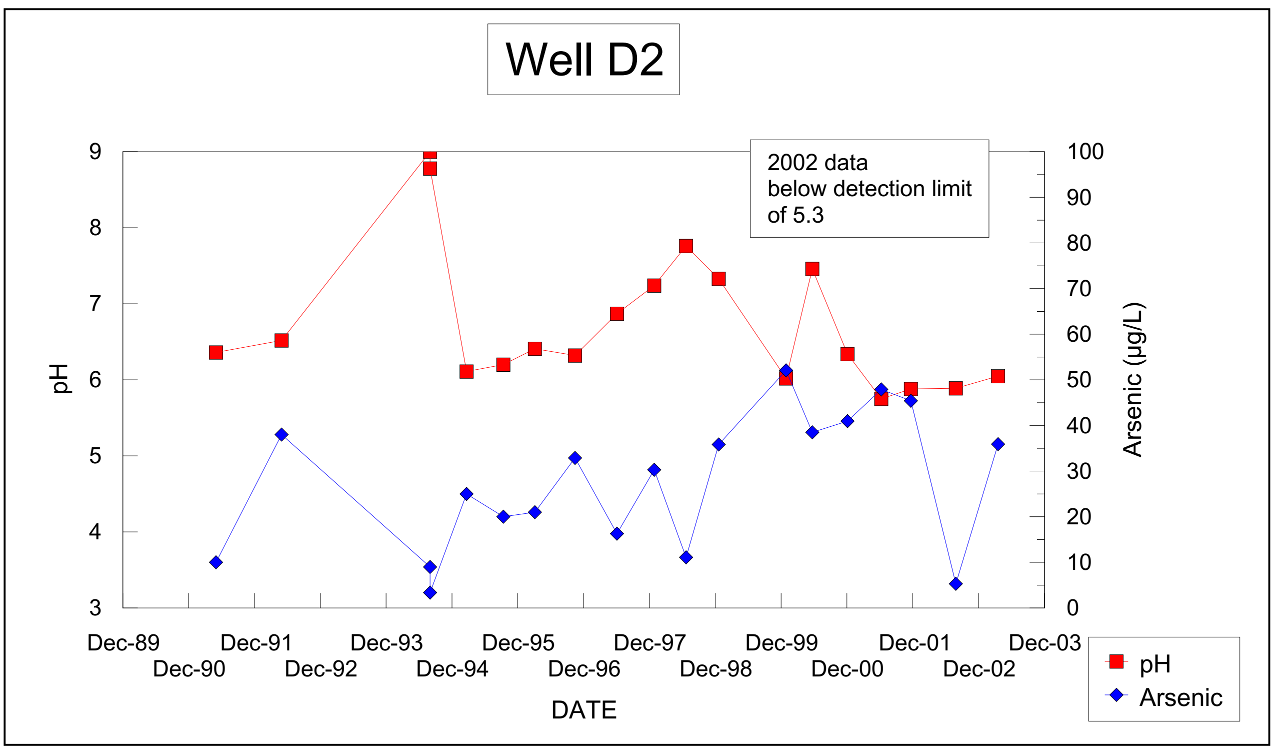


Figure 2-38. Zinc and arsenic concentrations for bedrock well D-2.

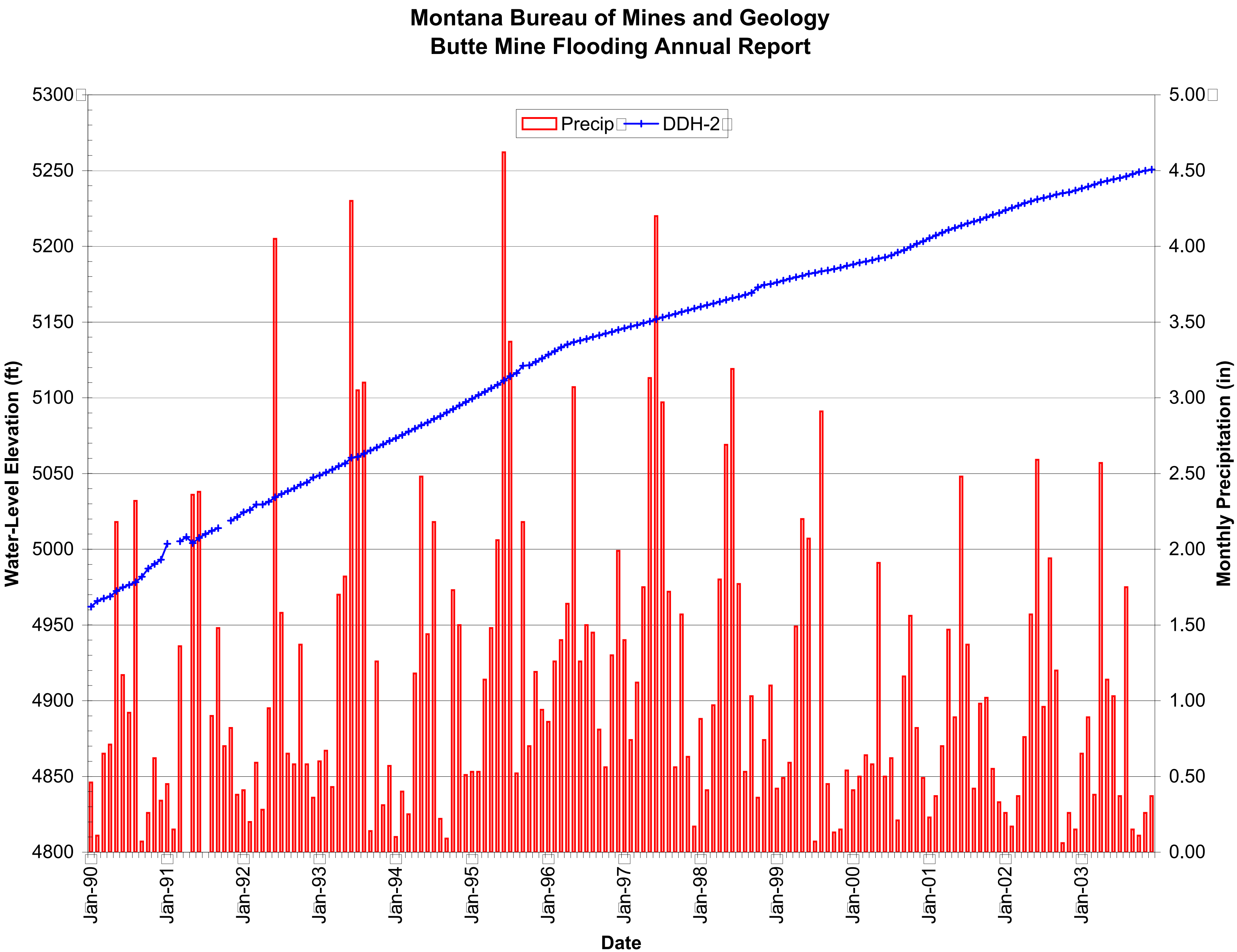


Figure 2-39. Water-level hydrographs for bedrock wells DDH-2 and DDH-4.

and East Camp mine shafts. Figure 2-39 shows a hydrograph for well DDH-2 showing water-level increases. Once again precipitation does not show any affect on water-level rise

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

Section 2.3 Berkeley Pit, Continental Pit, and Horseshoe Bend Drainage

The Berkeley Pit water-level elevation was surveyed each month to coincide with monthly water-level monitoring in wells. Figure 2-40 is a hydrograph showing the pit's 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 decrease in the filling rate (seen as a change in slope on the graph) when the HSB drainage diversion occurred in April of 1996; the second is an almost instantaneous water-level rise from the September 1998 landslide; and the third depicts an increased filling rate (seen as a change in slope on the graph) following MR's June 2000 suspension of mining 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 into the mining and milling process. Following the 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 3.2 billion gallons from July 2000 through November 2003 when the water treatment plant came online (figure 2-41). This represents an average flow of 1,820 gallons per minute (gpm) and a net input of 616 million gallons of additional water during 2003. The overall Berkeley Pit water-level rise for 2003 was 13.08 feet.

As discussed in previous reports, the 90°, V-notch weir was relocated upstream in the HSB drainage to accommodate infrastructure changes associated with the water-treatment plant construction. Construction activities affected flow monitoring at times from April through October 2002, however, there were no major disruptions of monitoring activities during 2003. The average 2003 flow rate was 1,382 gpm.

Flows measured at the HSB Falls flume averaged 152 gpm for the year, a decrease of 100 gpm from last year. This flow is well below the historic flows of 1,000 gpm or more reported by MR. The decreased flow from this source would account for a portion of the flow change seen in the HSB drainage for 2003.

The Continental Pit water level was measured by monitoring the water level in the Sarsfield dewatering well. The pump in the dewatering well operated almost constantly from May, following the announced mine start-up, through December 2003. A total of 9.1 million gallons of water was pumped during that time. The water level in this well declined over 78 feet during 2003 as a result of dewatering activities. Additional pumps were operated directly in the pit for dewatering purposes; however, no volume was recorded from those pumps. Therefore, the total volume of water pumped to dewater the Continental Pit for the resumption of mining is unknown.

Section 2.3.1 Berkeley Pit, Continental Pit, and Horseshoe Bend Drainage Water Quality

Water-quality samples collected from both the surface and from various depths in the Berkeley Pit show little change between 2002 and 2003; indeed, there is little trend to the data for the past several

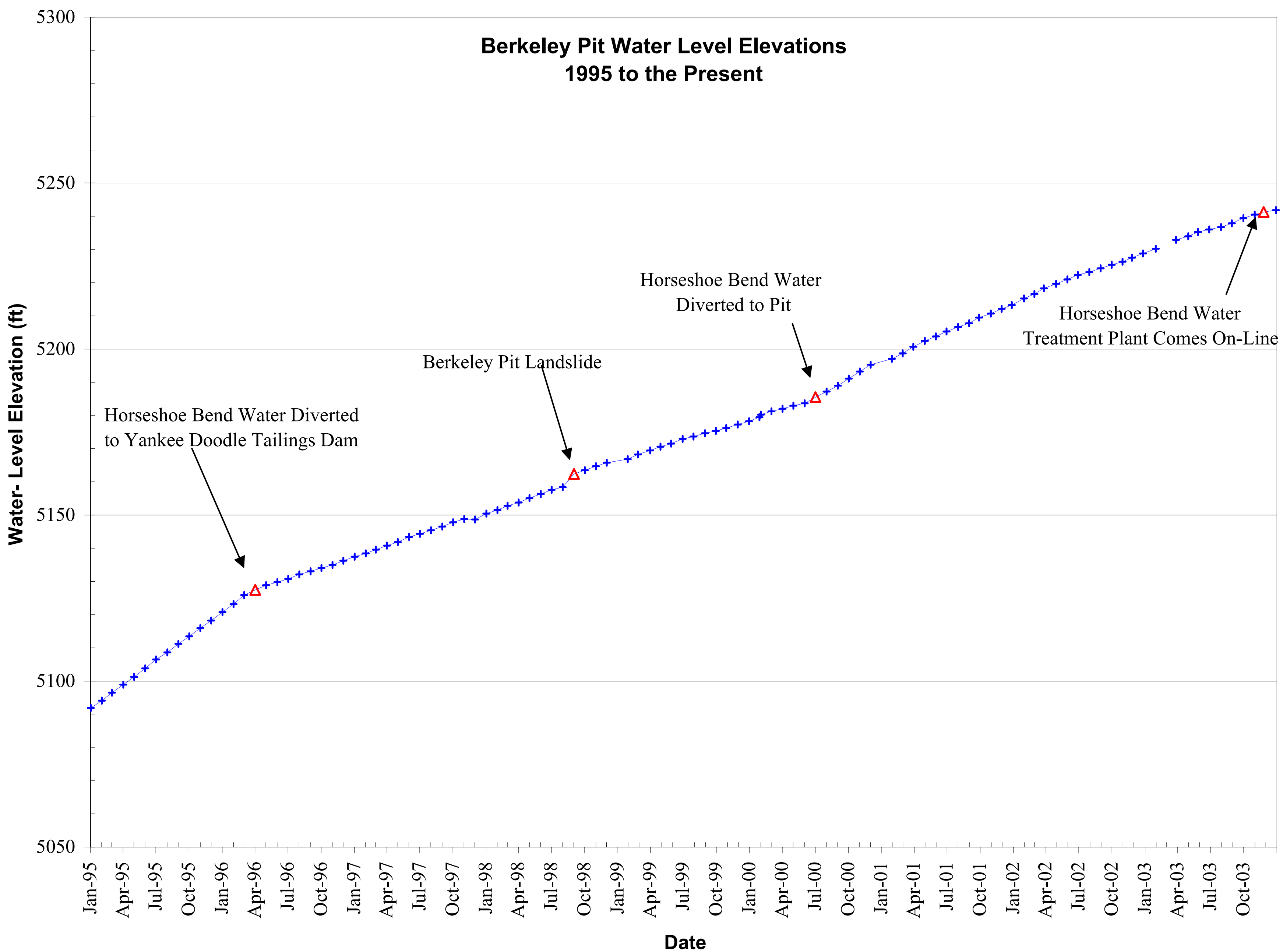


Figure 2-40. Water-level hydrograph of Berkeley Pit, 1995-2003.

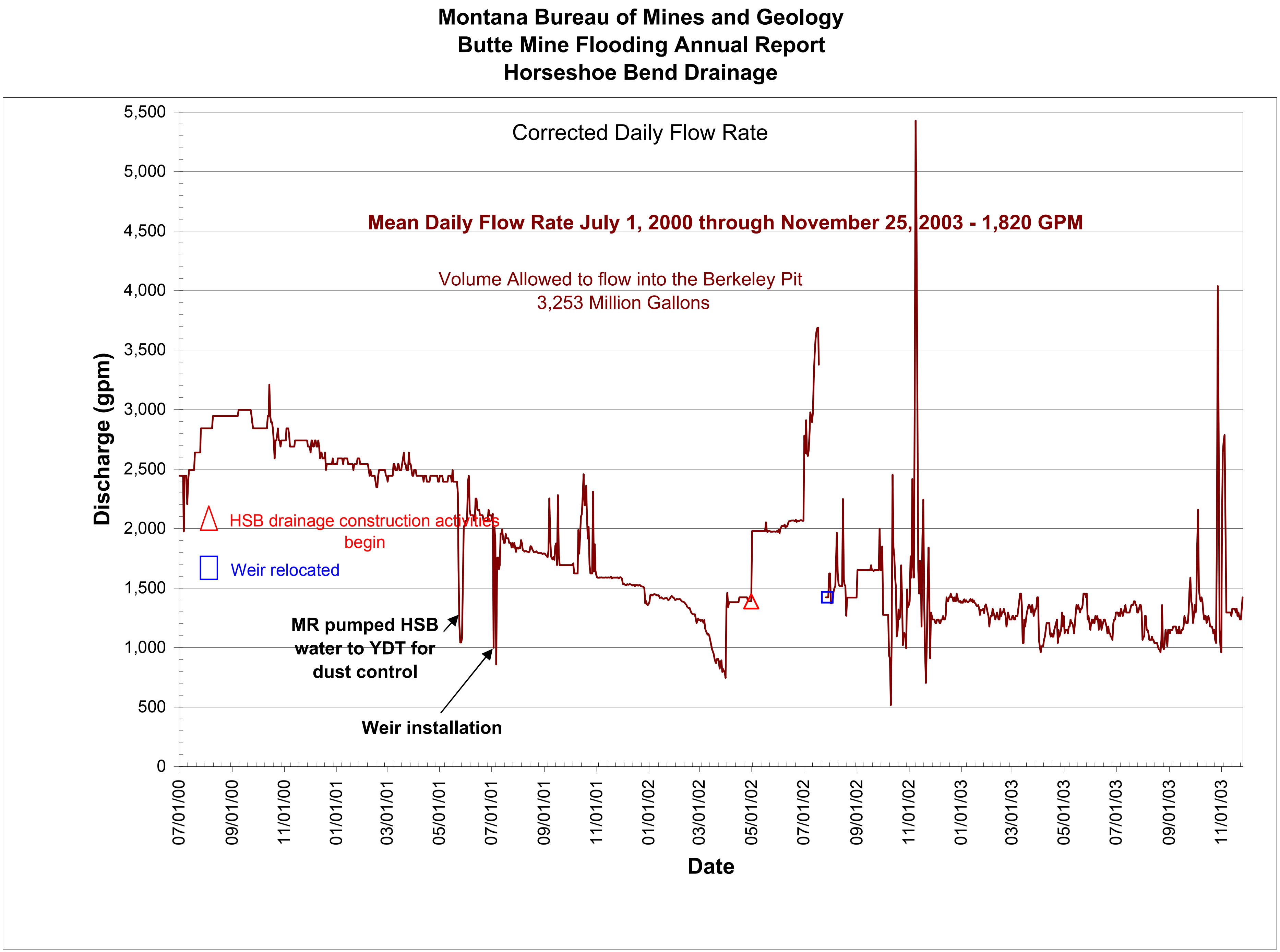


Figure 2-41. Horseshoe Bend drainage flow rate, July 1, 2000 through November 25, 2003.

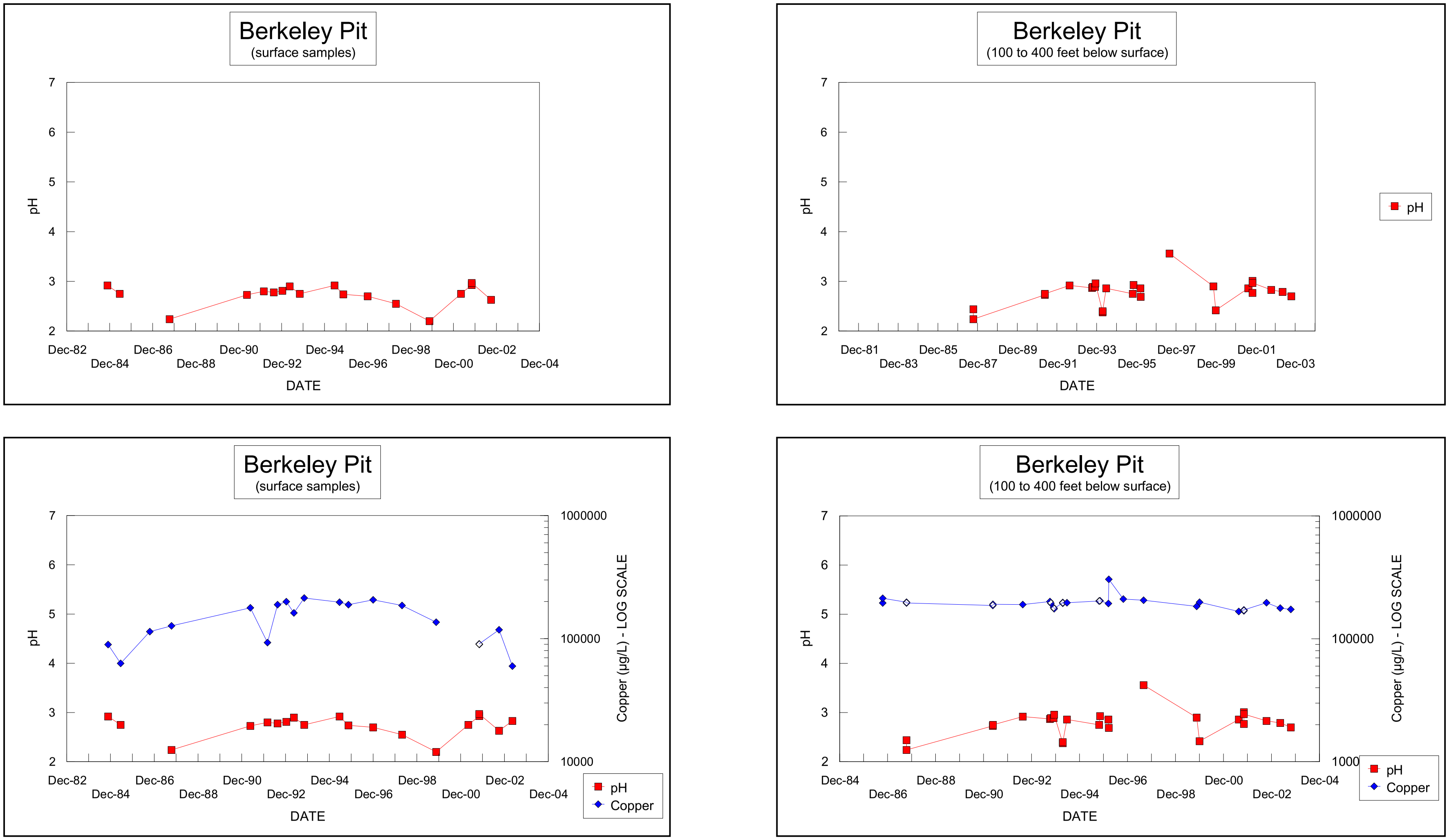


Figure 2-42a. Selected chemistry for the Berkeley Pit.

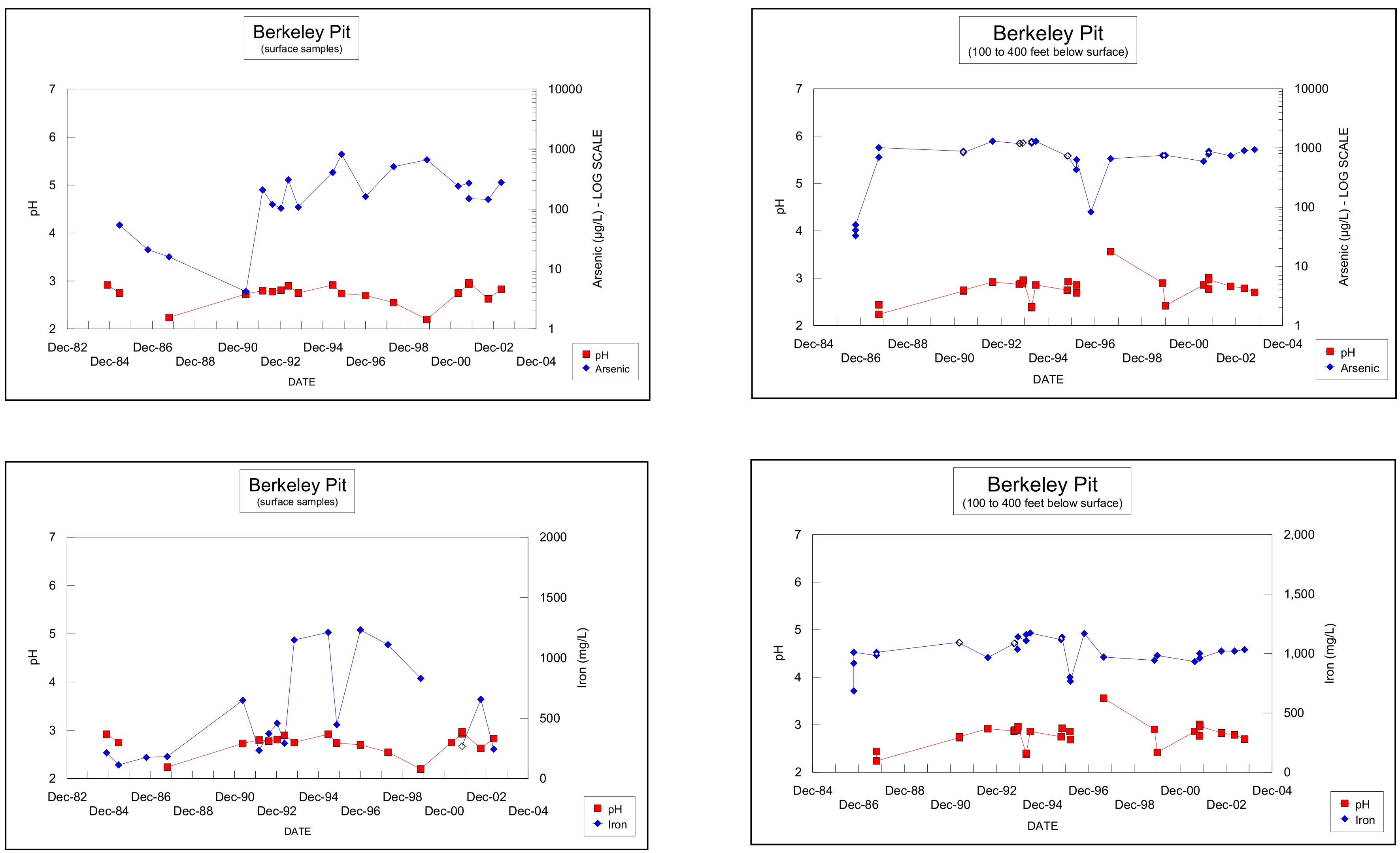


Figure 2-42b. Selected chemistry for the Berkeley Pit.

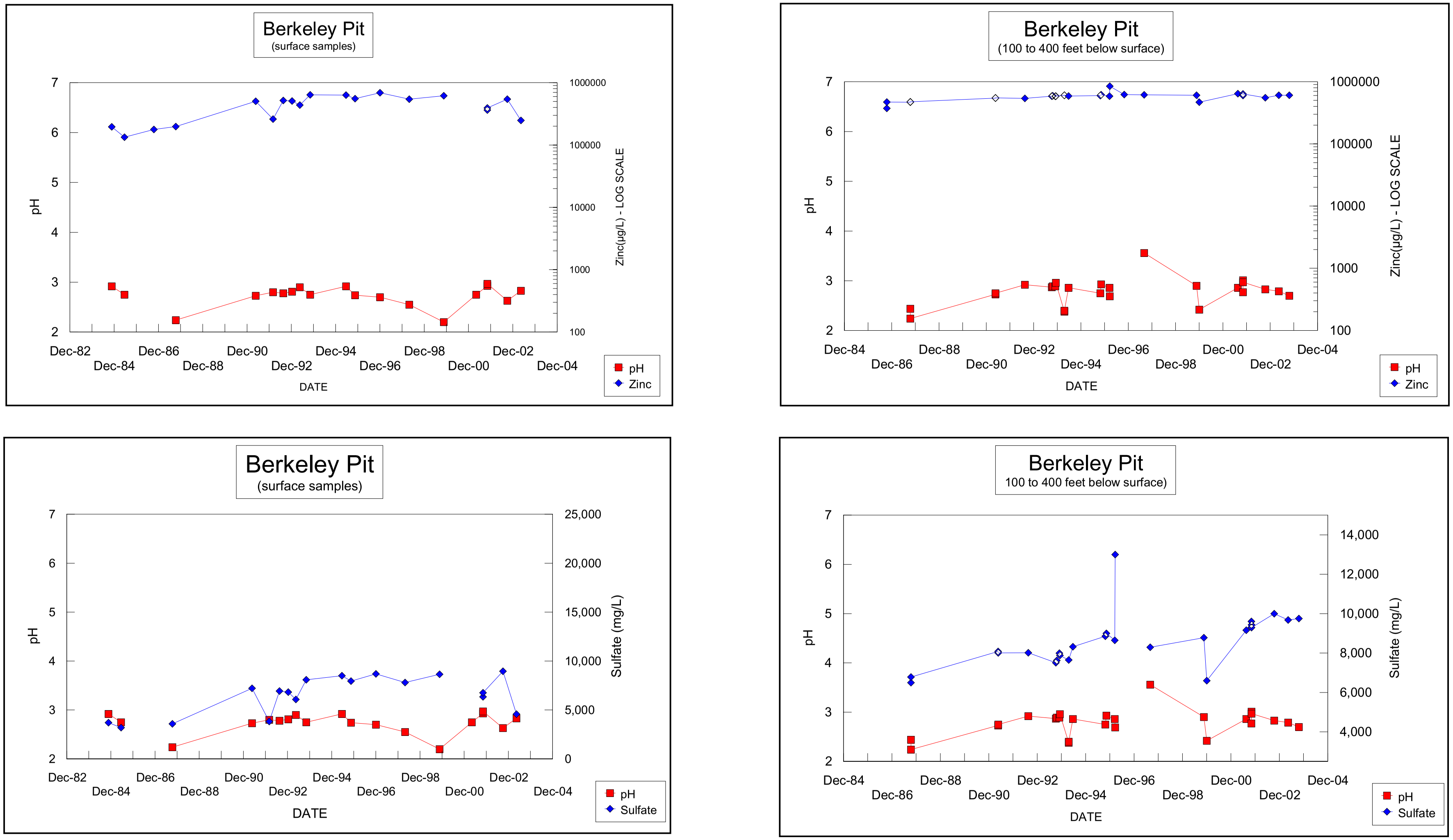


Figure 2-42c. Selected chemistry for the Berkeley Pit.

years (fig. 2-42a, b, and c). It is important to note that the concentration of iron at the surface of the pit has declined since the early 1990s and is about 500 mg/L at present. The deeper samples indicate a concentration of iron consistently near 1,000 mg/L. This contrasted further with the recent increase in iron concentrations in the Kelley shaft, which are about 2,000 mg/L.

The Horseshoe Bend drainage continues to show a slight decline in the concentrations of nearly all the dissolved constituents (fig. 2-43). As with the Berkeley pit samples, iron concentrations are less than 500 mg/L. Overall, water quality of the HSB drainage is slightly better than that of the Berkeley Pit (table 2.3.1).

The concentrations of some dissolved constituents, such as zinc and sulfate, in the discharge from the Sarsfield well have increased over the period of record (fig. 2-44), but overall, the water quality in the well is good. The well was pumped intermittently and, when operating, discharged about 250 gpm; 6 samples were collected in 2003.

Table 2.3.1 Selected chemistry from the Berkeley Pit, Horseshoe Bend, and Sarsfield well, 2003 data

Area	Sample Date	pH (S.U.)	Al (μg/L)	Cu (μg/L)	Pb (μg/L)	SO_4 (mg/L)	Zn (μg/L)
Berkeley							
Surface	10/22/03	2.47	125,393	69,702	36	5,453	287,233
HSB	12/18/03	3.21	118,700	52,100	14	3,980	184,000
Sarsfield	8/26/03	6.45	482	7	<10	1,338	2,992

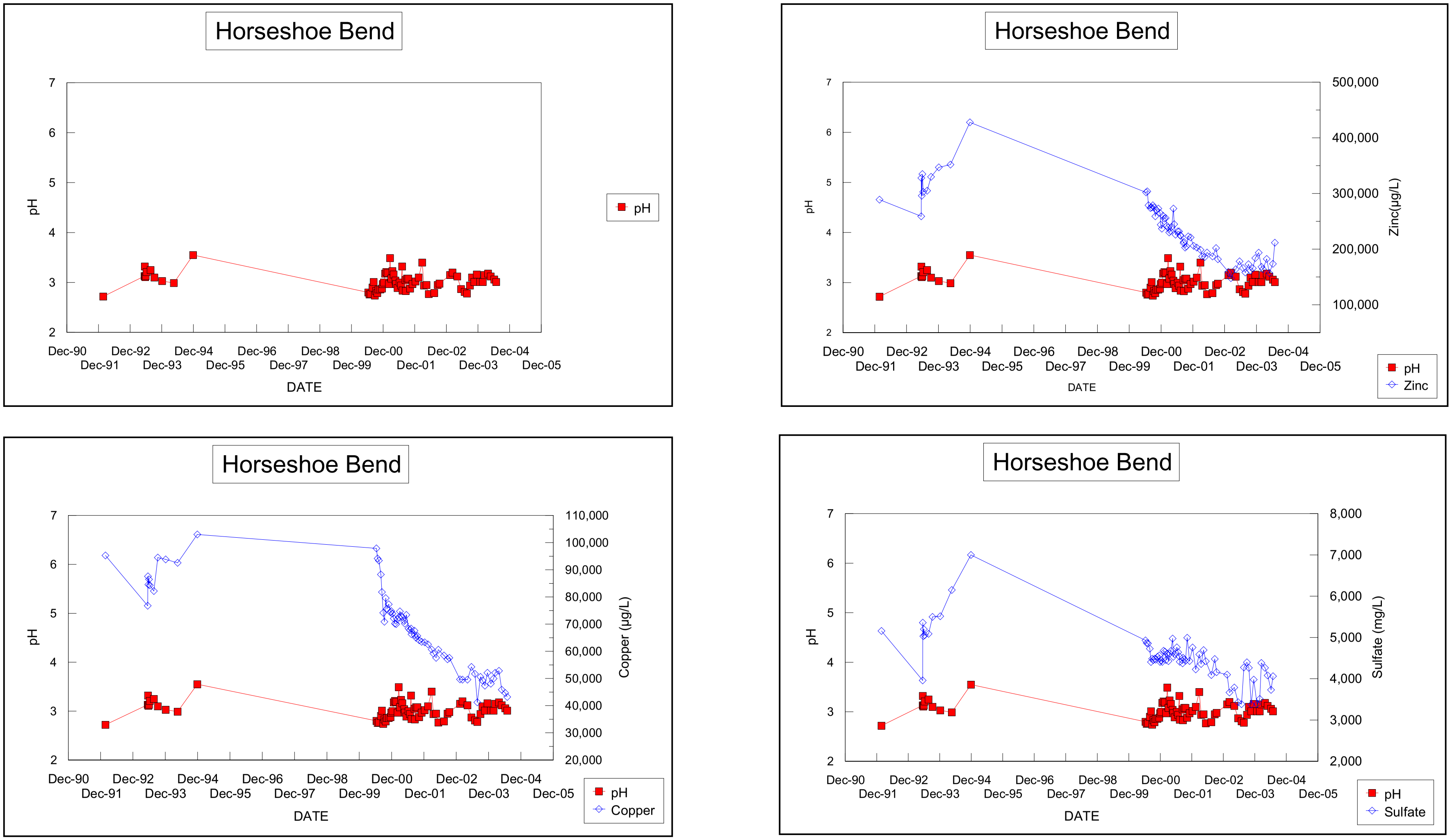


Figure 2-43. Selected chemistry for the Horseshoe Bend discharge.

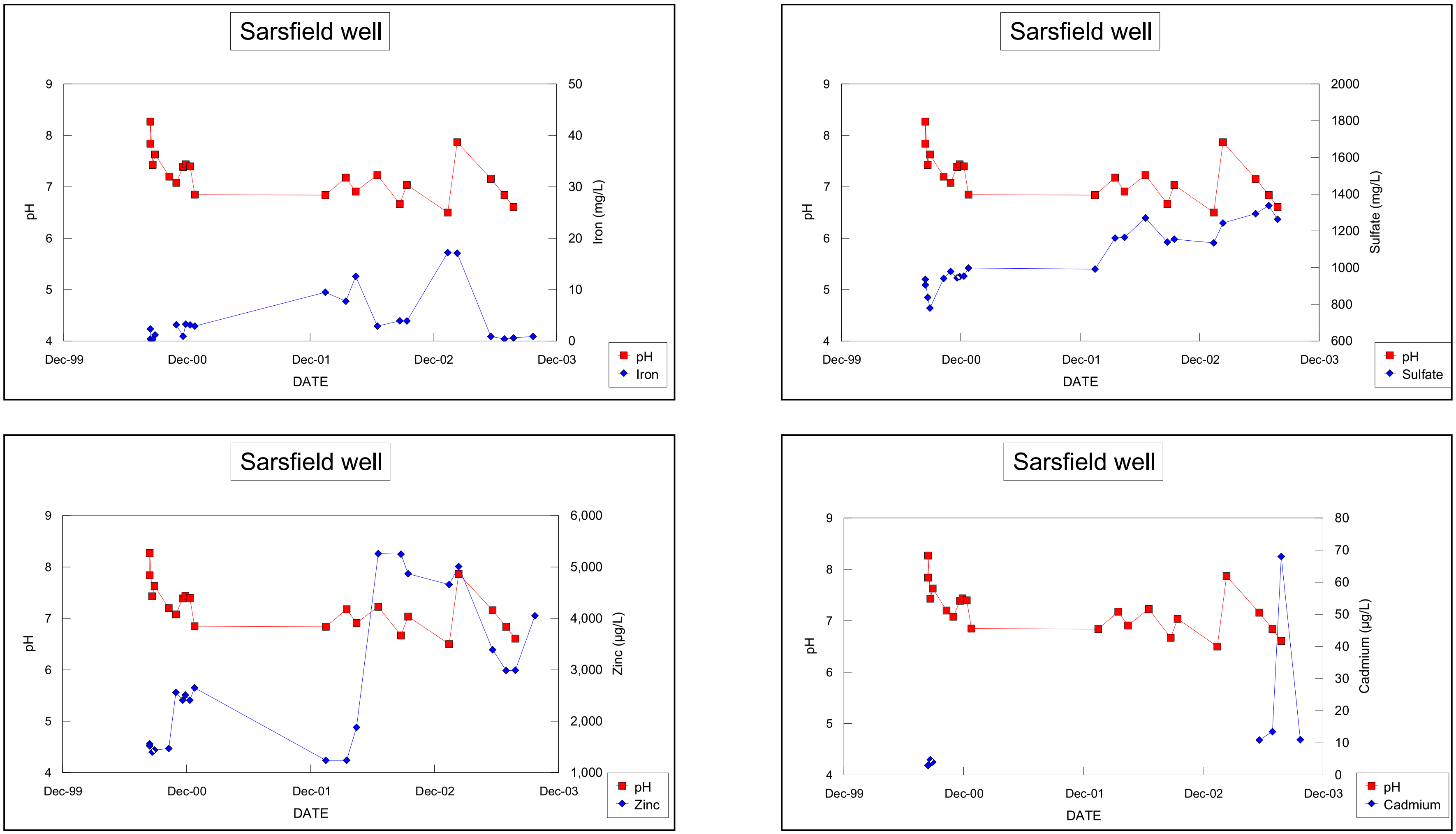


Figure 2-44. Selected chemistry for the Sarsfield well.

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring continued during 2003 in the mine shafts and six monitoring wells (fig. 3-1). ARCO diverted the water pumped from the West Camp to the Lower Area One wetlands demonstration site during March 2002. Pumping rates continued at a reduced level with water levels rising slightly for the year.

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 sites. 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. The pump and pipeline at the Travona Mine were left intact allowing it to serve as a backup pumping system.

The West Camp pumping system operated almost continuously during 2003, 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 231 acre-feet of water was pumped in 2003, compared to 247 acre-feet in 2002, and 260 acre-feet in 2001. Table 3.1 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 amount of water pumped annually and the percent of average annual precipitation since 1982.

Table 3.1 Annual quantity of water pumped from the West Camp, in acre-feet.

Year	Total Amount Pumped (Acre-ft)	Change From Prior Year (Acre-ft)	Percent Change From 1996
1989	8.50		
1990	212.54	+204.04	
1991	130.16	-82.38	
1992	92.82	-37.34	
1993	140.18	+47.36	
1994	109.31	-30.87	
1995	182.54	+73.23	
1996	244.56	+62.02	
1997	287.70	+43.14	118
1998	370.72	+83.02	152
1999	326.56	-44.16	134
2000	270.20	-56.36	110
2001	260.37	-9.83	106
2002	247.66	-12.71	101
2003	231.43	16.23	95

Water-level changes in the West Camp mines reflect changes in pumping rates in the WCP. The reduced pumping rate resulted in a net water-level increase between 0.8 feet and 1.25 feet in the West Camp mines for 2003 (table 3.2). Figure 3-3 shows annual water-level changes for the West Camp sites.

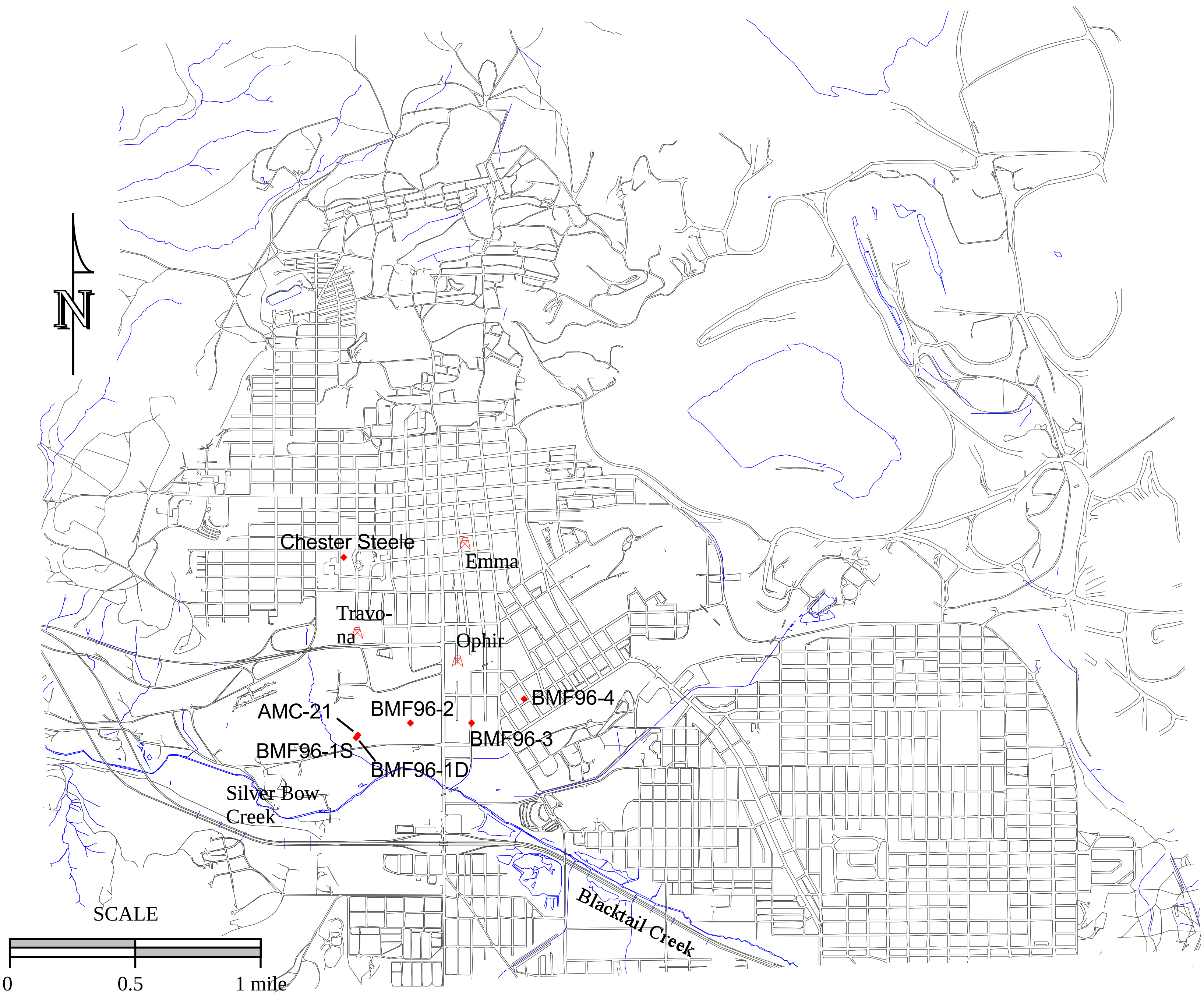


Figure 3-1. West Camp monitoring sites location map.

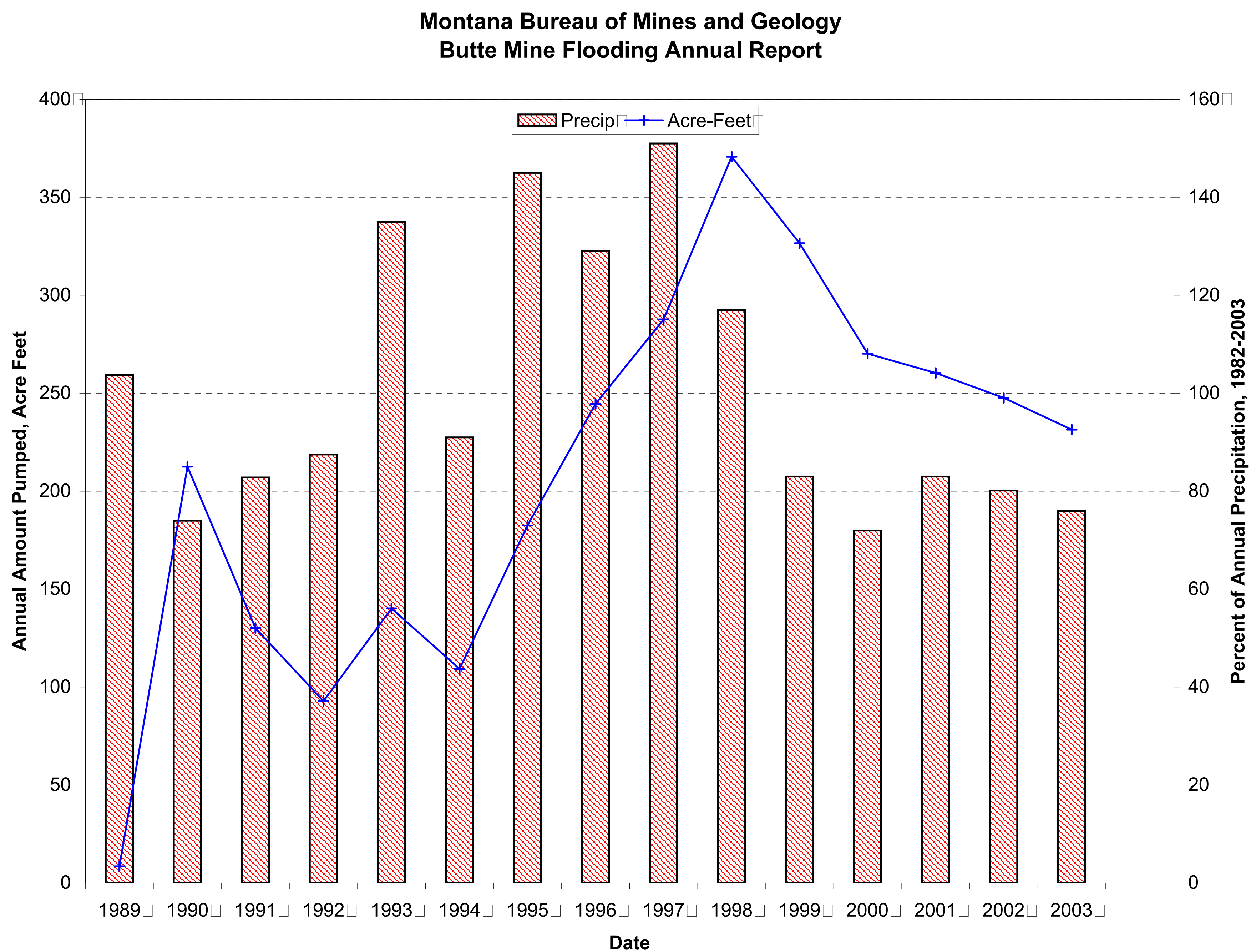


Figure 3-2. Annual amount of water pumped from the West Camp system.

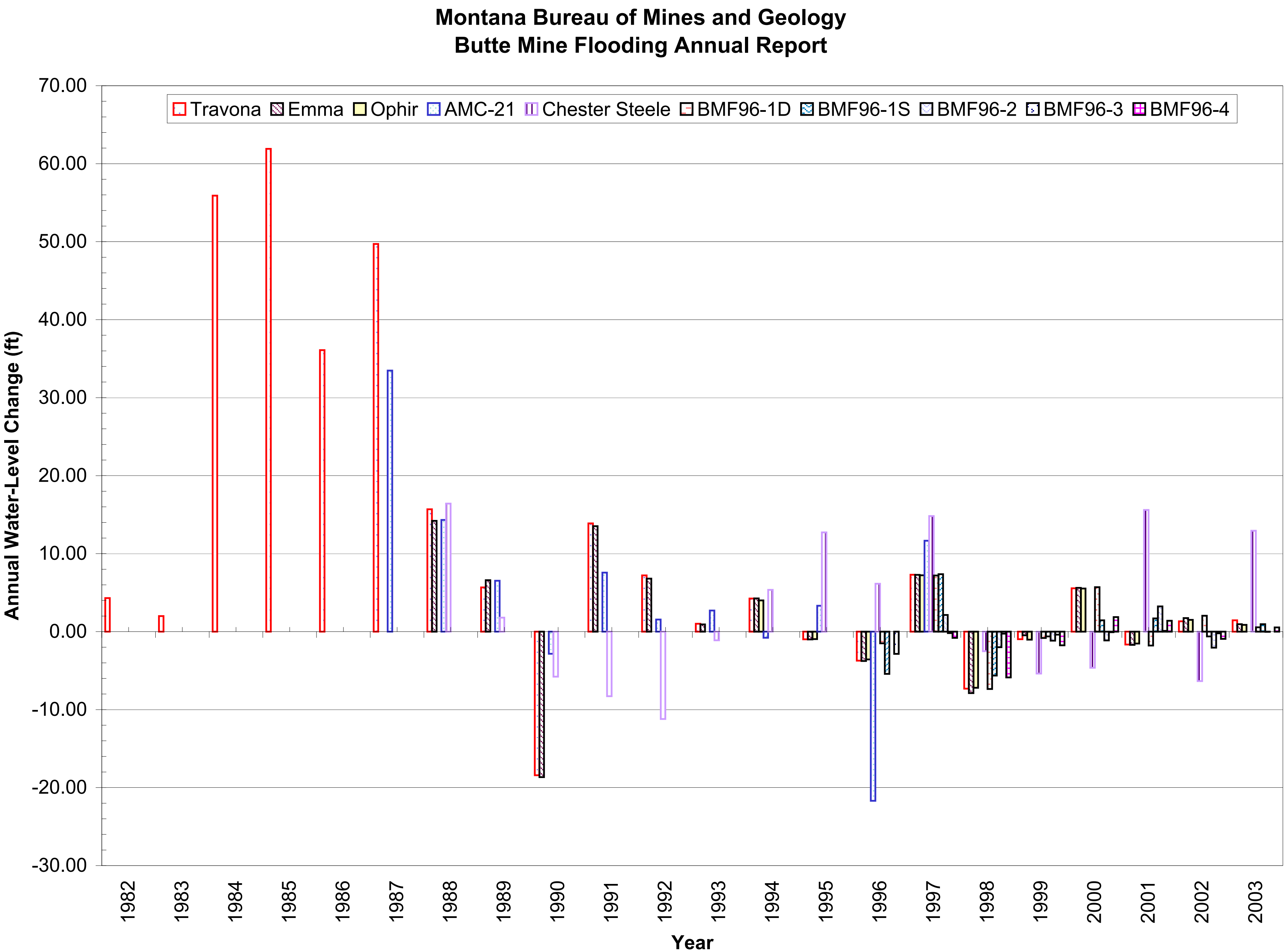


Figure 3-3. Annual water-level change for West Camp sites.

Water levels are more than 10 feet below the West Camp action level of 5,435 feet stipulated in the 1994 ROD.

Water-level elevations for the three West Camp mines are shown on fig. 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.

Section 3.2 West Camp Monitoring Wells

Water-levels rose in three of the five BMF96 West Camp wells and were unchanged in another during 2003. Well BMF96-1D, which was completed into the Travona Mine workings, had water-level changes similar to the three West Camp mines. The water level in well BMF96-1S rose almost 1 foot. These changes are shown in table 3.2 and on fig. 3-3.

Table 3.2 Annual Water-Level Changes for the West Camp Sites, in feet

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	P&A	-2.51	-7.35	-5.63	-2.00	-0.26	-5.88
1999	-0.97	-0.47	-1.03	P&A	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	P&A	-4.64	5.70	1.45	-1.13	-0.07	1.86
2001	-1.65	-1.70	-1.52	P&A	15.61	-1.78	1.70	3.23	0.10	1.40
2002	1.33	1.74	1.51	P&A	6.35	2.03	-0.62	-2.06	-0.21	-0.93
2003	1.45	0.95	0.87	P&A	12.94	0.56	0.96	-0.01	0.00	0.54
Total Change*	**240.18**	**28.41**	**4.86**	**55.82**	**40.57**	**4.04**	**-0.80**	**-0.98**	**-3.86**	**-5.57**

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

Figure 3-5 contains 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 Duaime and others, 1998 for a greater discussion of historic flooding problems in the West Camp system). The overall trends in these wells were still the same. There is a lag time between the responses seen in these two wells,

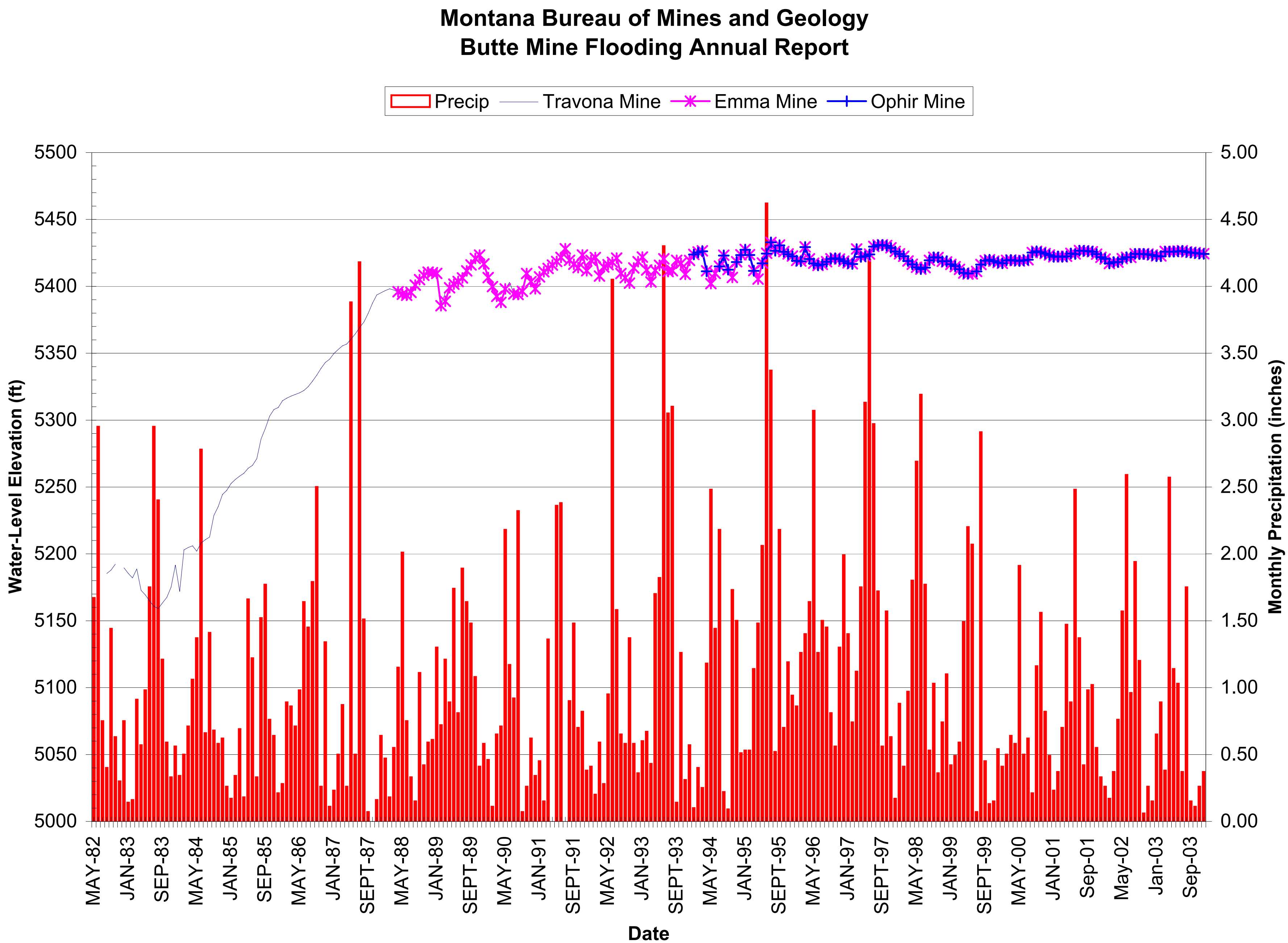


Figure 3-4. West Camp Mines water-level hydrographs and monthly precipitation totals.

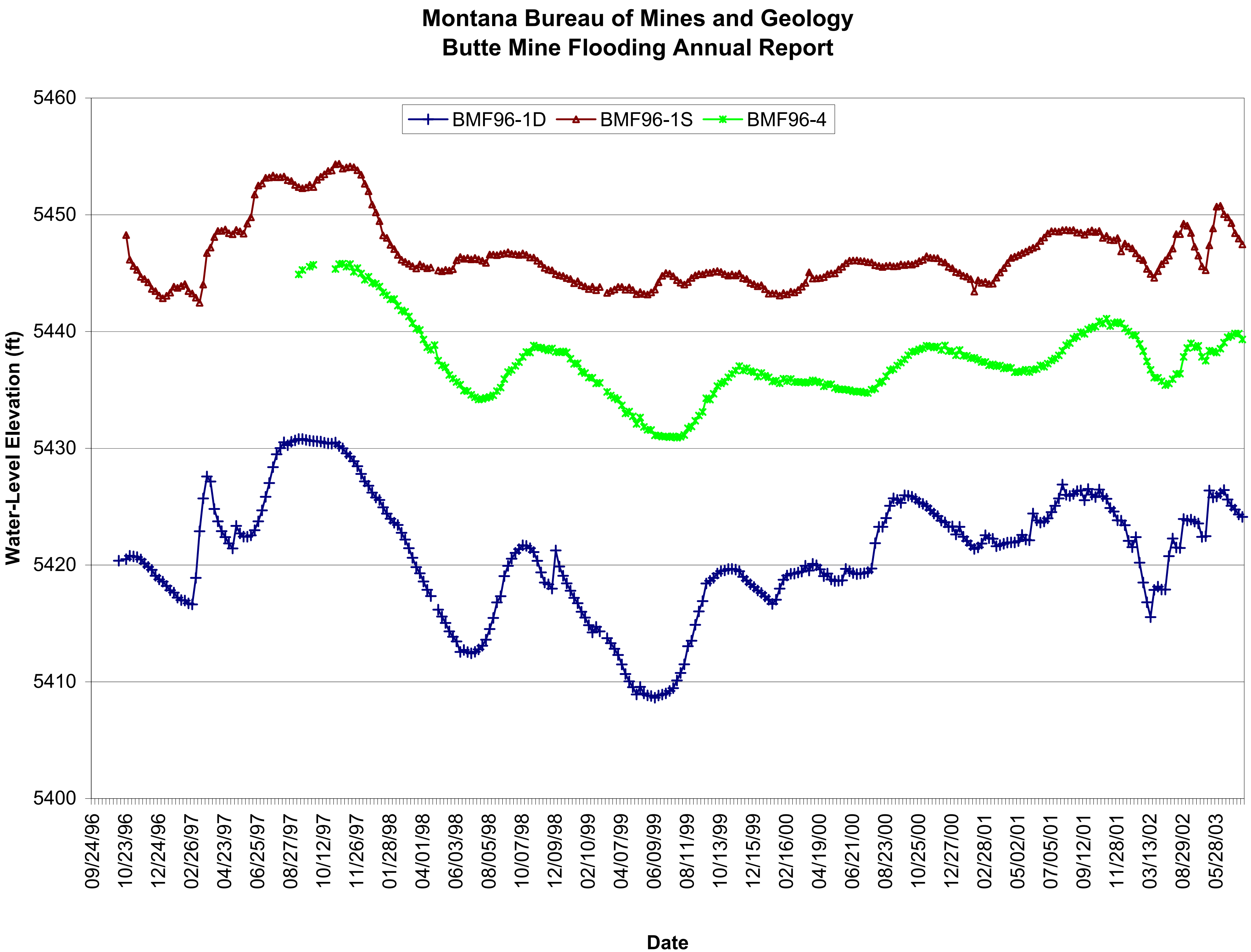


Figure 3-5. Water-level hydrographs for West Camp BMF96-1D, BMF96-1S, and BMF96-4 wells.

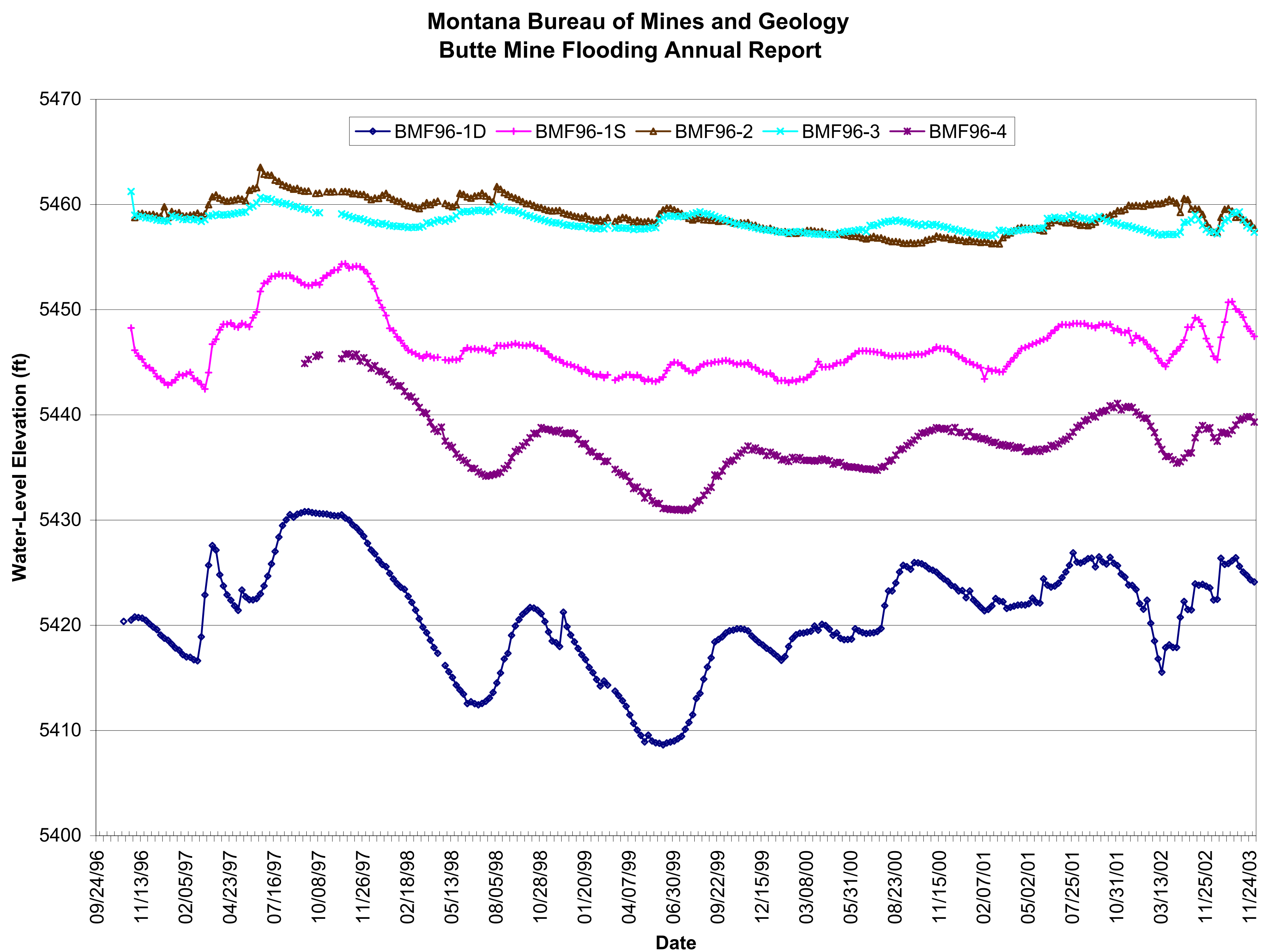


Figure 3-6. Water-level hydrographs for BMF96 series wells.

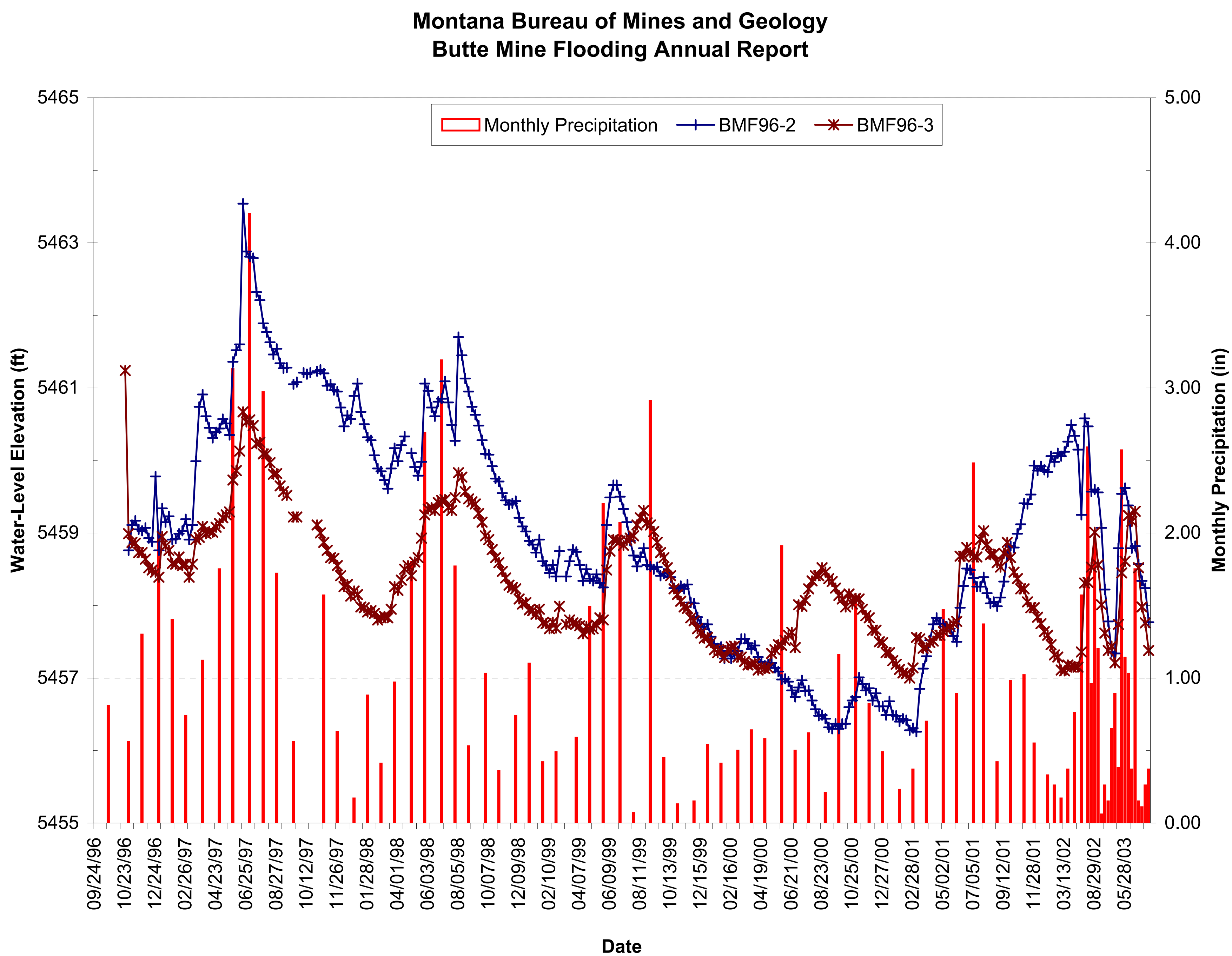


Figure 3-7a. Water-level hydrographs for BMF96-2 and BMF96-3 wells.

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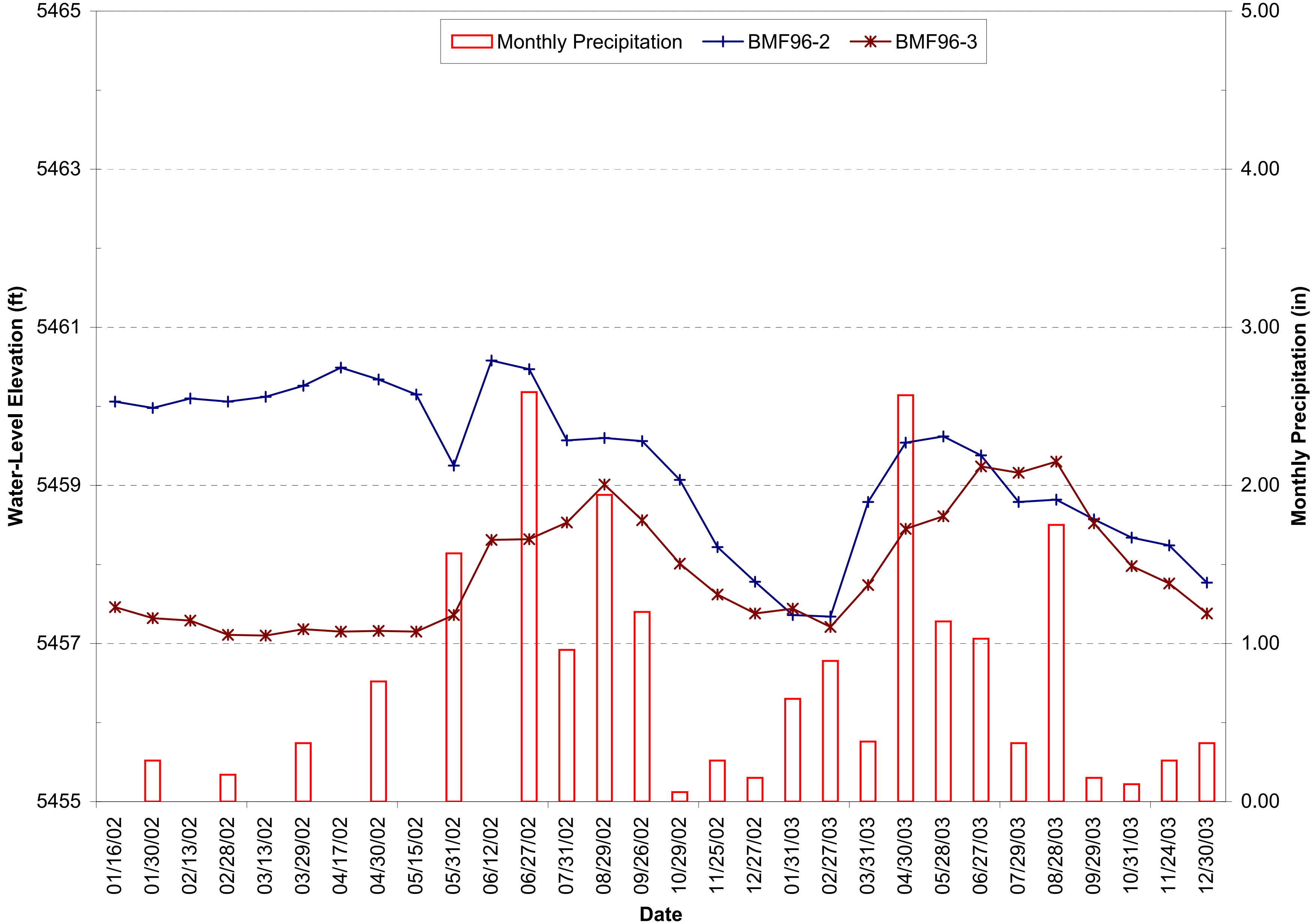


Figure 3-7b. Water-level hydrographs for BMF96-2 and BMF96-3 wells from 2000 through 2003.

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 appears to be a similarity in water-level change in well BMF96-1S. Well BMF96-1S is located adjacent to well BMF96-1D, but was completed at a much shallower depth in the weathered bedrock of the Missoula Gulch drainage. This well also 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 previous 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 (fig. 3-6). However, when these wells are plotted separately (fig. 3-7a), there is considerable variation in monthly water levels, and water levels in both wells respond similarly. Monthly precipitation is shown on this figure and water levels are seen to respond very quickly to precipitation events. Although these wells were completed at depths of 175 feet below ground surface, their water levels are less than 20 feet below ground surface. Water-level trends during 2003 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 in well BMF96-2 that was not seen in other wells. This trend did not continue in 2002; the water level in well BMF96-2 followed that of well BMF96-3 throughout 2003. Water levels rose with precipitation. Figure 3-7b is a hydrograph for these two wells for the period 2000-2003 to better show recent water-level changes.

Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

The concentrations of manganese, zinc, sulfate and most other dissolved constituents in the Travona workings are continuing to decrease and are approaching their lowest concentration within the period of record (fig. 3-8a). Conversely, arsenic concentrations have increased to near historic levels (fig. 3-8a). It is important to note that the samples collected in 2003 were from the shaft rather than the pumping well and there appears to be a good correlation of data from the two sample sites.

The Emma shaft, which is connected to the Travona Mine by workings at several levels, continues to show large fluctuations in concentrations as well as a large difference in concentrations compared to the Travona shaft. Many of the large increases in concentrations in 2002 became large decreases in 2003 data. For example, zinc concentrations were reported at 39,500 μg/L for 2002 and increased from 5,500 and 1,300 μg/L in the previous two years; 2003 samples yielded a concentration of about 20,000 μg/L. Cadmium concentrations in 2000 and 2001 were 9.8 and less than 1.1 μg/L, respectively, and increased in 2002 to about 87 μg/L; cadmium decreased to about 56 μg/L in 2003. Sulfate concentrations in the Emma shaft have not changed appreciably over the past few years and the 2003 data did not indicate a significant change. Iron decreased from about 5 mg/L in 2001 to 0.22 mg/L in 2002 and increased to about 0.4 mg/L in 2003. Figures 3-8a and 3-8b present a comparison of selected dissolved constituents for the Travona / BMF96-1D and the Emma shaft.

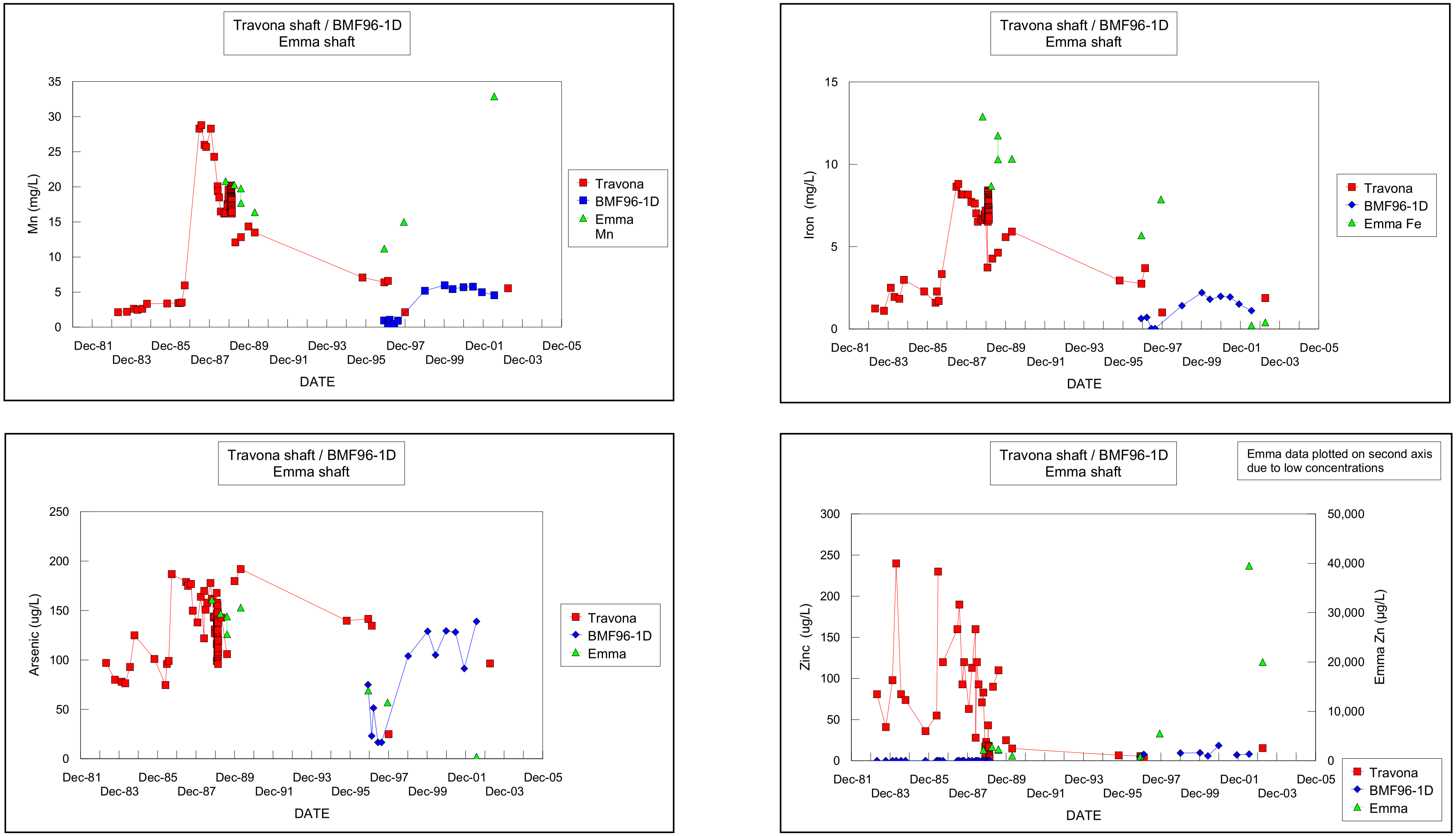


Figure 3-8a. Selected chemistry for the Travona shaft (and replacement well) and the Emma shaft.

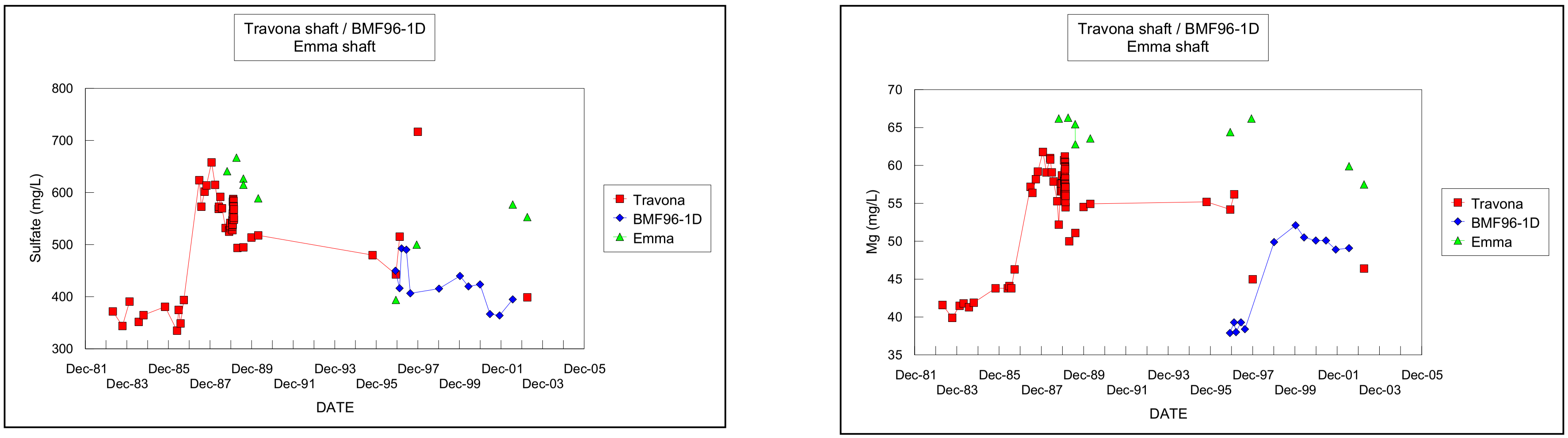


Figure 3-8b. Selected chemistry for the Travona shaft (and replacement well) and the Emma shaft.

The concentration of most dissolved metals in the Ophir Mine has remained relatively low and exhibited a slight downward trend through 2003. The most notable exception is the concentration of zinc, which increased from less than 300 μg/L in 2001 to 1,800 in 2003. The trends of arsenic and sulfate concentrations have been slightly downward (figure 3-9).

Water-quality data for the West Camp monitoring wells in 2003 are limited to BMF96-04. Data for the period of record for all the wells is presented in figure 3-10. With the exception of zinc, which increased from about 9 to 108 μg/L, the concentration of dissolved constituents shows little change in trends.

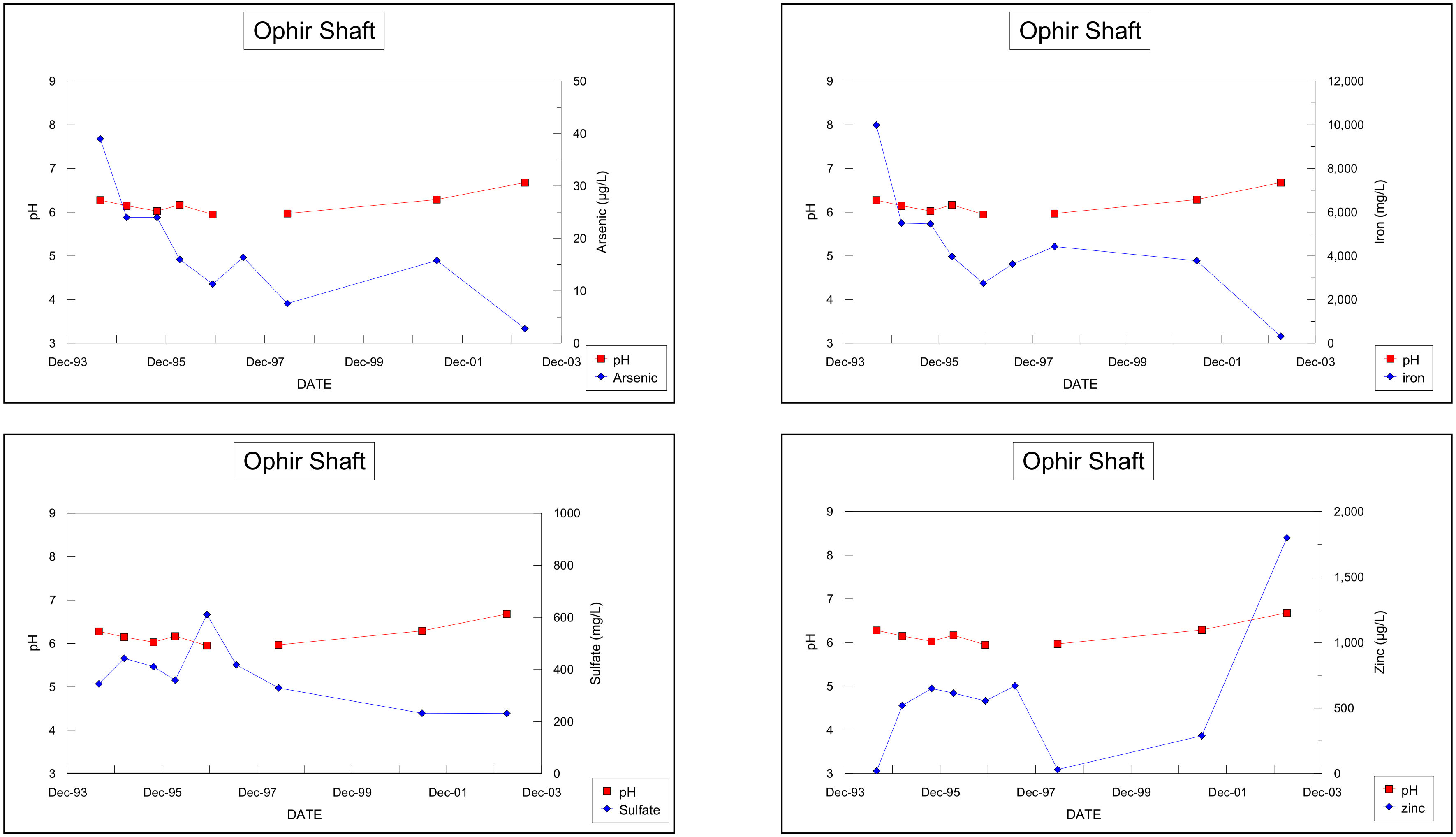
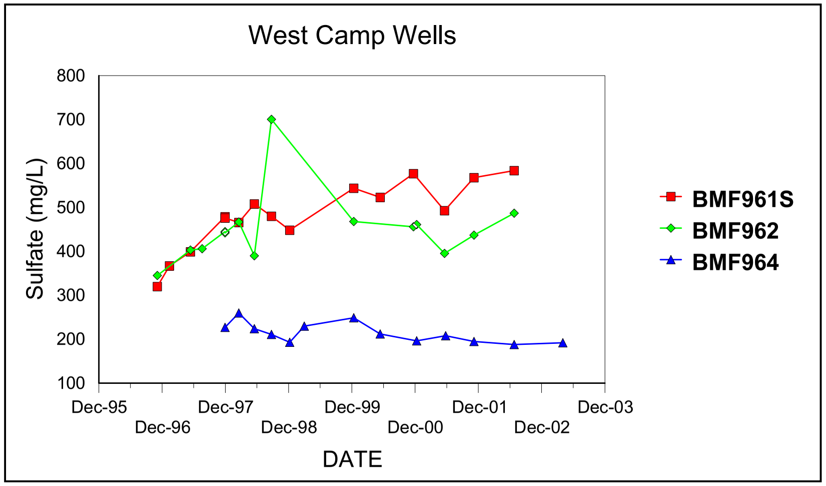
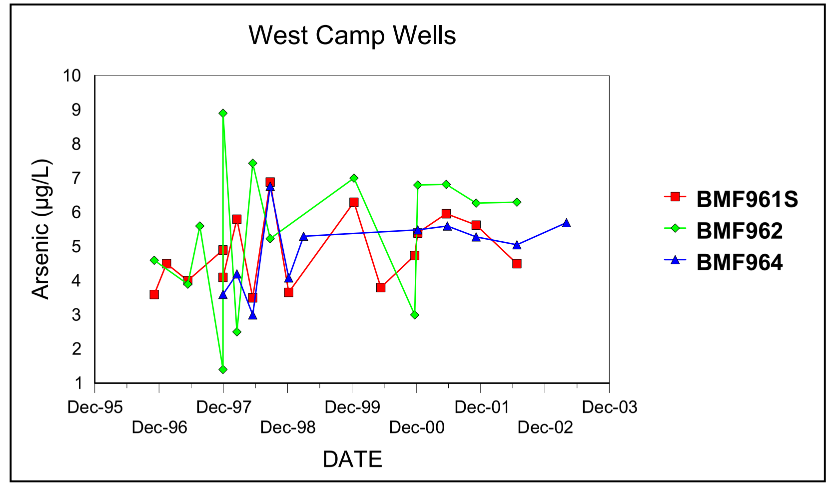
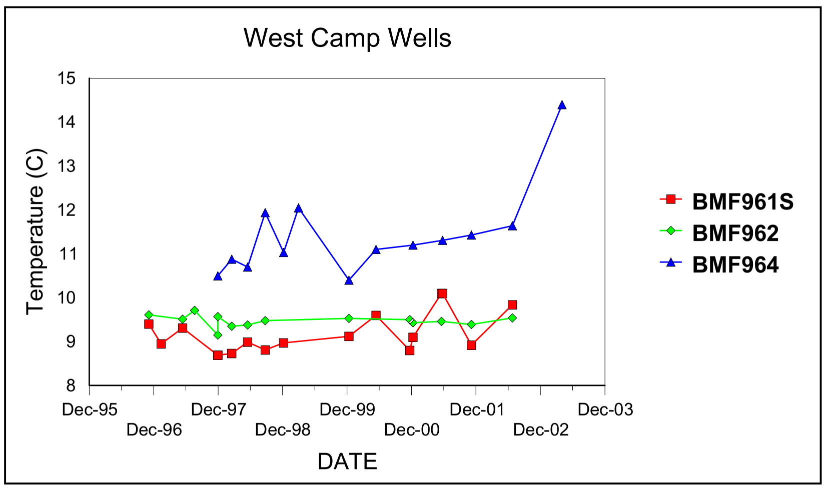


Figure 3-9. Selected chemistry for the Ophir shaft.







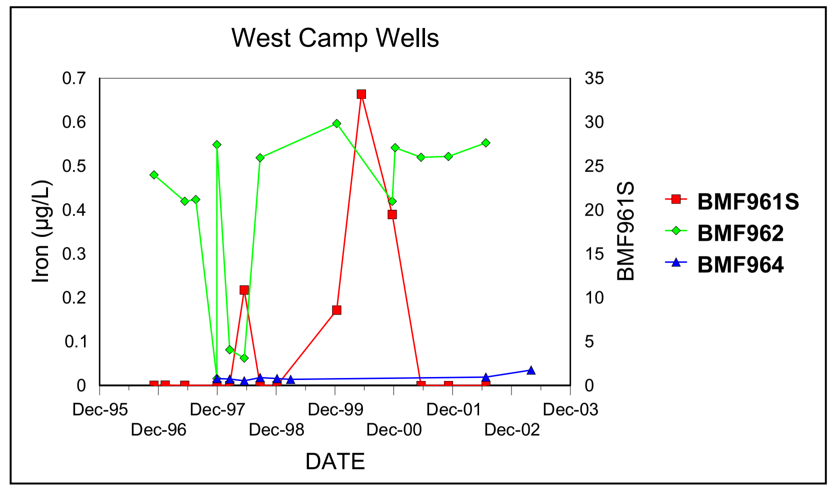


Figure 3-10a. Selected chemistry for the West Camp monitoring wells.

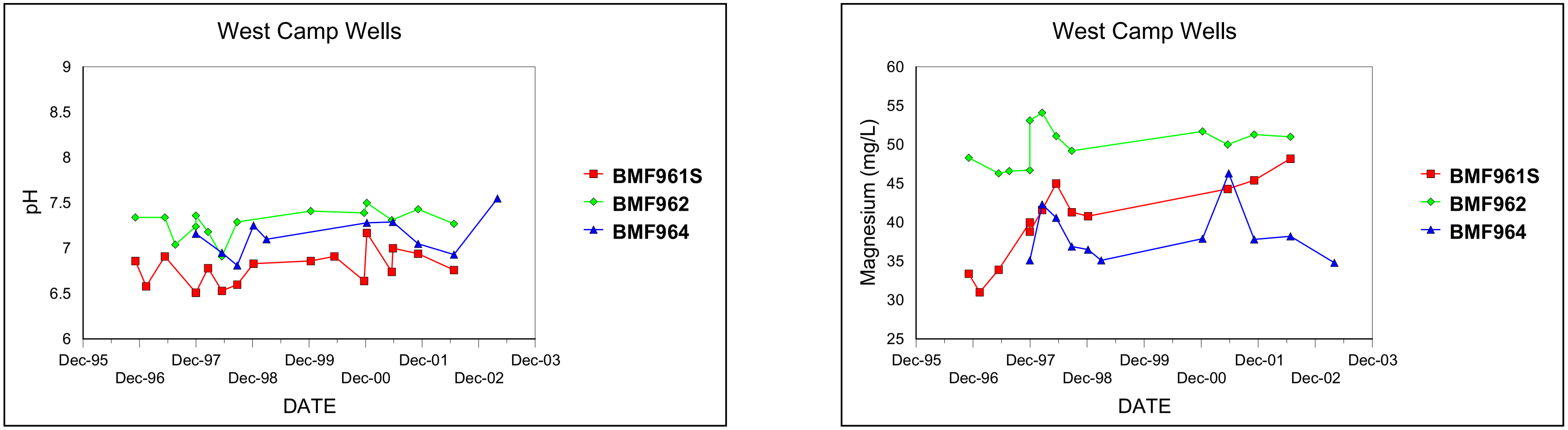


Figure 3-10b. Selected chemistry for the West Camp monitoring wells.

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 (fig. 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.

Section 4.1 Outer Camp System Water Levels

Outer Camp water levels rose in 2003 for the first time in 5 years. This is similar to the trend seen in a number of the LP series wells for 2003, that is, a net water-level increase for the first time in 5-6 years. Table 4.1 contains yearly water-level change data, while fig. 4-2 shows these changes graphically.

Table 4.1 Annual Water-Level Changes for the Outer Camp Sites, in feet.

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	-1.10			
1989		-3.56	-3.56	
1990		-1.34	-4.23	
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	-4.71	-4.08	-4.24
2001	NA	-1.49	-1.59	-1.79
2002	NA	-2.99	-3.13	-3.64
2003	NA	1.09	2.23	2.76
Total Change*	**14.79**	**26.73**	**20.32**	**4.44**

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

Surface subsidence around the Orphan Boy Mine shaft has prevented monitoring of this site since June 1999. However, based upon previous comparisons between this site and the Montana Tech well, water levels probably rose throughout 2003. The Orphan Girl Mine site was suggested as a replacement monitoring location and a preliminary study of access to the Orphan Girl Mine was conducted by the MBMG during the summer of 2003, however, no access has been gained.

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 a similar response to precipitation events as was seen in 2002 and prior years, rising in the spring and declining throughout the winter. However, during 2003 water levels continued to rise for a longer period of time into the fall and winter before starting to decline. The net 2003 water-level rise is the first net rise at this site in six years.

Water levels in the Marget Ann Mine and well S-4 increased between 1 foot and 2.2 feet during 2003. 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 regardless of precipitation amounts. From 1999 through 2002, water levels declined with little apparent influence from precipitation. Water levels in the Marget Ann Mine and well S-4 increased throughout 2003. The initial 2003 water-level rise occurred shortly after a substantial amount of precipitation in the spring (April) of 2003 and continued to rise regardless of precipitation trends the remainder of the year.

No water-quality samples were collected during 2003 in the Outer Camp system.

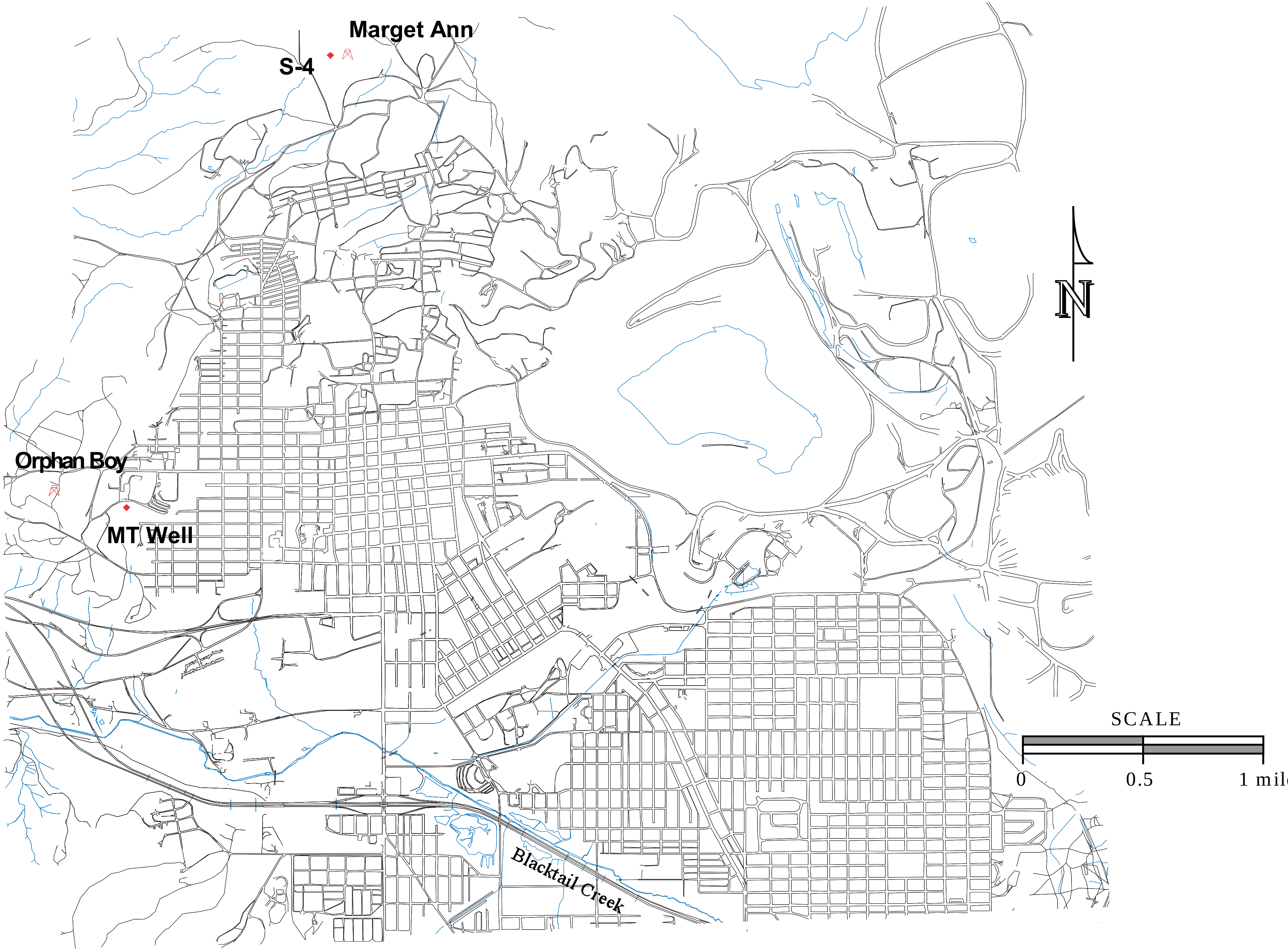


Figure 4-1. Outer Camp monitoring sites location map.

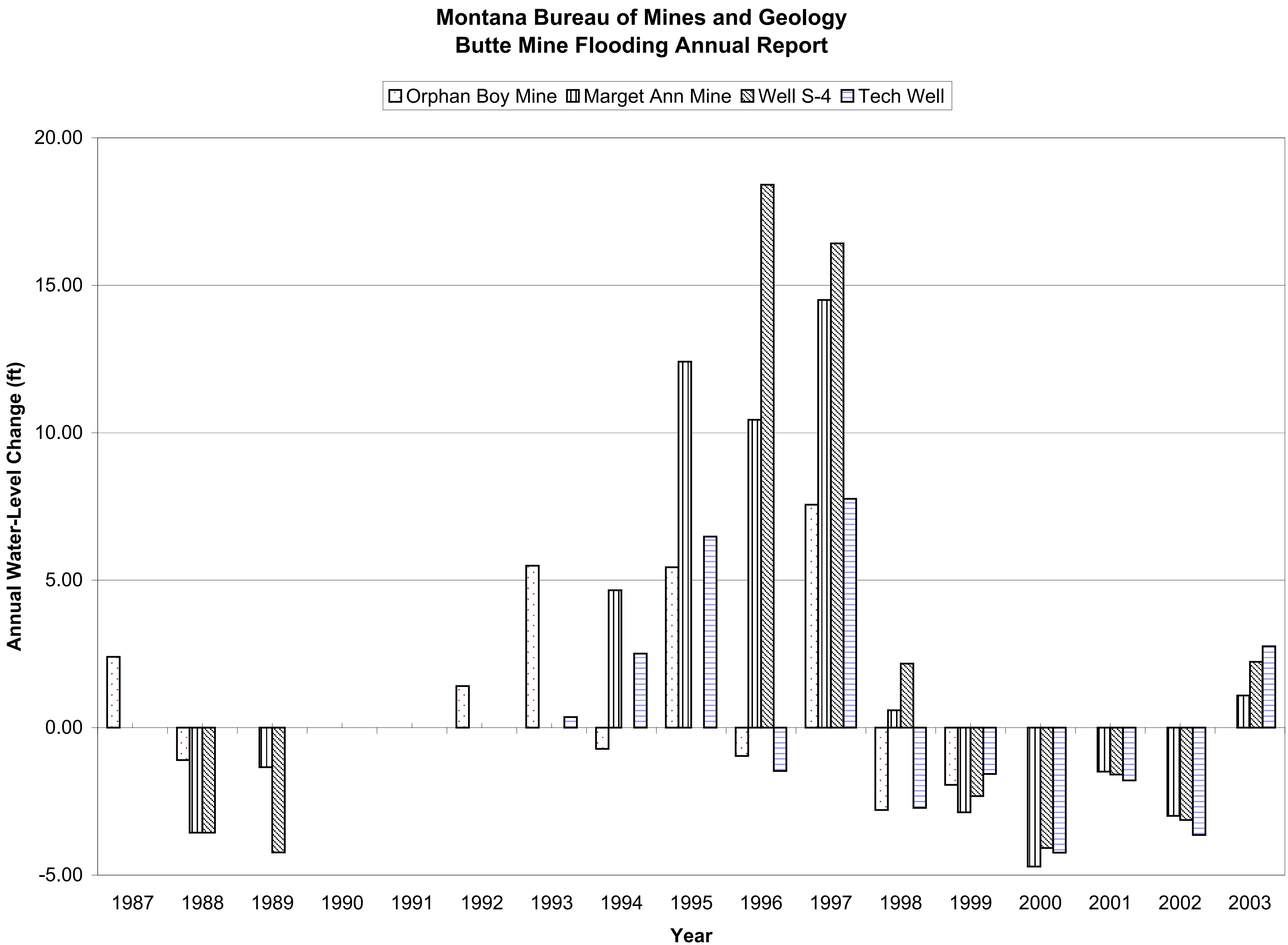


Figure 4-2. Annual water-level change at Outer Camp sites.

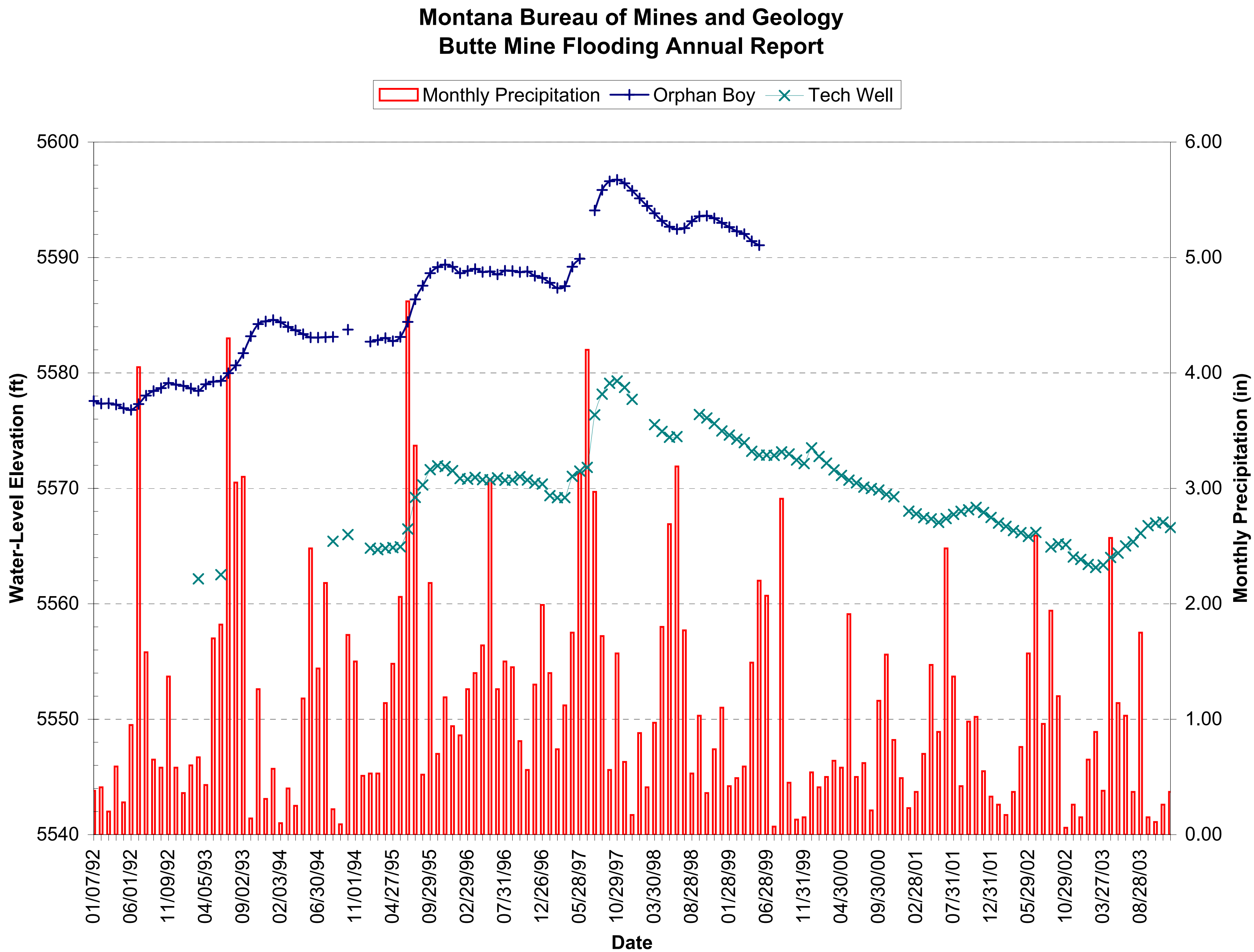


Figure 4-3. Water-level hydrograph of the Orphan Boy Mine and Montana Tech wells.

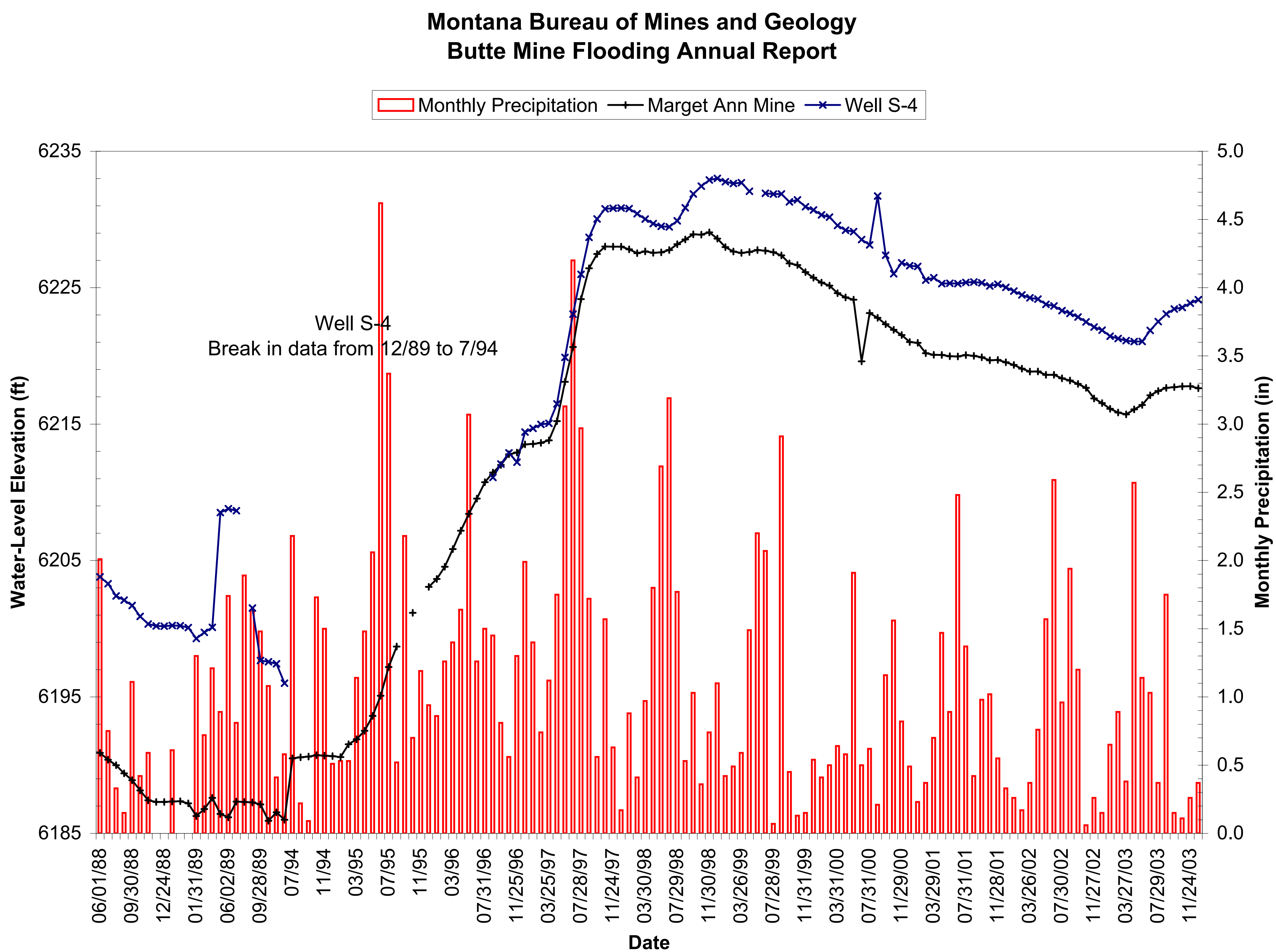


Figure 4-4. Water-level hydrograph for Marget Ann Mine and well S-4.

SECTION 5.0   MISCELLANEOUS WELLS

The locations of the miscellaneous monitoring wells are shown on fig. 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. While the Hebgen Park and Parrott Park wells are both part of the monitoring program specified in the 2002 CD, the shallow alluvial wells (MF) are not; therefore, the frequency of monitoring was changed to quarterly in these wells.

Water levels declined in all eight of the alluvial wells during 2003. Annual water-level changes are listed in Table 5.0. Total water-level changes since 1983 are less than two and one-half feet (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 water-level elevations along with monthly precipitation totals. Water levels respond to precipitation events very quickly in all of these wells. The reduced frequency of monitoring makes it a little harder to see all the responses to precipitation in 2003, but the general trends are similar to those seen in the past. 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 levels appeared to have stabilized somewhat the previous two years, while showing more change during 2003. Water-level response to precipitation was much more dramatic in 2002 than in the two previous years. Construction activities in the general area of these alluvial wells may have influenced water-level changes during a portion of 2003. The HSB water treatment plant discharge line was installed adjacent to the historic Silver Bow Creek channel, currently referred to as the Metro Storm Drain (MSD) during 2003. Dewatering activities in the lower portion of the MSD occurred from summer through the winter of 2003. It appears that these dewatering activities affected the water levels in the alluvial aquifer in the area. Water levels declined between 1.5 feet to over 2.5 feet in wells near the MSD from May through December 2003. This decline is very noticeable in fig. 5-2 through 5-4.

Water-level responses in the Hebgen Park well were similar to those seen in 2001 and most likely 2002. Access problems in 2002 prevented monitoring for a portion of the year, therefore, it is hard to draw too many conclusions about 2002 water levels responses to precipitation, but it does appear that there was a slight increase in water levels during the late summer. Water levels begin to rise during the late spring and continue through the fall, which coincides with both summer precipitation and lawn watering of the park. Precipitation, or the lack of, does not appear to influence water levels once they begin to rise in the spring. 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 not the result of precipitation. The water level in this well rose 1.25 feet during 2003, which is the largest increase in six years.

Table 5.0 Annual Water-Level Change for Miscellaneous Wells, in feet

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 -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	-5.34
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	1.50
2001	0.03	P&A	0.03	0.45	-0.15	P&A	0.08	-0.06	0.09	0.10	-0.12	0.37	5.47
2002	0.16	P&A	0.07	P&A	-0.15	P&A	-0.21	0.70	-0.15	-0.07	-0.18	-0.41	-3.27
2003	-1.08	P&A	-2.13	P&A	-0.76	P&A	-1.77	-2.67	-0.85	-1.63	-0.51	1.25	3.52
Total Change*	**-1.00**	**0.48**	**-2.10**	**0.19**	**-1.02**	**-0.30**	**2.49**	**-1.11**	**-2.19**	**-1.57**	**-1.77**	**3.73**	**16.43**

[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.

The water-level hydrograph for the Parrott Park well is shown on fig. 5-6, along with monthly precipitation totals. Water levels declined during most of the 2002 before leveling off and rising during December of 2002. The 2002 water-level decline was completely offset by the 2003 rise. This year's rise was similar to that of 2000 and 2001. Once again, it appears that irrigation of the park lawn has more of an effect on water-level increases than precipitation, and extends these increases into the fall. Figure 5-7 is a water-level hydrograph for both the Parrott and Hebgen Park wells which shows the similarity in recent water-level trends.

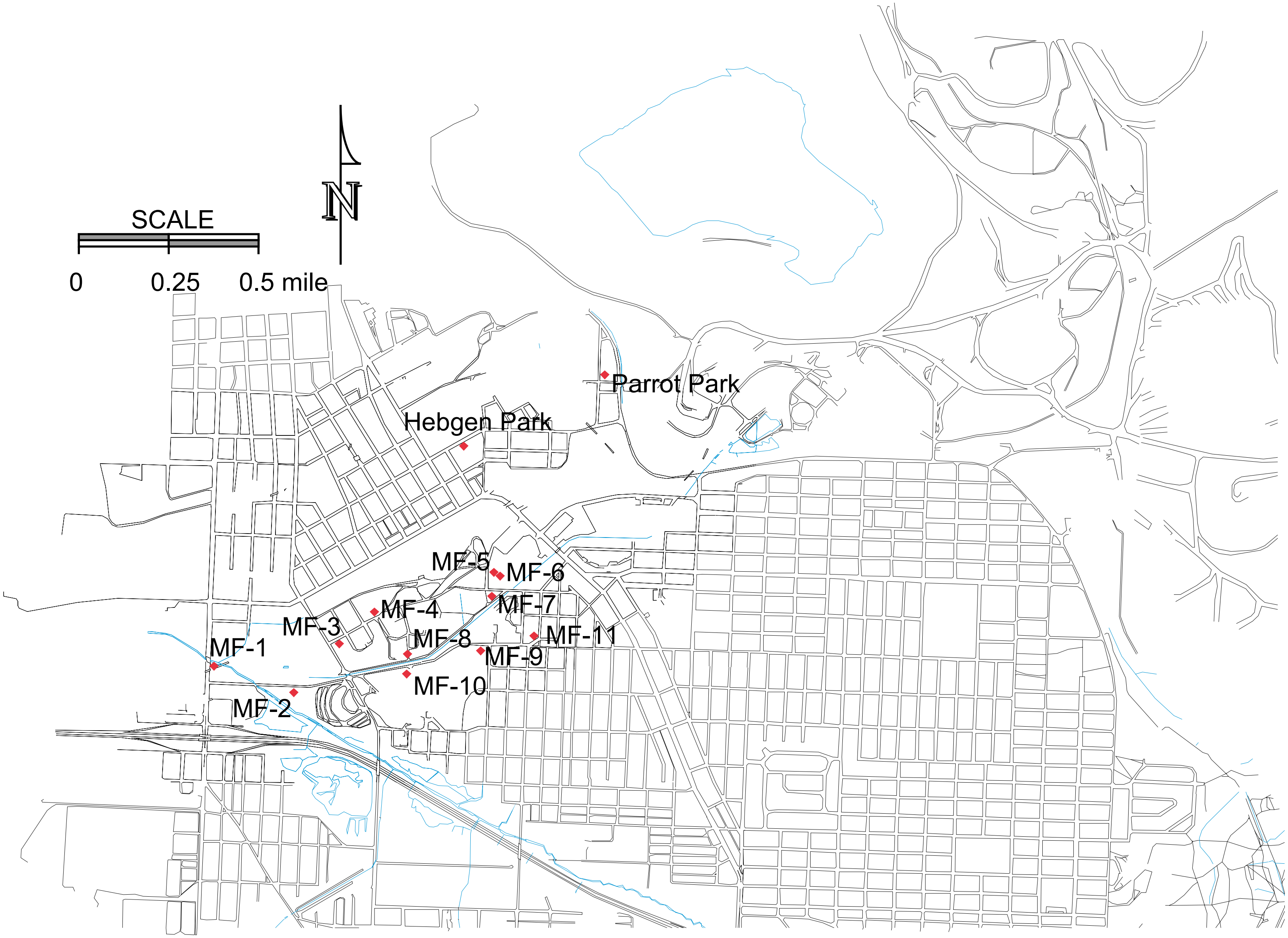


Figure 5-1. Miscellaneous monitoring wells location map.

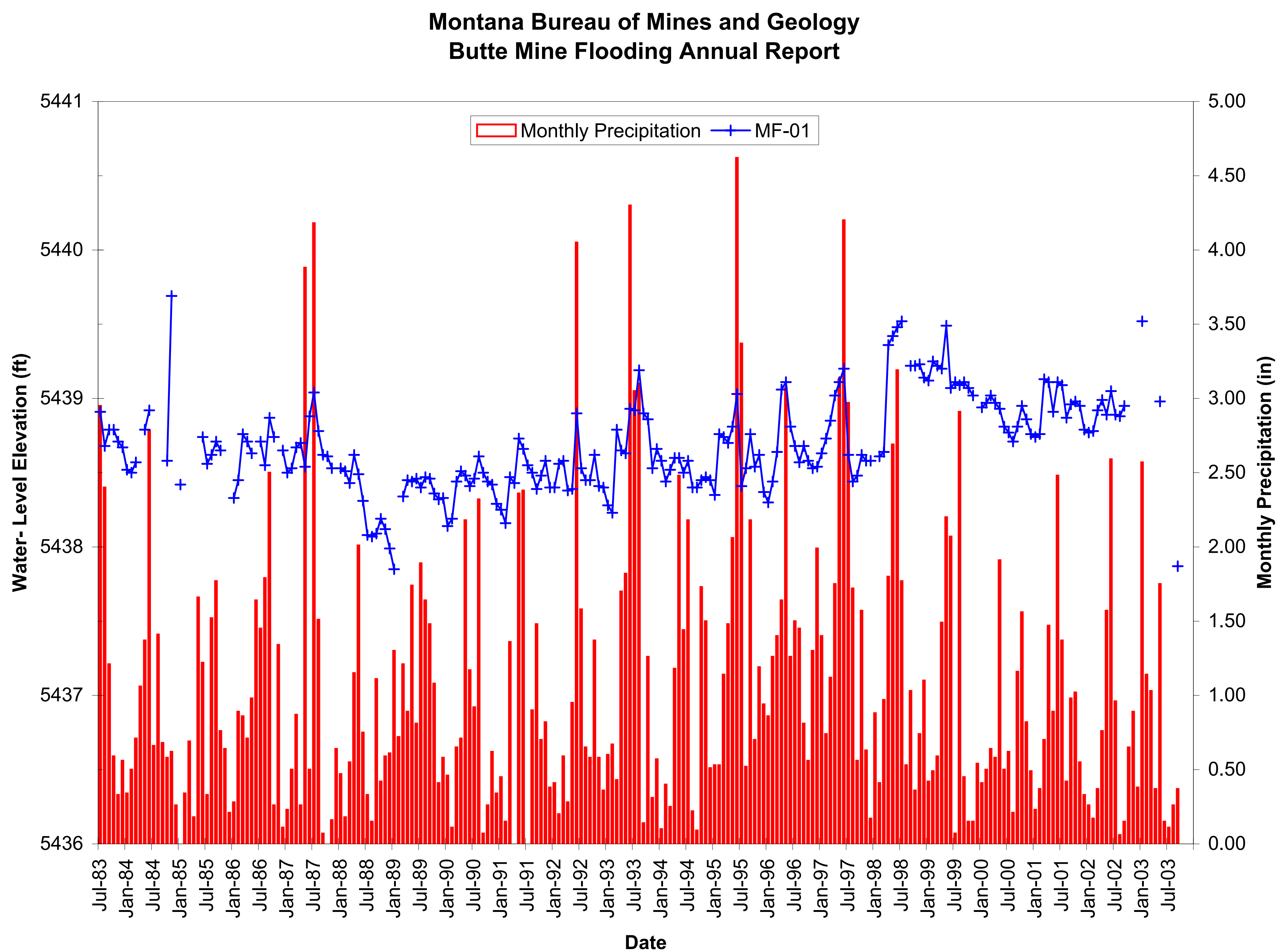


Figure 5-2. Water-level hydrograph for MF-01 well.

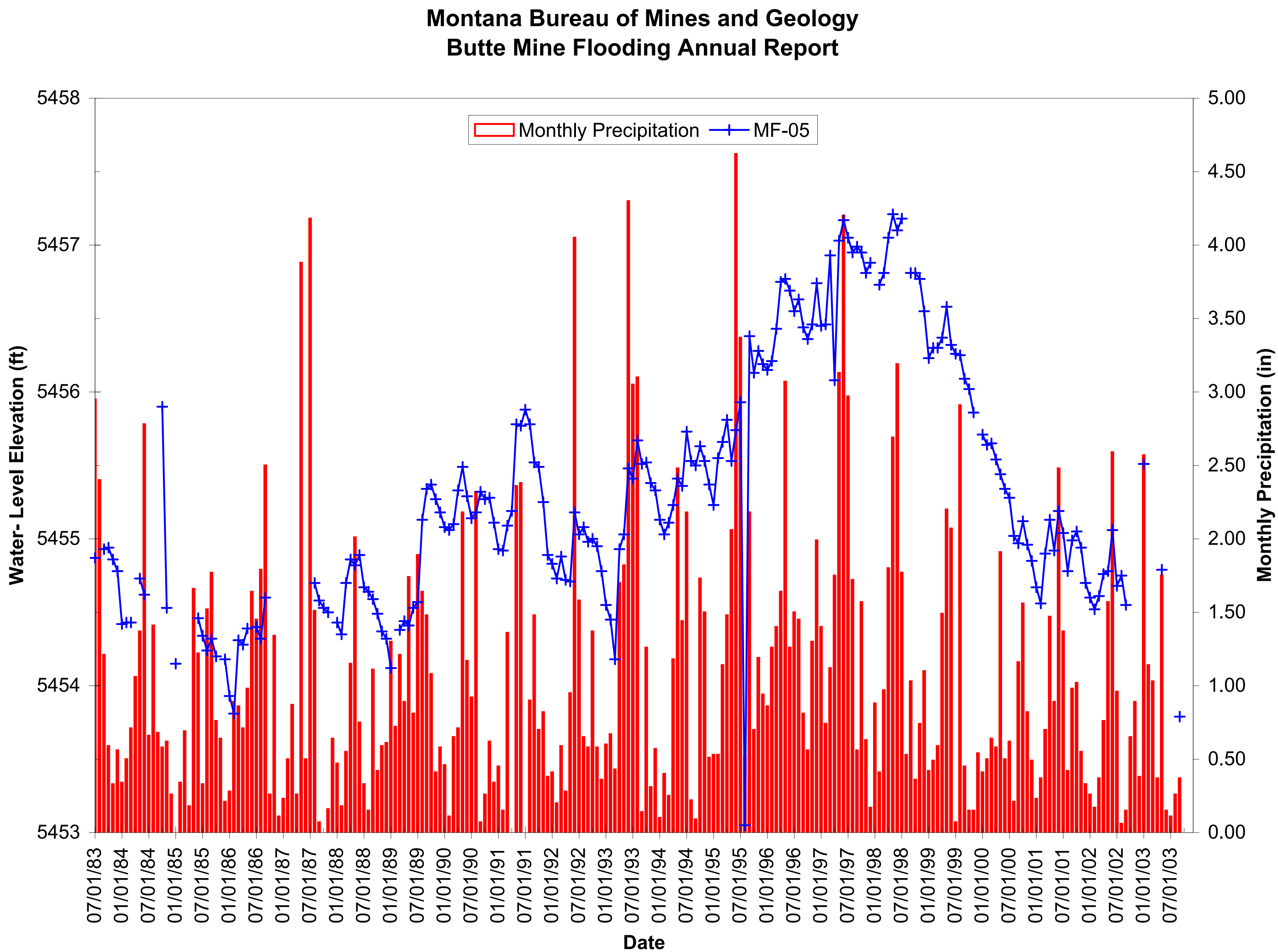


Figure 5-3. Water-level hydrograph for MF-05 well.

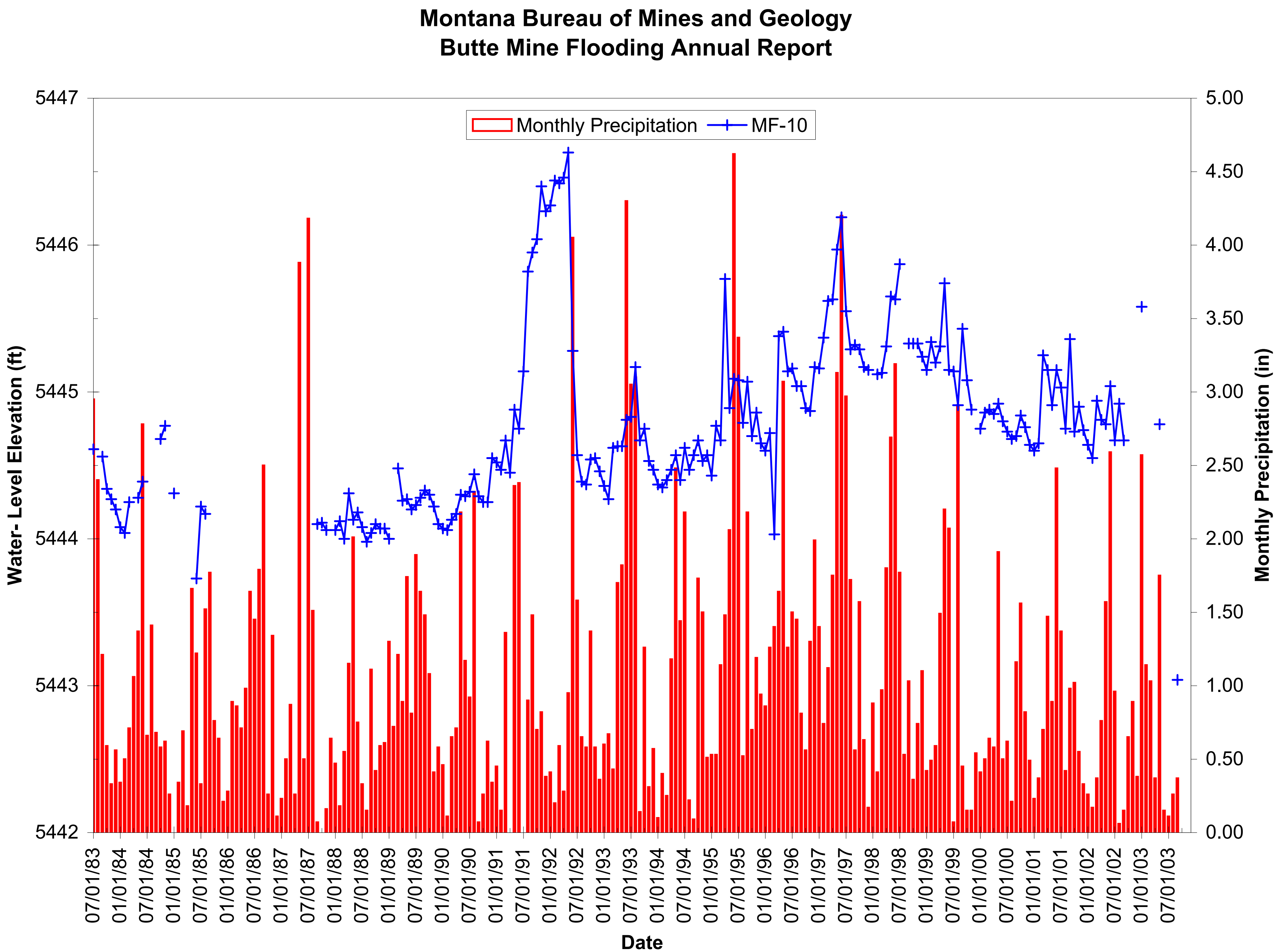


Figure 5-4. Water-level hydrograph for MF-10 well.

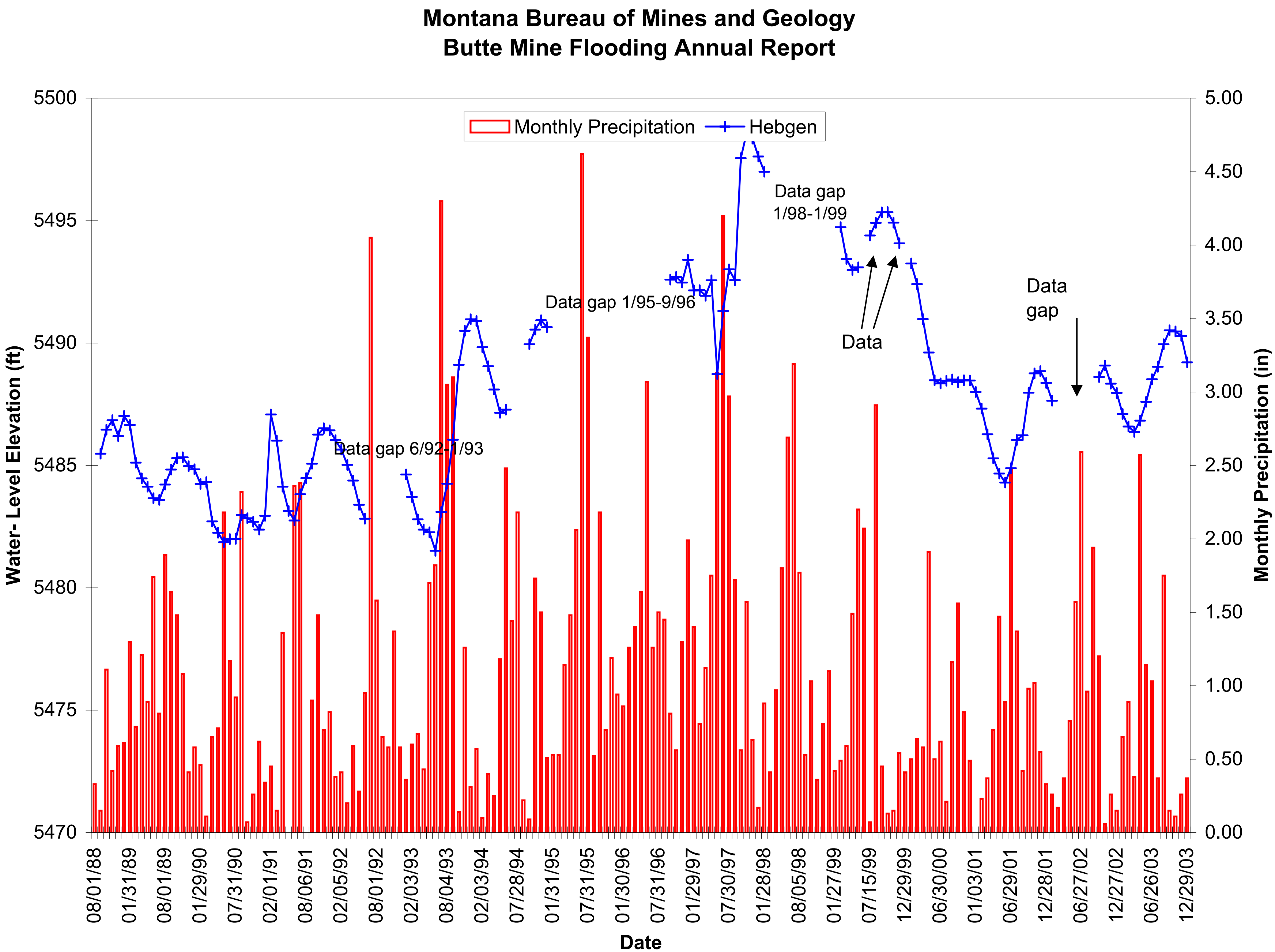


Figure 5-5. Water-level hydrograph for the Hebgen Park well.

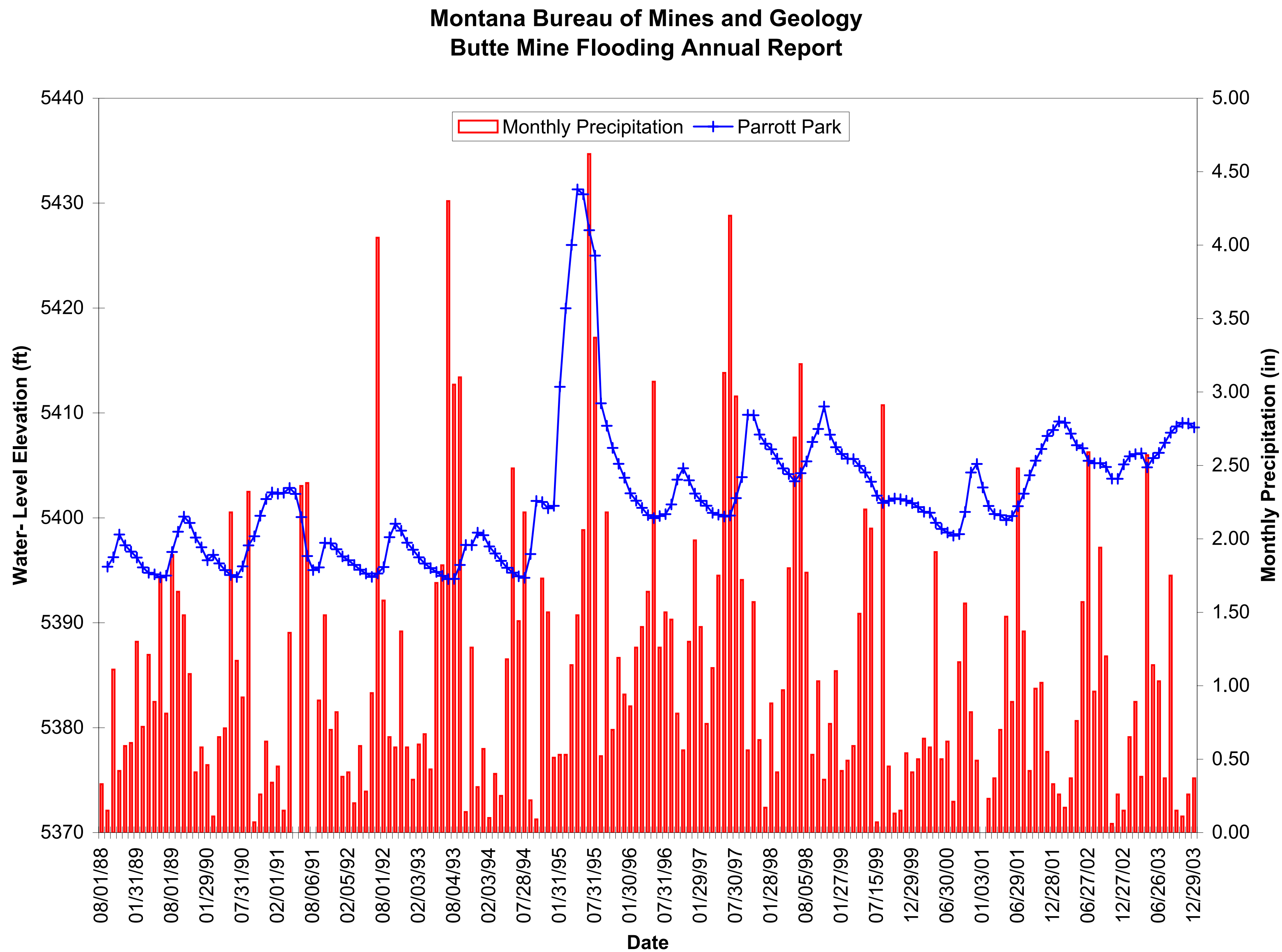


Figure 5-6. Water-level hydrograph for Parrott Park well.

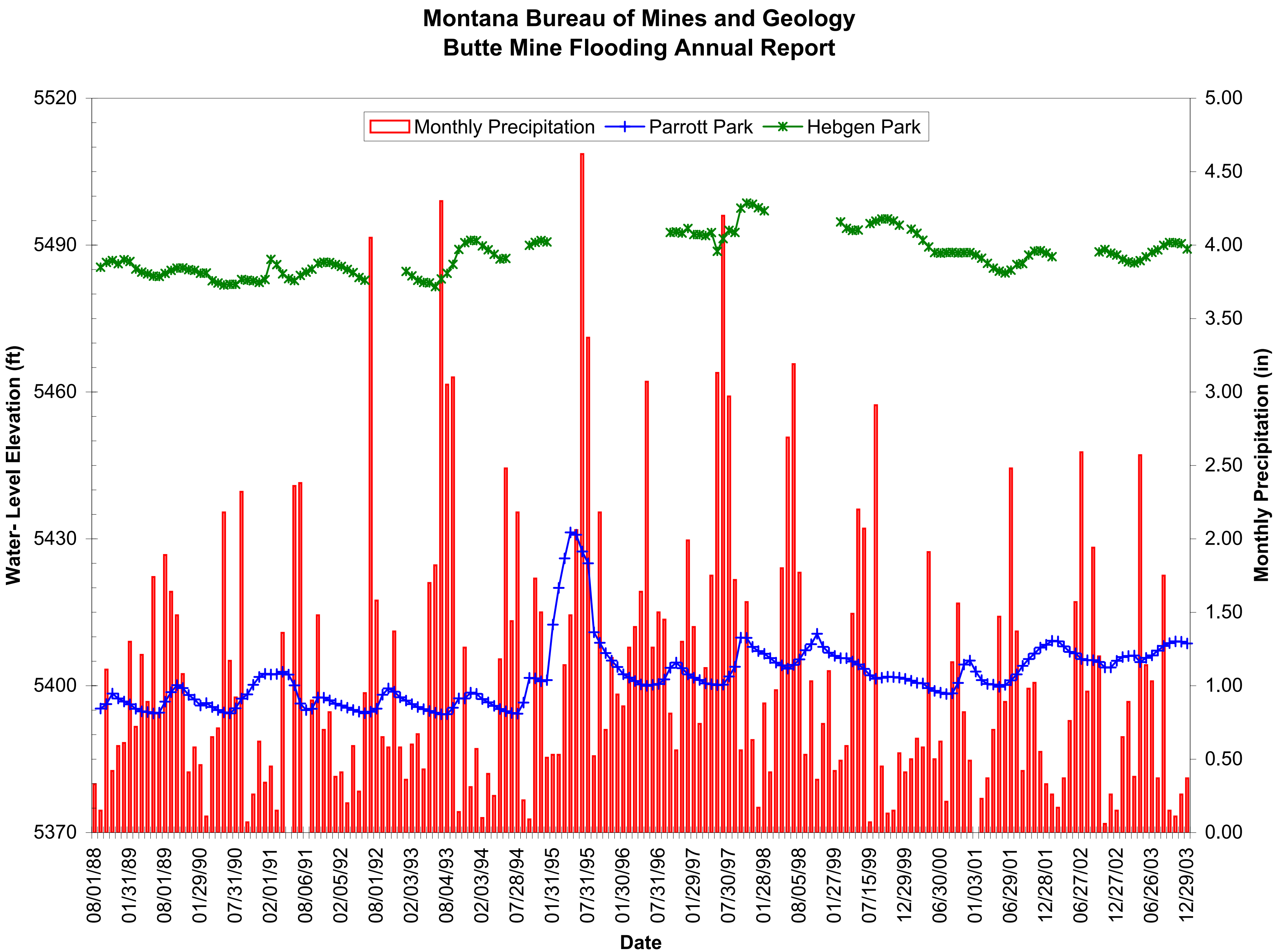


Figure 5-7. Water-level hydrograph for Parrott and Hebgen Park wells.

SECTION 6.0 REVIEW OF THE BERKELEY PIT MODEL

MR did not update the Berkeley Pit water-level model based upon actual 2003 water-level measurements and HSB-inflow volumes since there were no significant changes to water-handling operations and the fact that mining operations were suspended for a majority of the year (personnel communication S. Czehura, 2005). The continued suspension of mining activities has resulted in the input of water from the HSB drainage into the Berkeley Pit since July 2000, until late November 2003 when the water treatment plant came on-line. This short period of operation of the water treatment plant and the resultant lack of HSB flow into the pit most likely would not have affected 2002 filling rate projects.

Based upon the 2002 model update, it was projected that the critical water level (CWL) of 5,410 feet will be reached at the Anselmo Mine in June 2018, 13 months sooner than predicted in the 2001 model (Czehura, 2003). The model update assumed the continued input of HSB drainage water through December 2003, when the HSB water treatment plant was scheduled for completion. Actual start-up of the water treatment plant occurred one month earlier. Water from the HSB drainage was diverted away from the pit and into the treatment plant. The treated water was used in MR's mining process for make-up water in the concentrator facility.

The treatment technology and plant-construction time frame for Berkeley Pit water are based upon the schedule listed in the EPA 1994 ROD, and included in the 2002 CD for the Butte Mine Flooding Operable Unit (EPA, 1994). Based upon the current water-level projections, a review of the HSB treatment plant design and operation would begin in June 2014. Any necessary upgrades would have to be completed by June 2016 (Czehura, 2003).

SECTION 7.0 CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system were different from those noted in previous reports at a number of the monitored sites. An increase in water levels occurred in a majority of the alluvial wells during 2003. The decline in water levels that has occurred the past five to six years in alluvial monitoring wells to the south and southeast of the September 1998 Berkeley Pit landslide was replaced by a slight increase in water levels for 2003.

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-level variations in these wells can be more closely related to mine operations.

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. While the decrease in annual precipitation in the Butte Basin since 1999 was considered a good explanation for the overall water level decrease seen in a number of monitoring wells in 2002, water levels increased in all of these wells (AMC and GS series) for 2003. This increase occurred although precipitation levels were less than previous years. The increases were greater in wells nearest the mine site and water levels rose the most from late summer through the remainder of the year. While this period of time coincides with MR's mine start-up activities, no direct link was found between start-up activities and water-level changes.

The increased water-level changes in the East Camp bedrock system are independent of precipitation, and are a result of the cessation of long-term mine dewatering activities in 1982. No notable precipitation influence was seen in any of the bedrock wells or underground mines' water levels.

However, the addition of HSB drainage water into the Berkeley Pit, which began the end of June 2000, did have an influence on East Camp bedrock water levels. Water levels rose an average of 0.89 feet 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 and 2002 monthly water-level rises were about 1.33 feet and 1.29 feet, respectively, while the average monthly rise in 2003 was about 1.10 feet. The lower rate of water-level rise 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 unchanged from June 2018. 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 lowest 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 2003 was less than in previous years; thus, water levels rose about one foot throughout this system and are now about 10 feet below the maximum-allowable level.

Monitoring wells in the alluvial aquifers associated with the Mine Flooding Operable Unit continue to show a wide range of water quality concentrations, both spatially and temporally. As is the case for the last few years, the AMC-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 recent trends in most wells for most constituents.

In several cases, chemistry data from the East Camp mines show a strong departure from previous trends, particularly with respect to iron concentrations. These changes were regarded in last year's report as possibly a sampling or analytical problem, but now must be considered, as likely a real change in the chemistry of water in the underground workings.

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. Data from the Emma shaft continue to show departure from recent trends and a notable difference in water quality compared to the Travona Mine.

Results of the 2003 monitoring program continue to show that the current monitoring (water level and water quality) 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.

Acknowledgments

The information contained in this report represents the work of many companies and agencies over the past 22 years. Without their cooperation, this report could not have been prepared. Numerous individuals have been responsible for actual data collection. Their dedication and creativity in monitoring and sampling of mine waters provided the information, which all future work and evaluations will rely upon. The continued cooperation of Montana Resources and British Petroleum/Atlantic Richfield Company is greatly appreciated.

Representatives of New Butte Mining and Montana Mining Properties continue to allow access to their properties for monitoring purposes.

The State of Montana, Department of Environmental Quality and the U.S. Environmental Protection Agency have provided funding for the Montana Bureau of Mines and Geology (MBMG) to conduct monitoring and sampling activities and preserve continuity between various studies. This support has been invaluable; while their realization that flexibility needed in the monitoring program has allowed modifications in monitoring as conditions change.

Special recognition is given to Mike Kerschen and James Rose, MBMG, for their dedication to monitoring and sampling tasks, and to Linda Albright and Peggy Delaney, MBMG, for assisting with the preparation of this report.

Errors and omissions remain the authors' responsibility.

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