Montana Bureau of Mines and Geology
Open File Report No. 435

The Flooding of Butte's Underground Mines and Berkeley Pit
Butte Mine Flooding Operable Unit
Annual Water-Level Update, 2000

By

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Cover photo courtesy of The World Museum of Mining, Butte, MT.
High Ore Mine 2800 Level Pump Station.

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Executive Summary

The Record of Decision (ROD) for the Butte Mine Flooding Operable Unit (BMFOU) stipulates that a yearly update of data collected from the Post RI/FS monitoring program is prepared. The report is to incorporate new data with the existing data. This report presents data collected during the year 2000, 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) The June 30, 2000 suspension of mining by Montana Resources and the resulting inflow of water from the Horseshoe Bend Drainage into the Berkeley Pit. This inflow increased the rate of rise in the Berkeley Pit and associated underground mines.

2) Rehabilitation work on bedrock well D-1.

3) Redevelopment of bedrock wells A, C, D-1, and D-2.

4) West Camp pumping activities continue to control the ground-water level below the 5435-foot elevation, stipulated in the 1994 Record of Decision. However, a reduction in the volume of water pumped from 1999 levels resulted in more than a 5-foot water-level increase. In 1999, 326 acre-feet of water were pumped, whereas only 270 acre-feet of water were pumped in 2000.

5) The annual Berkeley Pit model update resulted in a 3-year change in the projected date (timeline) when the 5410-foot water-level elevation would be reached at the Anselmo Mine. Water levels were predicted to reach this elevation in 2018, 3 years earlier than shown in the 1999 model. The anticipated addition of Horseshoe Bend Drainage water into the pit for the next 3 years is responsible for this increase in filling rate.

Water-level data are presented in the same order and manner as the previous reports (MBMG Open-File Report No. 376 and No. 410) for the reader's convenience. Hydrographs for selected sites and total and yearly water-level changes for all sites are presented.

Acknowledgements

The information contained in this report represents the work of many companies and agencies over the past 19 years. Without their cooperation, this report could not have been prepared. Numerous individuals have been responsible for actual data collection. Special recognition is given to Montana Resources and its contractor, ESE, particularly Joe Griffin, Jeff Martin, and Gary Pierce, and to MBMG employees, Betty Babb, Mike Kerschen and James Rose.

The cooperation initially given by the Anaconda Company, and continued by Montana Resources and ARCO has been invaluable in collecting the monitoring data. Representatives of New Butte Mining and Montana Mining Properties continue to allow access to their properties for monitoring purposes. Special acknowledgement is given to the citizens of Butte who allow access to their private wells for monitoring purposes.

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

Errors and omissions remain the authors' responsibility.

Section 1.0 Introduction

The Butte Mine Flooding Operable Unit (BMFOU) Record of Decision (ROD) specifies that an annual review of water levels and water quality be performed. The first water level review was completed in 1998 as a 15-year evaluation from the beginning of flooding of the Butte underground mines and Berkeley Pit in 1982 through 1997 (Duaime, 1998); this is the third such report. Any notable changes are discussed and a comparison of water levels, precipitation and trends are discussed.

This report does not present an overview of the history of mining on the Butte Hill, nor the Superfund processes that have followed since the Environmental Protection Agency (EPA) designated the flooding underground Butte mines and Berkeley Pit a Superfund site in 1987. The reader is referred to the Butte Mine Flooding RI/FS, Butte Mine Flooding ROD, or MBMG Open-File Report No. 376 for greater detail and information about the site.

Monitoring activities continued in 2000 in the East Camp, West Camp and Outer Camp systems (figure 1-1). The East Camp System includes mines and mine workings draining to the Kelley Mine pump station when mining and dewatering were suspended in 1982. The West Camp System includes workings that historically drained to the East Camp from the southwest portion of the Butte Mining District but were hydraulically isolated by the placement of bulkheads in interconnected mine workings to separate the West Camp from the East Camp. The Outer Camp System consists of the western and northern extents of mine workings that were interconnected to the East Camp at some time, but have been isolated with water levels returning to, or near, pre-mining conditions.

Section 1.1 Notable 2000 Water Level Changes and Activities

(1) Montana Resources (MR) suspended mining and milling operations on June 30, 2000 due to their inability to secure affordable electric rates. As a result of this suspension, water from the Horseshoe Bend Drainage (HSB) was once again discharged into the Berkeley Pit. Since April 1996 this water had been used in MR's mining operations and kept out of the Berkeley Pit, as specified in the BMFOU ROD. This water was kept out of the pit to slow its filling rate. Following ARCO's 1982 suspension of mining, water from HSB flowed into the Berkeley Pit.

MR incorporated water from HSB in their mining operations by first pumping it to the precipitation plant for removal of copper. The water was then treated with lime and pumped to the Yankee Doodle Tailings Dam (YDT) where it mixed with tailings from the concentrator that were pumped to the YDT. Decant water from YDT was then used as makeup water in the concentrator for milling purposes. The June 2000 suspension of mining shut down the precipitation plant in addition to the mining and milling operations. As a result MR was no longer able to treat the HSB water, so it was again discharged into the Berkeley Pit.

The 1994-ROD contained a provision for such an occurrence that stipulated that the Potentially Responsible Parties (PRP's), in this case MR and ARCO, were to begin the preliminary design for a water treatment plant. The EPA and DEQ issued this order that gave the PRP's 6 months, after which they would have to begin final design of a plant. The PRP's submitted a preliminary design at the end of December 2000.

The EPA and DEQ implemented a schedule for flow monitoring and water quality sampling of the HSB and Continental Pit that began immediately upon the suspension of MR's operations. The monitoring and sampling consists of continuous flow monitoring and bi-weekly water quality sampling of both the HSB and Continental Pit.

The addition of HSB water into the pit resulted in an increased rate of rise throughout the East Camp mine-bedrock system. The average monthly rate of rise for 1999 and the first 6 months of 2000 were 1.04 ft and 0.89 ft, respectively. The average monthly rise for the last 6 months of 2000 was 1.93 ft. The input of HSB water resulted in an additional 733 million gallons of water entering the East Camp system during 2000.

(2) Water pumped from the Continental Pit was allowed to flow into the Berkeley Pit for a period of time. A totalizing flow meter was installed in the discharge pipeline in early September. This meter recorded a total of 36.5 million gallons of water pumped through the end of the year. Not all of this water was diverted to the pit however; a portion was pumped to the YDT dam.

(3) Previous investigations (Kerschen 1998) and recent observations using a downhole camera had shown a deterioration of the steel casing and the presence of foreign objects in several of the bedrock monitoring wells. Work was undertaken and completed on redevelopment and rehabilitation of four East Camp bedrock monitoring wells. Wells A, C, D-1, and D-2 was redeveloped using a combination of air injection and flushing with water and pumping.

Foreign debris was removed from bedrock well A as part of the redevelopment work. The debris turned out to be broken pieces of 4-inch schedule 40 PVC. This well had been constructed using steel and stainless steel casing, so the origin of the PVC is unknown.

Well D-1 was identified by DEQ in 1998 as having extensive pitting on the inside of the casing, and needing repair. The well was lined with 4-inch, schedule 80 PVC and remains a part of the monitoring system. See Section 2.2.1.1 for further discussion about the redevelopment and rehabilitation of these wells.

(4) The final activity of note in 2000 was the plugging and abandonment of bedrock well DDH-5. Significant water-level variations were noticed in this well during the first part of 2000. Attempts to identify the cause of these changes were unsuccessful, but it appeared that the water level in the inner casing was rising to the same level as the water level in the outer casing. These changes would be indicative of casing problems at depth. This well had been drilled as a mineral

exploration hole and no completion information was available. The well contained three different size casings, with the inner two appearing to be loose in the hole. Therefore, it was decided to plug and abandon the well.

The well was plugged by installing an inflatable rubber packer at a depth of 450 ft below ground surface. A cement plug was poured on top of the packer and allowed to cure for several days. The remainder of the borehole was then filled with bentonite to ground surface. A steel cap was then welded on top of the casing. The well has been removed from the monthly water level monitoring program. Bedrock well J is nearby, and water levels measured in this well were historically similar to those in well DDH-5.

Section 1.2 Precipitation Trends

Precipitation during 2000 was well below average. Total precipitation was 9.4 inches compared to the long-term average of 12.89 inches. This is a decline of twenty-eight percent and is the second consecutive year of below–average moisture. Table 1.2.1 contains monthly precipitation totals from 1982 through 2000, while figure 1-2 shows this information graphically in comparison to the long-term yearly average. Figure 1-3 shows departure from normal for precipitation from 1895 through 2000.

Table 1.2.1 Butte NOAA Precipitation Statistics, 1982-2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN	0.54	0.48	0.88	0.96	2.06	2.19	1.61	1.33	0.99	0.76	0.69	0.58	13.09
STD. DEV.	0.36	0.29	0.39	0.57	0.77	1.36	1.23	0.91	0.71	0.52	0.40	0.42	3.39
MAX	1.40	1.26	1.84	1.80	3.88	4.62	4.18	3.10	2.50	1.73	1.50	1.99	19.96
MIN	0.10	0.11	0.25	0.00	0.95	0.50	0.00	0.15	0.07	0.00	0.15	0.01	8.32
Number of years													19
Number of years greater than mean													6
Number of years less than mean													13

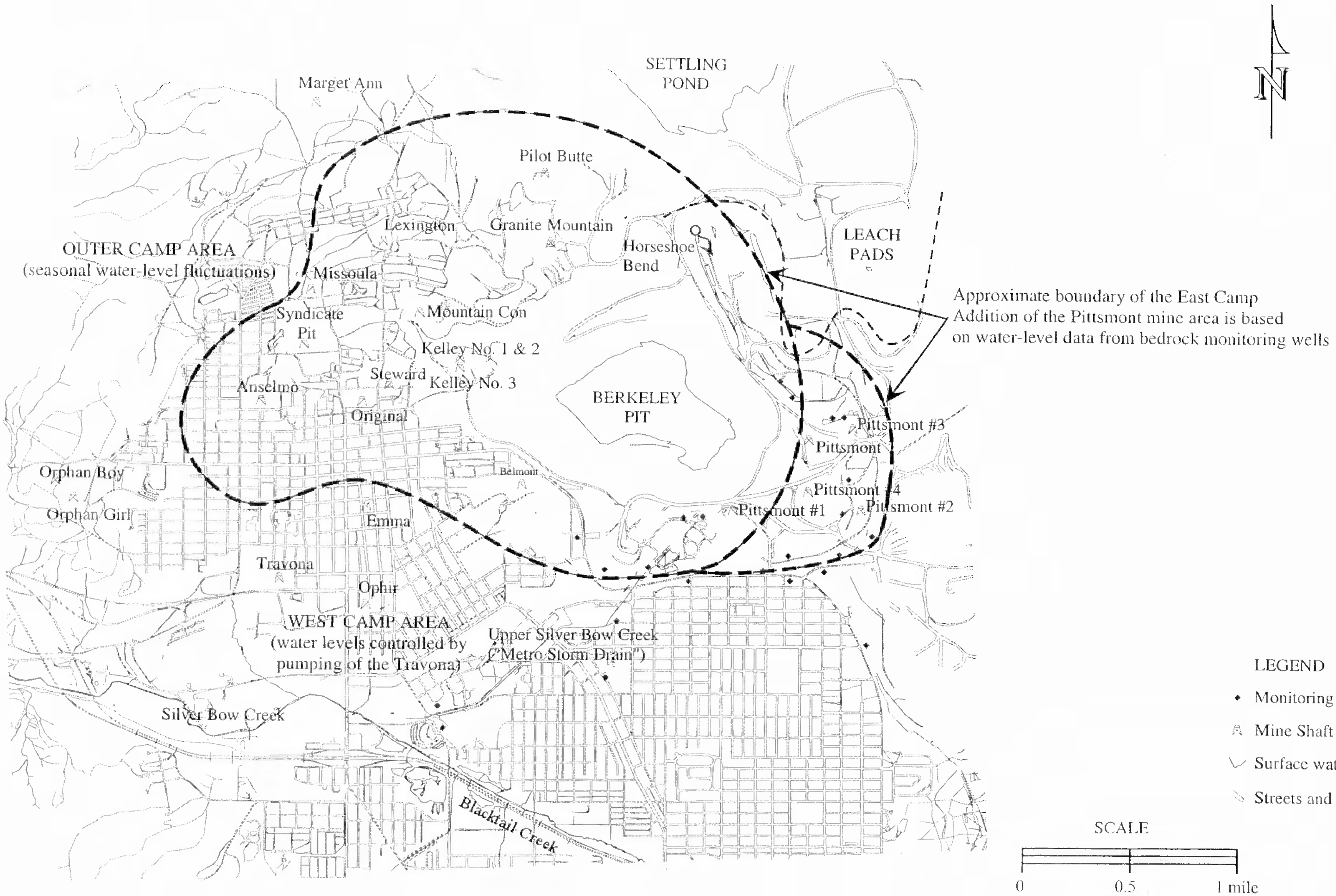


Figure 1-1. East Camp, West Camp, and Outer Camp boundaries.

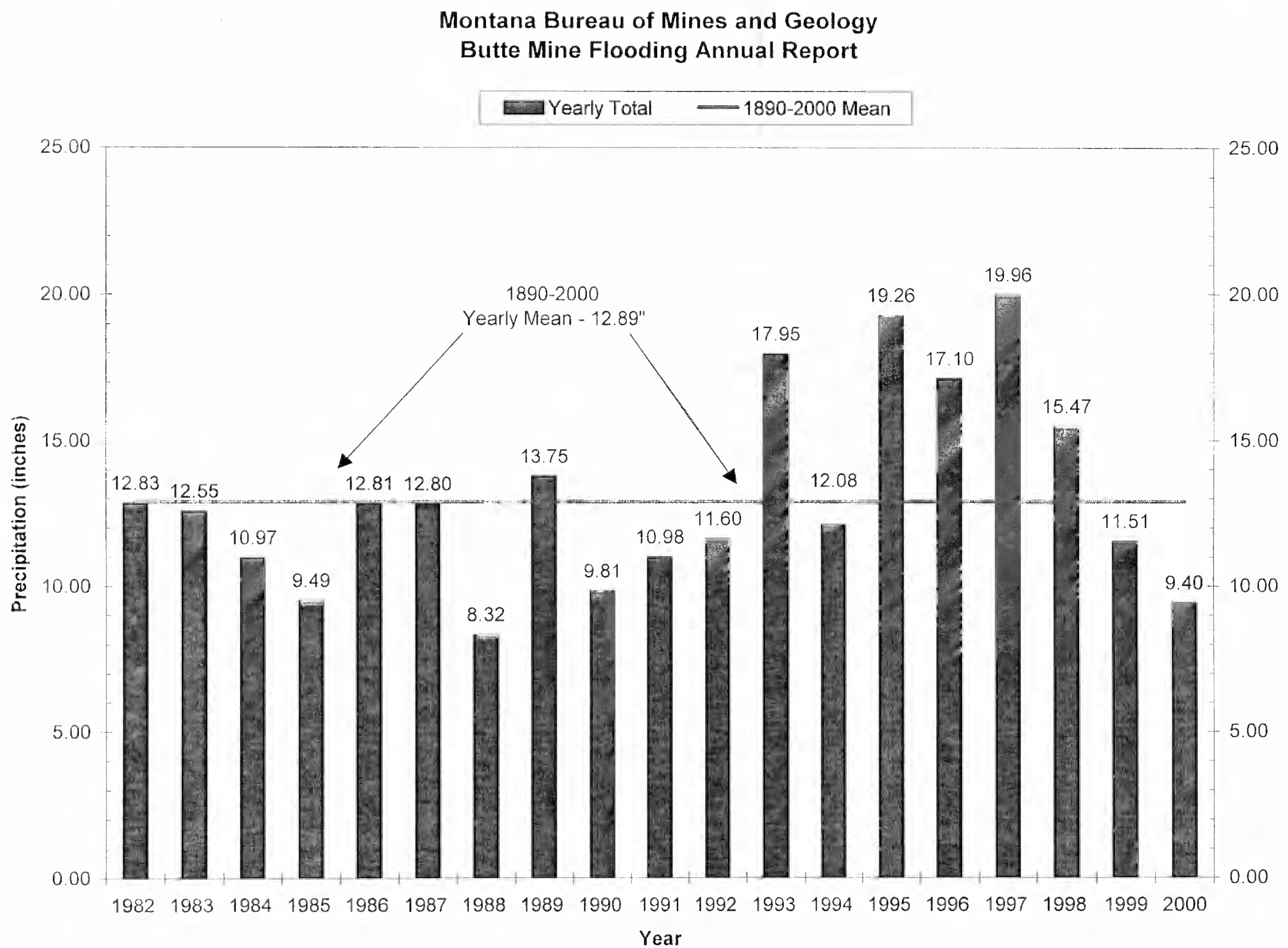


Figure 1-2. Yearly precipitation totals, 1982-2000, showing 1890-2000 yearly mean precipitation total.

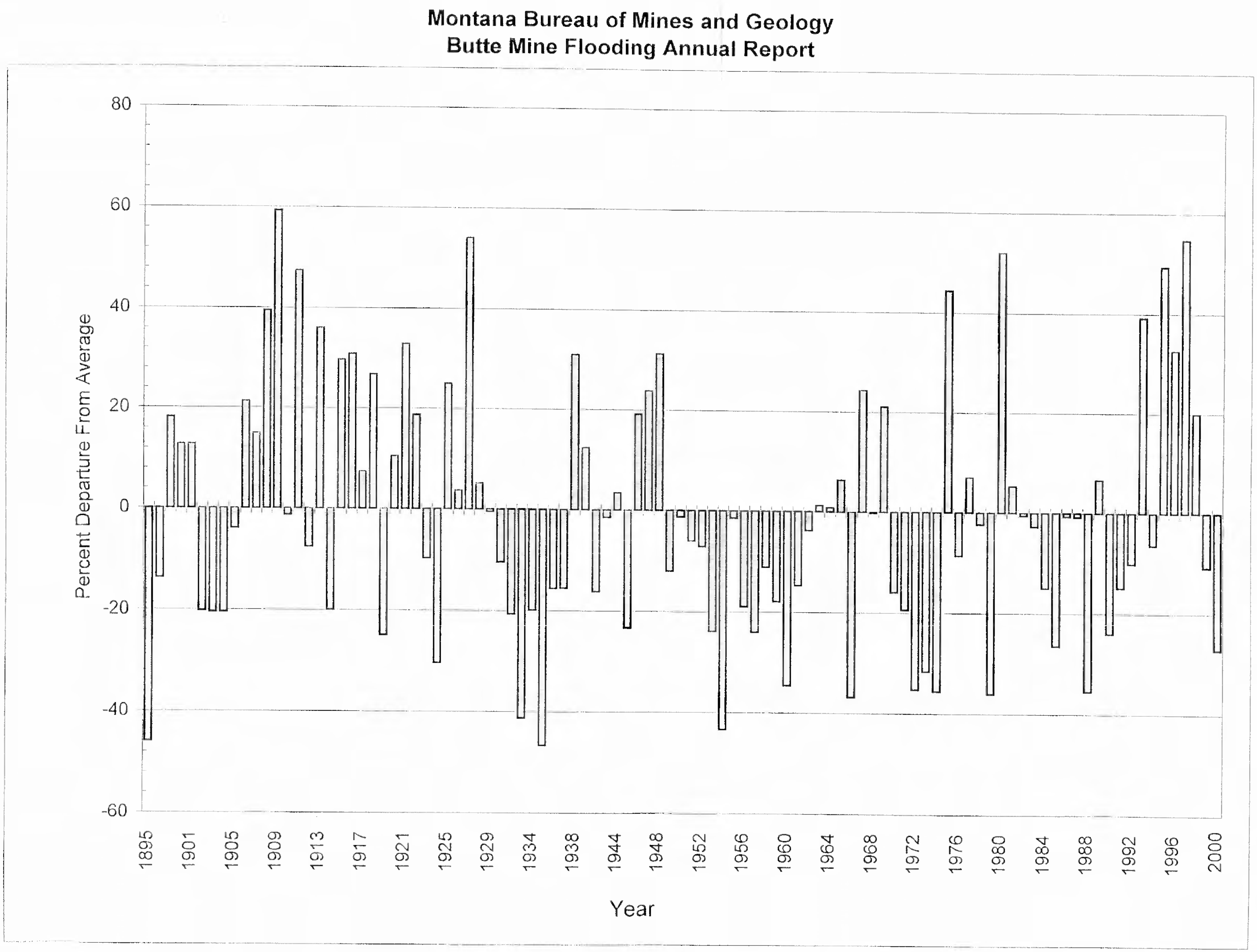


Figure 1-3. Percent precipitation departure from average, 1890-2000.

Section 2.0 East Camp System

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

Section 2.1 East Camp Alluvial System

The East Camp alluvial monitoring system consists of a series of four different groups of wells. Each group of wells represents sites installed or monitored during different studies that have been incorporated in the BMFOU monitoring program. Water-level changes and monthly precipitation amounts are shown on hydrographs for selected wells.

Section 2.1.1 AMC Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown on figure 2-2; table 2.1.1.1 lists the annual water level changes for these sites. Water levels declined in 8 of the 10 wells during 2000. Wells 10 and 11 remained dry. Net water level changes from 1983 are rises in 2 wells; declines in 6 wells and 2 wells remain unchanged (dry).

Table 2.1.1.1 AMC Wells Annual Water Level Change

Year	AMC-5	AMC-6	AMC-8	AMC-10	AMC-11	AMC-12	AMC-13	AMC-15	AMC-23	AMC-24
1983	-23.75	-2.30	-4.90	DRY	DRY	0.20	0.60	-5.80	0.00	-0.10
1984	-4.50	-2.55	-3.75	DRY	DRY	-1.80	-1.10	-3.40	0.00	0.18
1985	-3.40	-3.90	-3.00	DRY	DRY	-2.45	-1.85	-2.80	0.00	0.10
1986	8.70	3.90	-0.90	DRY	DRY	1.90	1.00	-2.10	0.50	0.40
1987	0.10	0.40	1.50	DRY	DRY	0.60	0.10	0.00	0.30	0.00
1988	0.20	-0.40	0.30	DRY	DRY	-0.10	-1.00	0.80	-0.10	-0.10
1989	-2.30	-0.80	-0.90	DRY	DRY	-0.20	-0.10	0.10	0.00	0.00
1990	0.20	0.10	0.30	DRY	DRY	1.10	0.00	-0.10	0.20	0.10
1991	0.00	0.30	0.80	DRY	DRY	-0.60	0.30	-0.30	0.10	0.00
1992	0.40	-0.40	0.50	DRY	DRY	-0.30	0.00	-0.10	0.00	0.00
1993	0.40	0.70	0.80	DRY	DRY	1.10	1.00	-0.40	0.40	0.10
1994	0.64	0.53	0.91	DRY	DRY	-0.19	-0.50	0.96	-0.32	0.07
1995	0.64	1.01	0.51	DRY	DRY	1.23	1.13	0.97	0.01	-0.07
1996	-0.05	0.62	2.14	DRY	DRY	0.74	0.69	2.60	0.38	0.12
1997	1.80	1.47	2.24	DRY	DRY	1.20	0.70	2.80	-0.36	-0.25
1998	-1.52	0.42	1.15	DRY	DRY	0.18	0.09	0.58	0.15	0.12
1999	-1.56	-2.03	-2.45	DRY	DRY	-1.56	-1.09	-1.50	-0.09	-0.18
2000	-2.46	-2.56	-3.88	DRY	DRY	-1.77	-1.17	-3.73	-0.14	-0.08
Net Change	**-26.46**	**-5.49**	**-8.63**	**0.00**	**0.00**	**-0.72**	**-1.20**	**-11.42**	**1.03**	**0.41**

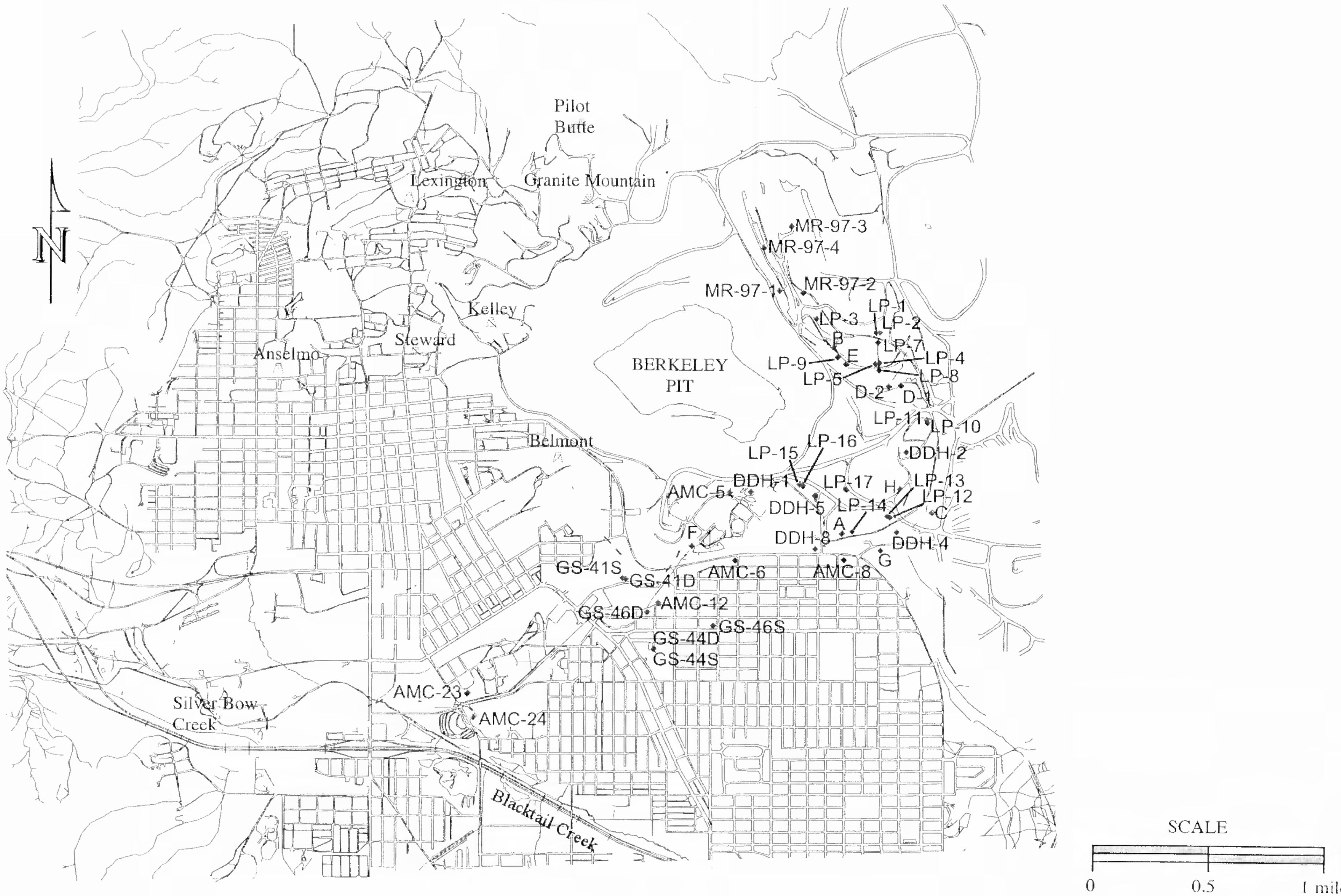


Figure 2-1. East Camp Monitoring Sites.

Figure 2-2. AMC well location map.

Wells AMC-5, AMC-6, and AMC-8 are located to the south of the active mine area and the Butte Concentrator facility (figure 2-2). Well AMC-12 is located west of these wells. Hydrographs for wells AMC-5 and AMC-12 (figure 2-3) and AMC-6 and AMC-8 (figure 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.

There were no noticeable changes in water level trends for any of these four wells. The water level decline that began following the September 1998 Berkeley Pit landslide continued. Precipitation had very little effect on well water levels and was very short lived. Water levels declined between 1.77 feet (ft) and 3.88 ft during the year 2000 in these four wells. These are comparable to 1999 declines.

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

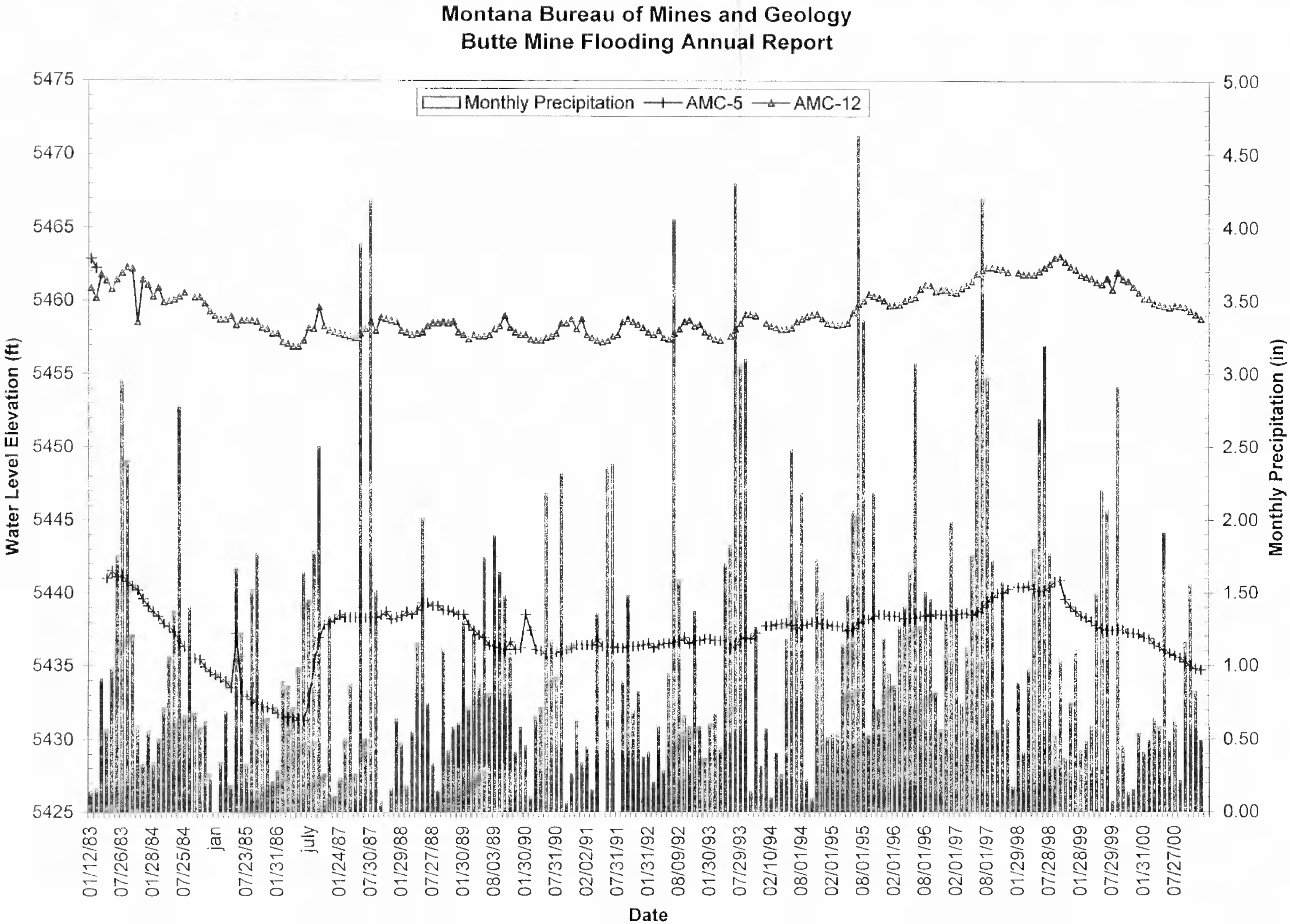
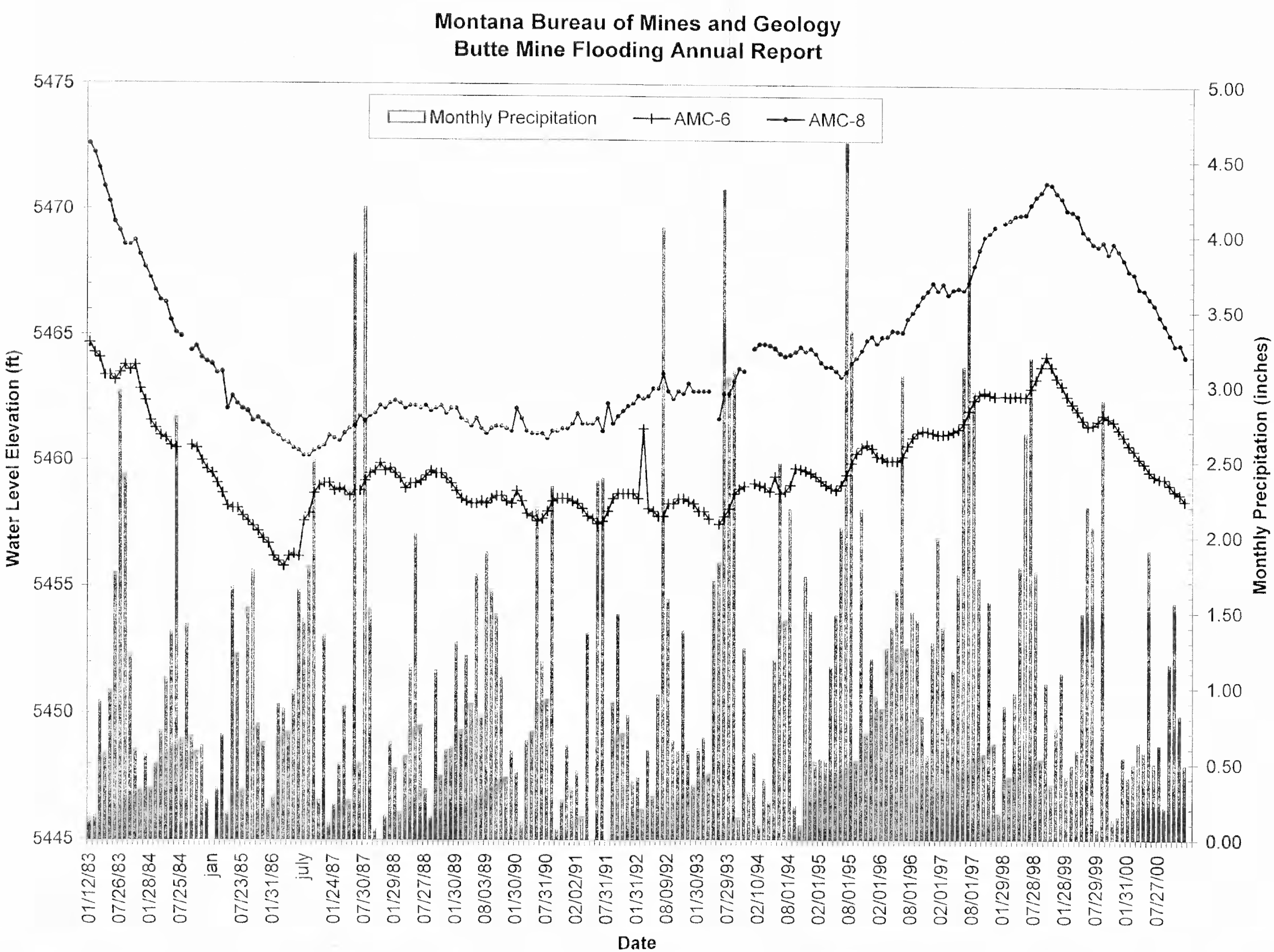


Figure 2-3. Water-level hydrograph for wells AMC-5 and AMC-12.



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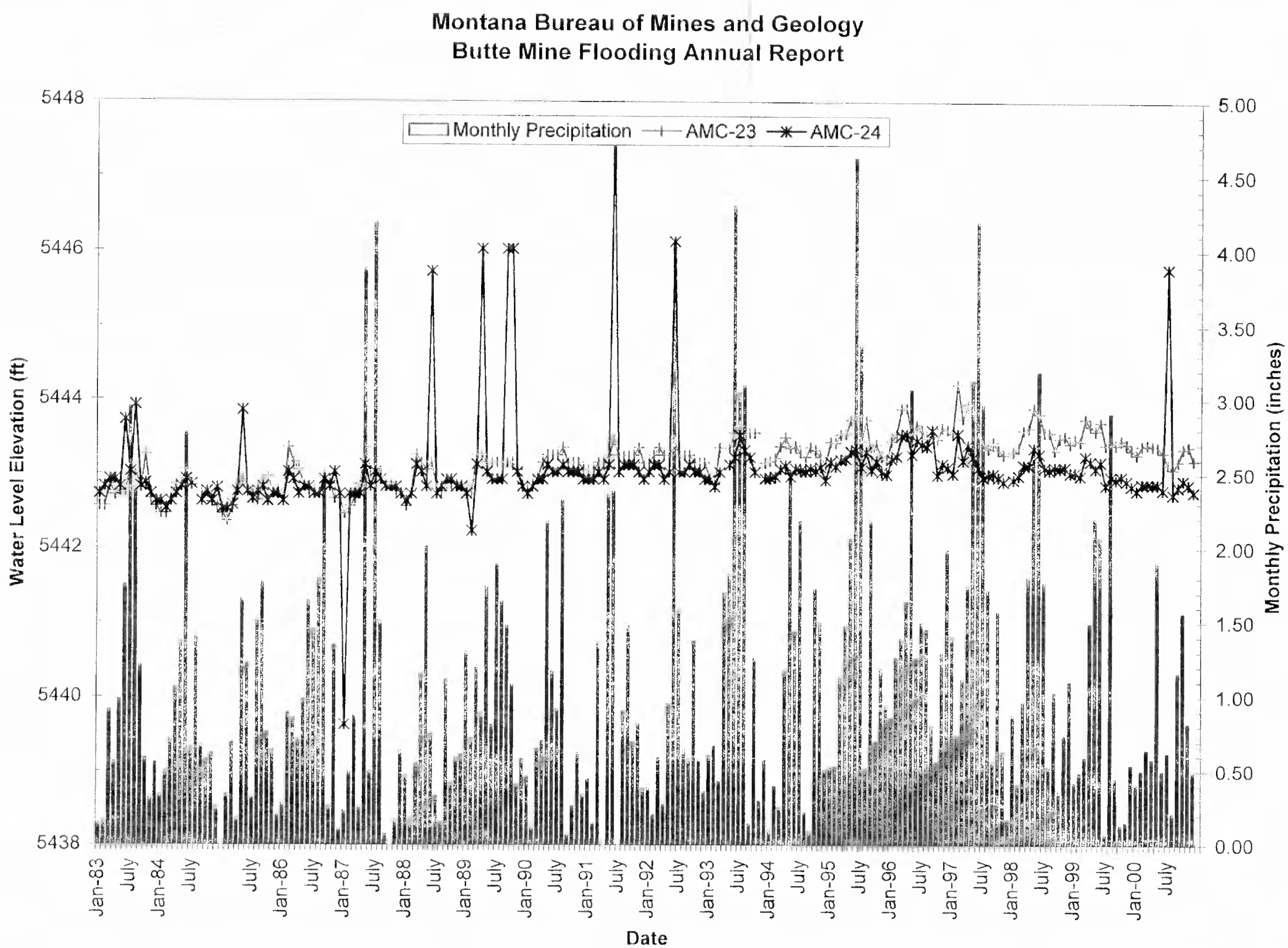

Figure 2-5. Water-level hydrograph for wells AMC-23 and AMC-24.

Section 2.1.2 LP Wells

The locations of the LP–series monitoring wells are shown on figure 2-6. Monthly water-level monitoring of the LP–series wells continued. Table 2.1.2.1 contains a summary of annual water-level changes for these 17 sites. Water levels declined in all 17 wells during 2000. Monitoring data through 2000 indicated that water levels in wells (LP-1 through LP-09) located to the north of the Pittsmont Waste Dump continued to decline more rapidly than in wells to the east and south of the Pittsmont Dump. Some of these declines were much greater than in previous years, most notably those at wells at LP-01, LP-02, LP-04, LP-08, and LP-09.

The water level decline in well LP-07 is greater than that shown in Table 2.1.2.1, as the well has been dry since approximately March 2000. The water level measured in this well for several months was actually standing water in the well bottom, as the level had dropped below the well's screened interval. Only one well has a net rise in water level since monitoring began in 1991, that being well LP-14. As discussed in MBMG OFR-376, these wells were installed in 1991 as part of the BMFOU RI/FS study.

Table 2.1.2.1 Annual Water Level Change in LP Wells

Year	LP-01	LP-02	LP-03	LP-04	LP-05	LP-06	LP-07	LP-08	LP-09
1991	1.23	-0.91	-2.02	1.38	4.35	-0.46	-	-	-0.70
1992	-1.14	-1.56	-0.66	-1.75	-1.08	0.80	-3.79	-3.78	-7.16
1993	-0.91	-1.69	1.84	-1.69	-2.42	-0.53	-3.06	-4.83	-2.24
1994	-0.53	-0.80	-1.61	-0.57	-1.42	-2.28	-1.03	-2.11	-2.90
1995	-0.08	-0.19	-1.74	2.94	0.34	0.47	4.91	4.30	3.35
1996	-2.05	-2.00	-0.73	-1.28	-3.40	2.01	-4.30	-1.14	-1.49
1997	-1.58	-1.86	-0.09	-1.73	-3.32	-1.37	-2.24	-2.63	-0.29
1998	0.12	0.23	-2.03	1.01	-0.03	-0.58	2.44	0.99	1.60
1999	-2.24	-1.76	-7.44	-2.64	-3.15	-1.65	-6.47	-3.52	-3.77
2000	-7.55	-7.16	-5.45	-10.83	-7.87	-0.96	-3.10	-14.03	-13.28
Net Change	**-14.73**	**-17.70**	**-19.93**	**-15.16**	**-18.00**	**-4.55**	**-16.64**	**-26.88**	**-26.88**

Year	LP-10	LP-11	LP-12	LP-13	LP-14	LP-15	LP-16	LP-17
1991	-	-	-	-	-	-	-	-
1992	-0.50	-1.83	0.31	-0.07	0.70	0.54	0.89	-
1993	-0.83	-2.78	1.42	1.11	1.18	1.62	1.83	-
1994	-2.14	1.65	-1.41	-0.47	-0.09	0.26	-1.16	-
1995	-0.57	-0.23	-0.16	0.43	0.18	1.89	3.57	3.10
1996	1.20	0.23	1.87	1.74	2.07	1.79	1.77	1.66
1997	0.23	-0.09	2.42	2.24	2.64	1.99	1.77	2.32
1998	0.92	0.07	1.00	-0.62	0.39	-7.90	-9.69	-2.41
1999	-2.05	-2.12	-2.94	-2.36	-2.73	-4.39	-4.60	-3.95
2000	-1.37	-0.28	-3.60	-2.93	-3.64	-1.73	-2.18	-2.86
Net Change	**-5.11**	**-5.38**	**-1.09**	**-0.93**	**0.70**	**-5.93**	**-7.80**	**-2.14**

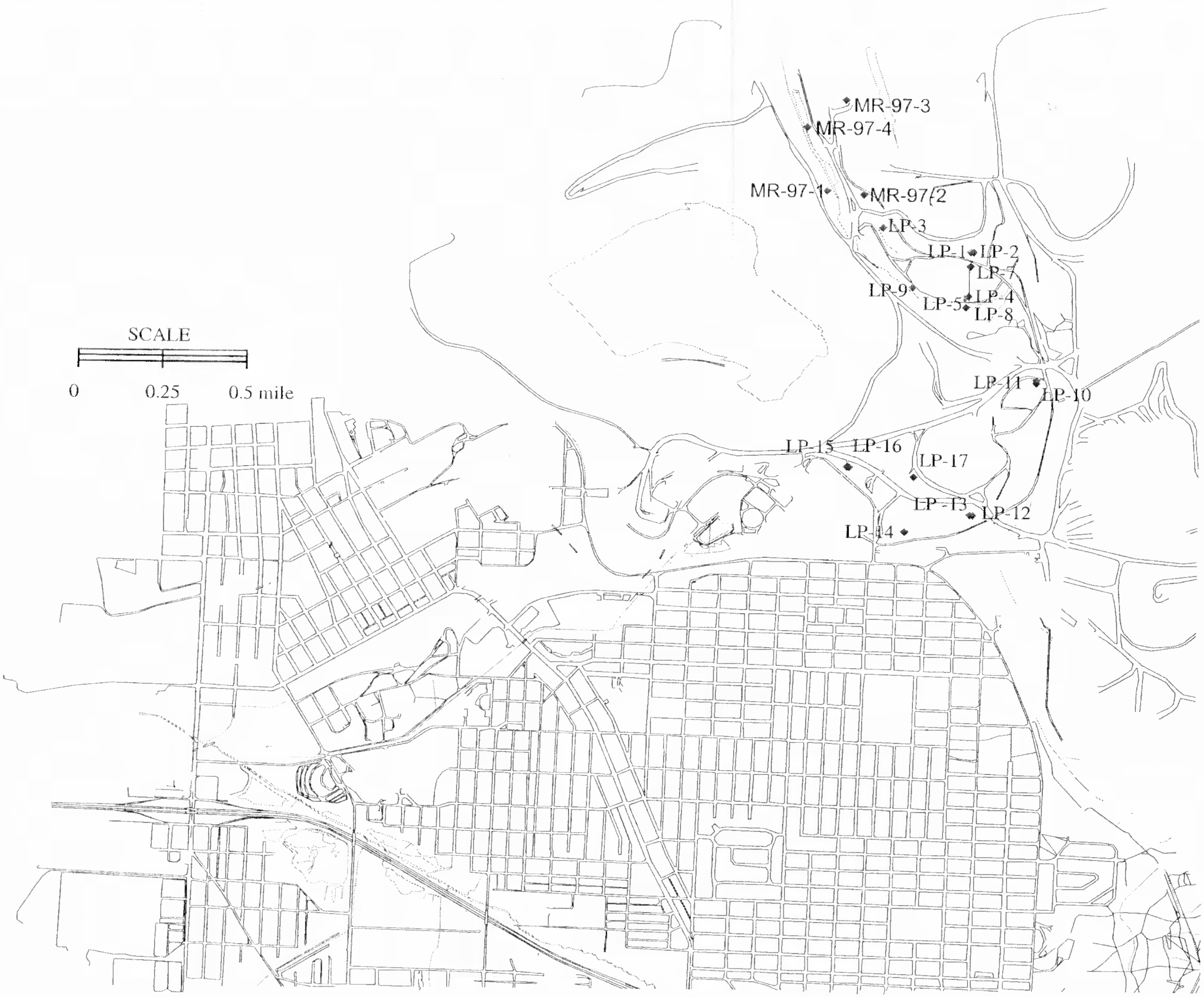

Figure 2-6. LP series and MR97 wells location map.

The steep decline noted in some of these wells in 1999 following MR's deactivation of the leach pads continued throughout 2000. Based upon observed 1999 and 2000 water levels, 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, to precipitation events.

Figures 2-7 through 2-9 show hydrographs from seven representative wells, along with monthly precipitation totals. LP wells 01 and 02 are located to the north of the site near the bases of various leach pads and are screened in two different intervals. Well LP-01 is screened deeper than well LP-02. Both wells are screened at depths of 125 ft and greater and are completed in the deeper portion of the alluvial aquifer. Water- level responses are similar in these two wells (figure 2-7). The downward water-level trend is very evident.

Wells LP-04 and LP-07 are located south of wells LP-01 and LP-02 and north of the Pittsmont Dump, (figure 2-6). These wells are completed at different depths also. Well LP-04 is screened from 125-145 ft below ground surface while well LP-07 is screened from 90-95 ft below ground surface. Based upon these well completion depths, well LP-07 would be considered to be completed in the upper portion of the alluvial aquifer, while well LP-04 would be considered to be completed in the deeper portion of the alluvial aquifer. Water levels declined in a similar manner in these wells throughout 2000 (figure 2-8). There was no noticeable effect of precipitation on water levels in either of these wells. The water level in well LP-07 has dropped below the bottom of this well's casing, meaning the well has gone dry. This occurred about March 2000. Therefore, the total water level decline in this area is not known.

LP wells 14, 15, and 16 are located southwest of the Pittsmont Dump (figure 2-6). A consistent increase in water levels occurred in these wells following their installation in 1992, until the Berkeley Pit landslide of 1998 (figure 2-9). Since that landslide, water levels have continued to decline in a similar nature in all three of these wells. Wells LP-15 and LP-16 are located near one another and were completed as a nested pair, with well LP-15 being screened from a depth of 215-235 ft below ground surface and well LP-16 screened from 100-120 ft below ground surface. Water level declines are similar in both of these wells.

Montana Resources 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 relieve 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 general observation made in last year's report that wells between the leach pads and Pittsmont waste dump were affected by leach pad-operations, including the 1999 leach pad dewatering and historic mine dewatering, remains true. The trend toward lower water levels seen in 1999 continued in 2000 and the rate of decline increased in a number of wells. Water levels in the LP series wells were either controlled by the operation and subsequent dewatering of the leach pads or by the depressed water levels in the Berkeley Pit. The influence of precipitation is minimal at best on any of these wells.

Figure 2-10 is an alluvial aquifer potentiometric map constructed using December 2000 water levels. It shows how alluvial water levels are flowing towards the Berkeley Pit from the north, east and south. Water contaminated by historic mining activities (Metesh, 2000) is flowing towards and into the Berkeley Pit, ensuring that there is no outward migration of contaminated water into the alluvial aquifer outside the mine boundary.

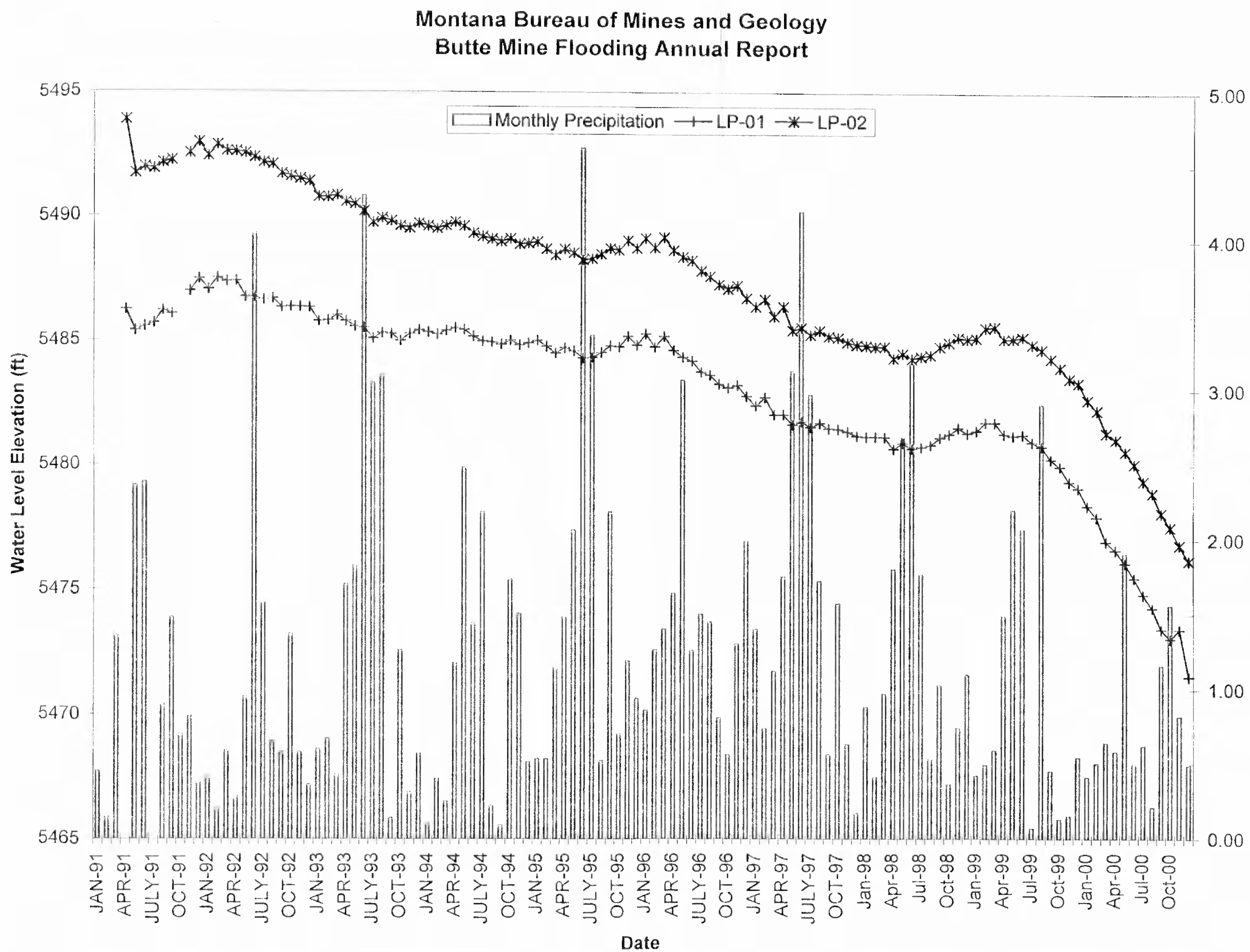

Figure 2-7. Water-level hydrograph for wells LP-01 and LP-02.

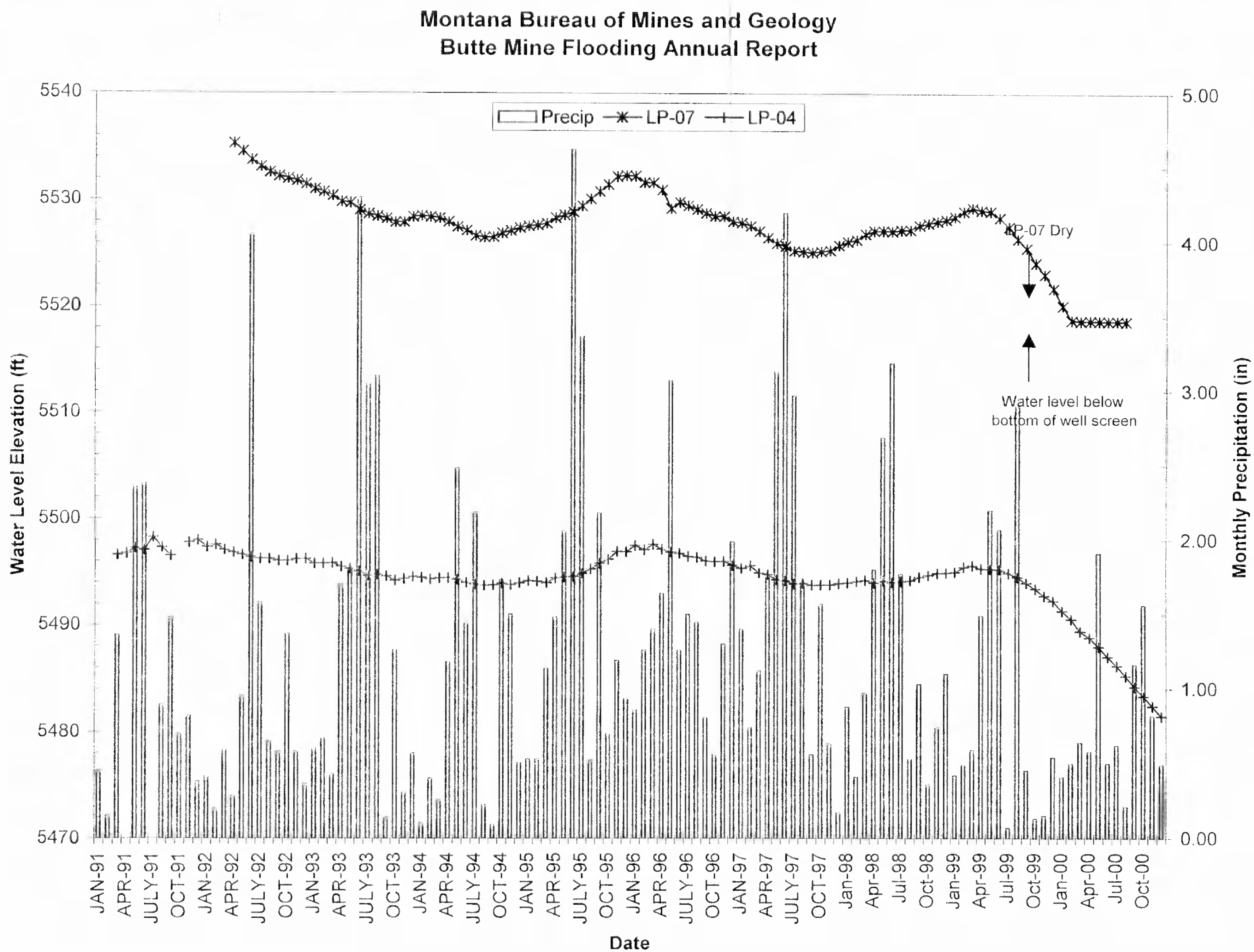

Figure 2-8. Water-level hydrograph for wells LP-04 and LP-07.

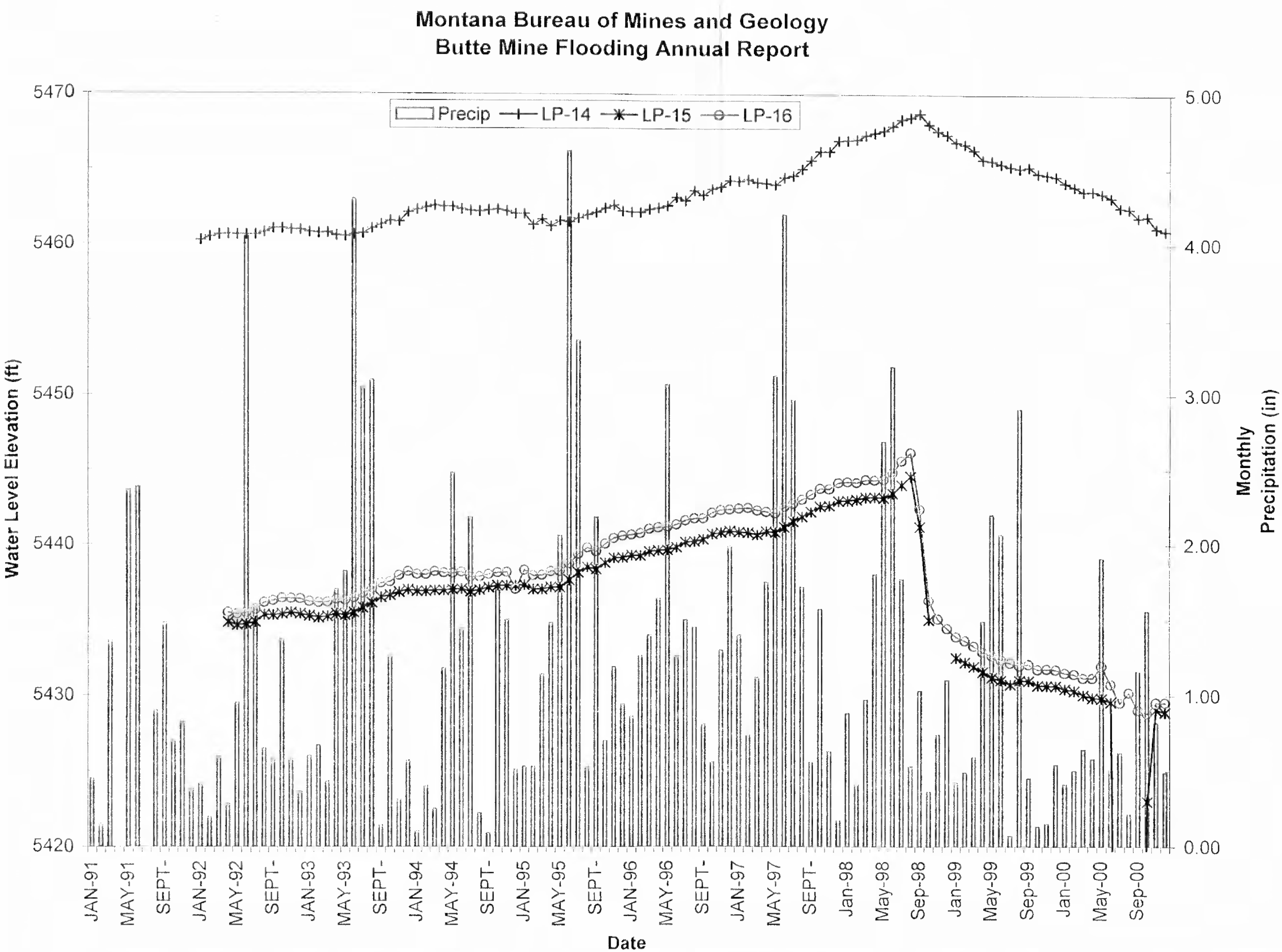

Figure 2-9. Water-level hydrograph for wells LP-14, LP-15, and LP-16.

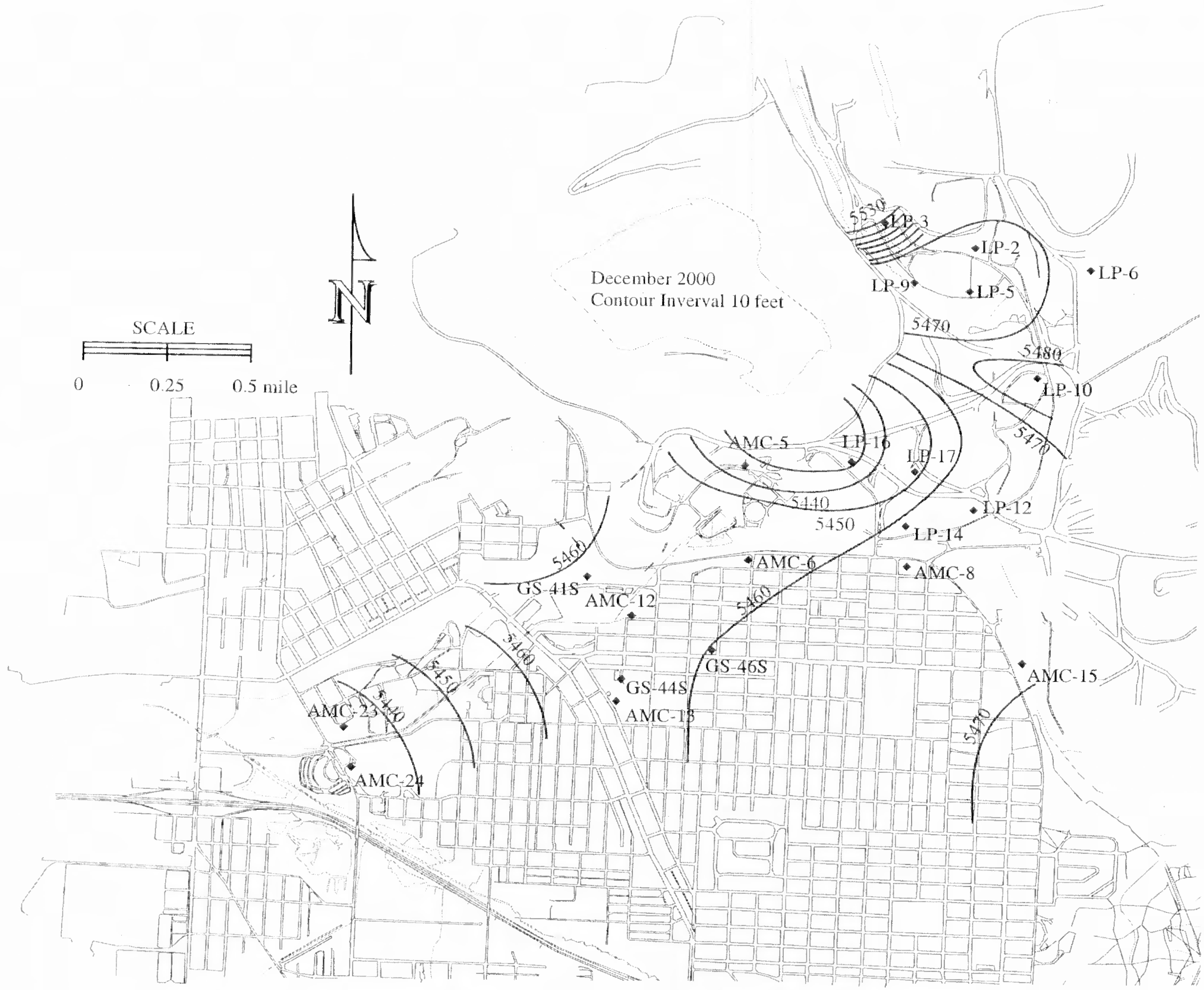

Figure 2-10. Alluvial aquifer potentiometric map for December, 2000

2.1.3 Precipitation Plant Area Wells

Wells MR97-1, MR97-2, MR97-3, and MR97-4 (figure 2-6) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Water-level changes appear to correspond to water levels and/or flow in ditches and ponds. This is especially apparent in the 1999 and 2000 water levels when MR began to make operational changes in leaching operations. As a result, the amount and level of water in collection ditches became less and was reflected in a drop of water levels in wells 97-2 and 97-3, which are adjacent to collection ditches, (figures 2-11 and 2-12). However, variations in water levels occurred in well MR97-1 (figure 2-13), when MR began to discharge water from their Berkeley Pit copper recovery project into the pit using the historic HSB drainage ditch. These variations are characterized by an initial increase in water levels followed by a gradual decline before leveling off. This ditch, which is adjacent to well MR97-1, had been unused since April 1996 when HSB drainage water was captured and prevented from flowing into the pit.

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

The water level in well MR97-3 shows very little, if any, response due to the 2000 suspension of mining. Instead it continued a steady decline from 1999 through 2000. This decline is most likely in response to the deactivation of the leach pad operations. This conclusion is based upon the fact that this well is the closest to the leach pads and several collection ditches. It is also the farthest MR–series well away from the HSB drainage ditch.

Table 2.1.3.1 MR97 wells annual water–level changes

Year	MR97-1	MR97-2	MR97-3	MR97-4
1997	-0.25	-0.84	-0.40	0.35
1998	1.07	-1.04	-0.67	2.20
1999	-0.27	-4.40	-3.91	0.02
2000	-0.20	-0.89	-2.88	-0.03
Net Change	0.35	-7.17	-7.86	2.54

Water levels have declined more than 7 ft in the two wells nearest the leach pads and ancillary facilities since their installation in 1997 (table 2.1.3.1), while having a net increase in the two wells nearest the precipitation plant and HSB drainage ditch. It appears there is a direct influence on the shallow alluvial aquifer in this area from the operations associated with mining operations. Changes in mine operations affect ground-water recharge in this area.

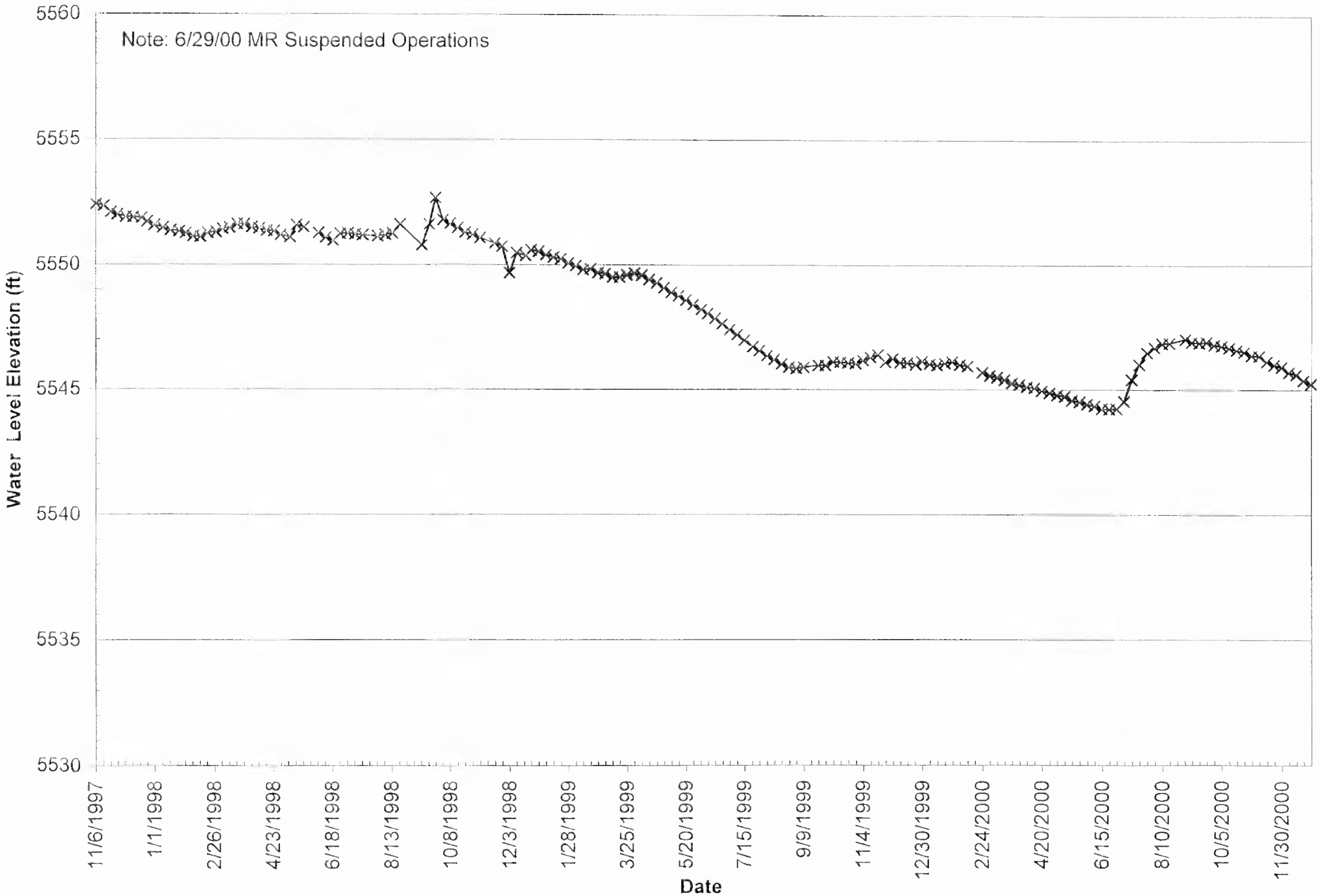

Figure 2-11. Water-level hydrograph for well MR97-2.

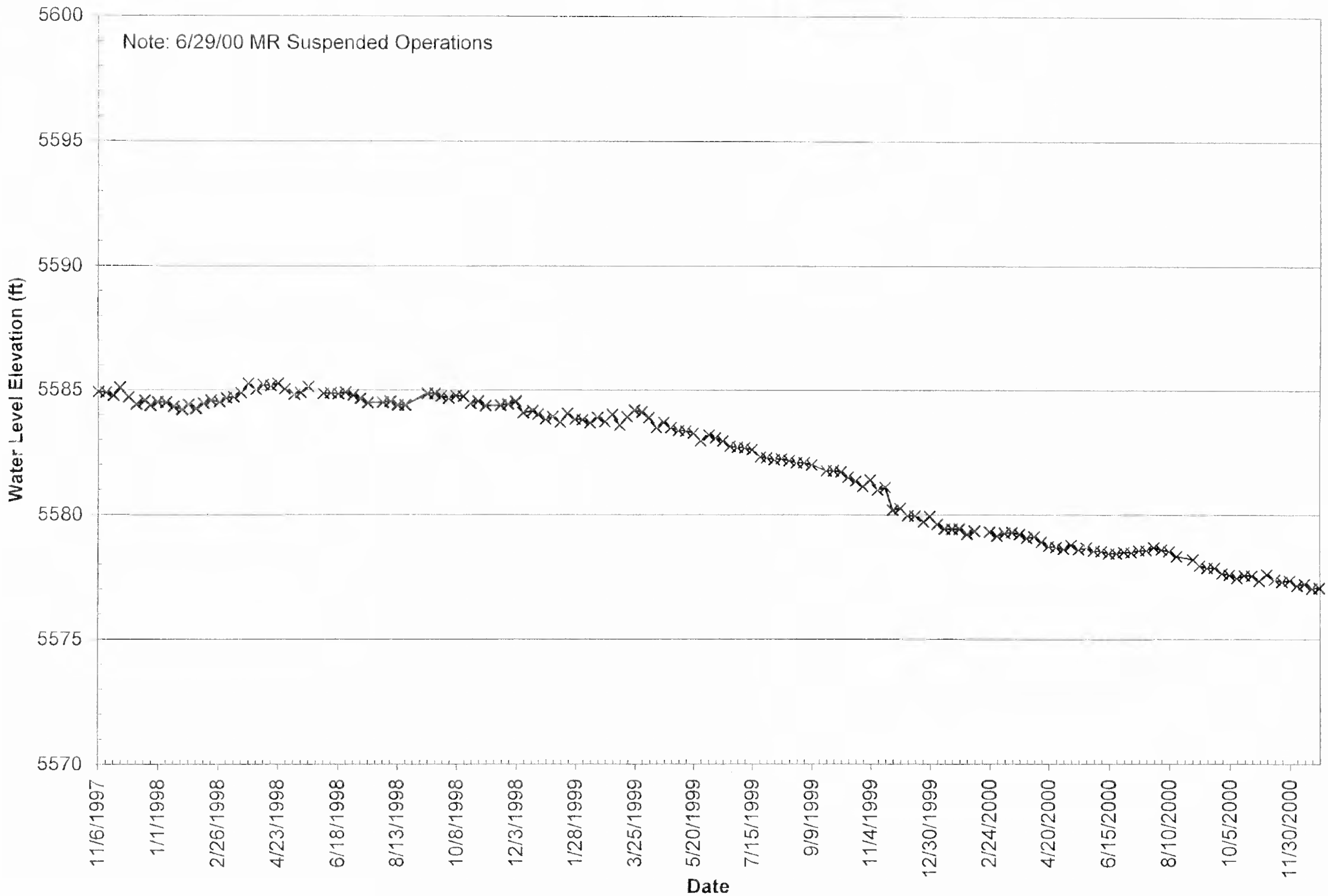

Figure 2-12. Water-level hydrograph for well MR97-3.

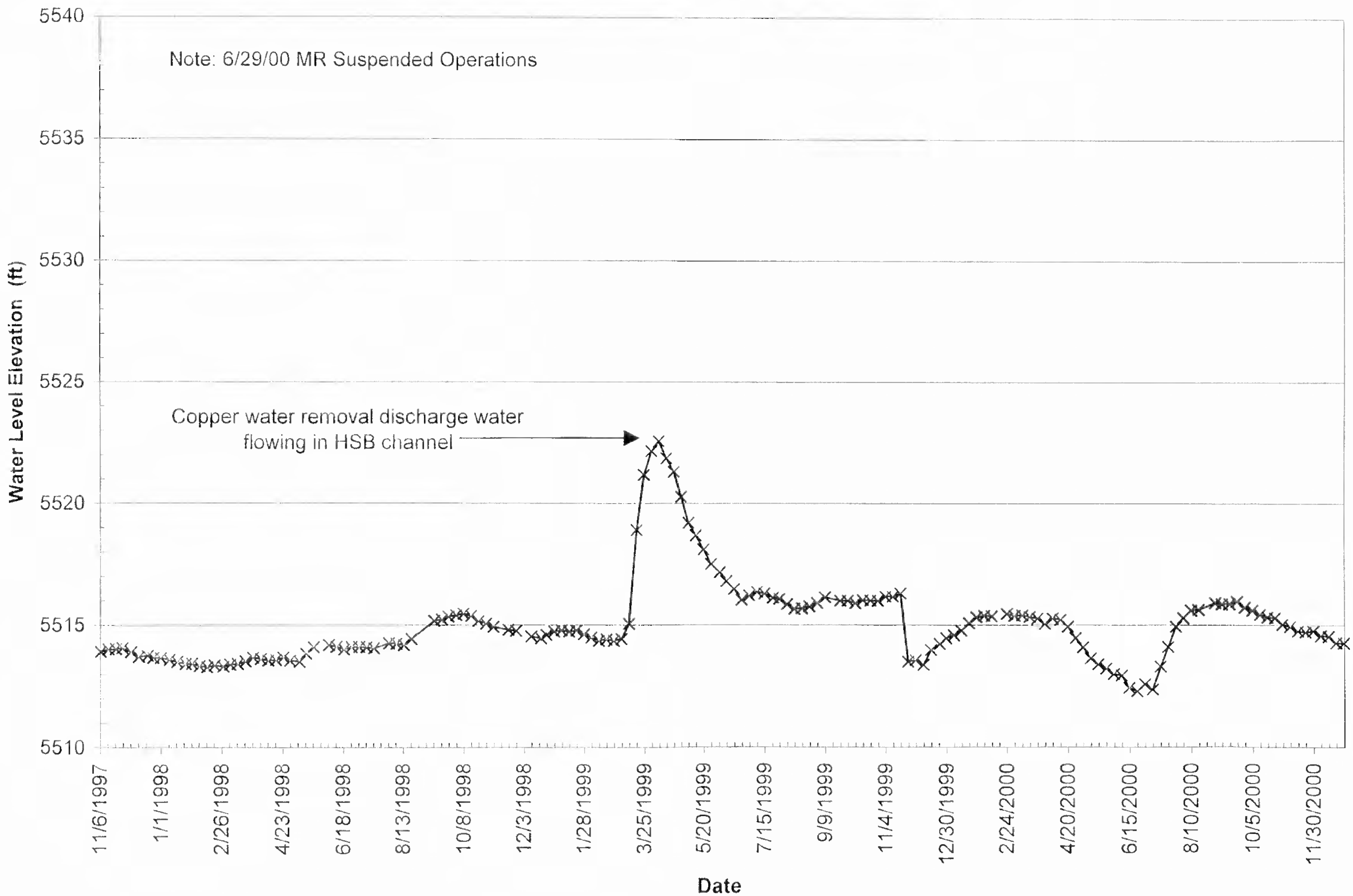

Figure 2-13. Water-level hydrograph for well MR97-1.

2.1.4 GS Series Wells

Continuous and monthly water level monitoring of the 6 GS wells continued throughout 2000. The location of these wells is shown on figure 2-14. Table 2.1.4.1 contains annual water level changes for these wells. The S and D identify the shallow and deep wells in each nested well pair. Wells GS-41 and GS-44 are paired, while wells GS-46S and GS-46D are 1000 ft apart; however, they are considered to be a nested pair.

Figures 2-15 through 2-17 are well hydrographs with monthly precipitation totals shown for the well series GS-41, GS-44, and GS-46. The seasonal rise and fall in water levels closely follow monthly precipitation trends. Water levels begin a gradual increase in the spring as precipitation increases. There is a 2 to 3 month lag (delay) between peak rainfall and peak water levels.

Table 2.1.4.1 Annual GS Wells Water-Level Change

Year	GS-41S	GS-41D	GS-44S	GS-44D	GS-46S	GS-46D
1993	0.76	0.78	0.62	0.66	0.80	0.78
1994	0.20	0.23	0.00	0.00	0.18	0.24
1995	1.35	1.29	1.32	1.26	1.38	1.30
1996	0.59	1.65	1.12	0.89	0.98	1.20
1997	1.32	0.20	0.58	0.79	1.09	1.18
1998	-0.18	-0.06	0.09	0.07	1.17	0.24
1999	-1.41	-1.49	-1.28	-1.25	-2.41	-1.65
2000	-1.91	-1.78	-1.51	-1.39	-1.21	-2.07
Net Change	**0.72**	**0.82**	**0.94**	**1.03**	**1.98**	**1.22**

Water-level changes in wells GS-41S and GS-41D were similar once again during 2000. Water levels continued their steep decline that began following the September 1998 Berkeley Pit landslide (figure 2-15). The influence of precipitation was limited. Water levels declined over 1.75 ft in these two wells during 2000.

Wells GS-44S and GS-44D had similar water level changes throughout 2000, (figure 2-16). The rise and fall of seasonal water levels are similar to that described for wells GS-41S and 41D. However, these wells showed a greater response to spring precipitation events than the GS-41 series wells. The trend noted above for the GS-41 wells from October 1998 through 2000 was observed in these wells also. The water level decline for 2000 was greater than 1.3 ft.

Figure 2-14 GS wells location map

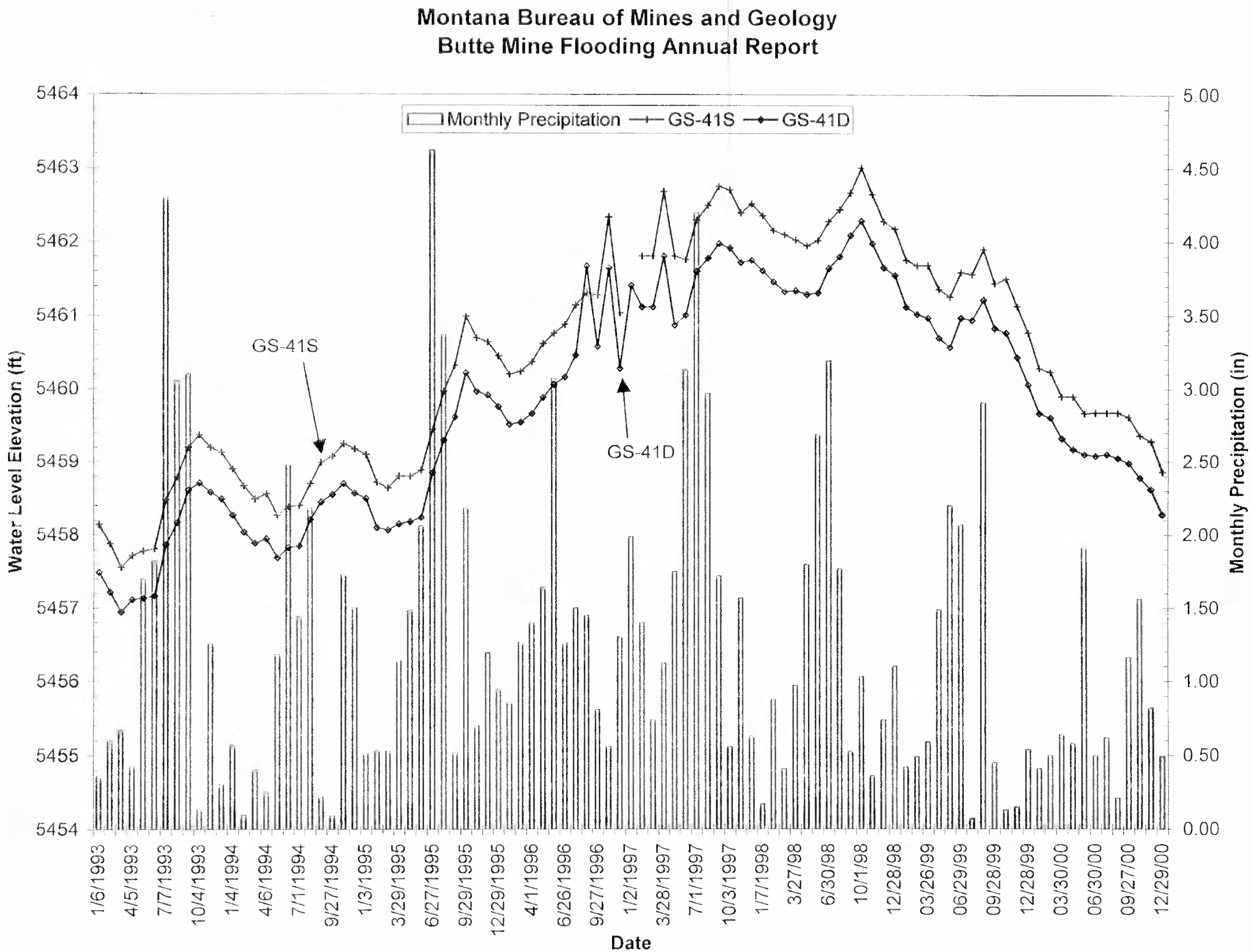

Figure 2-15. Water-level hydrograph for wells GS-41S and GS-41D.

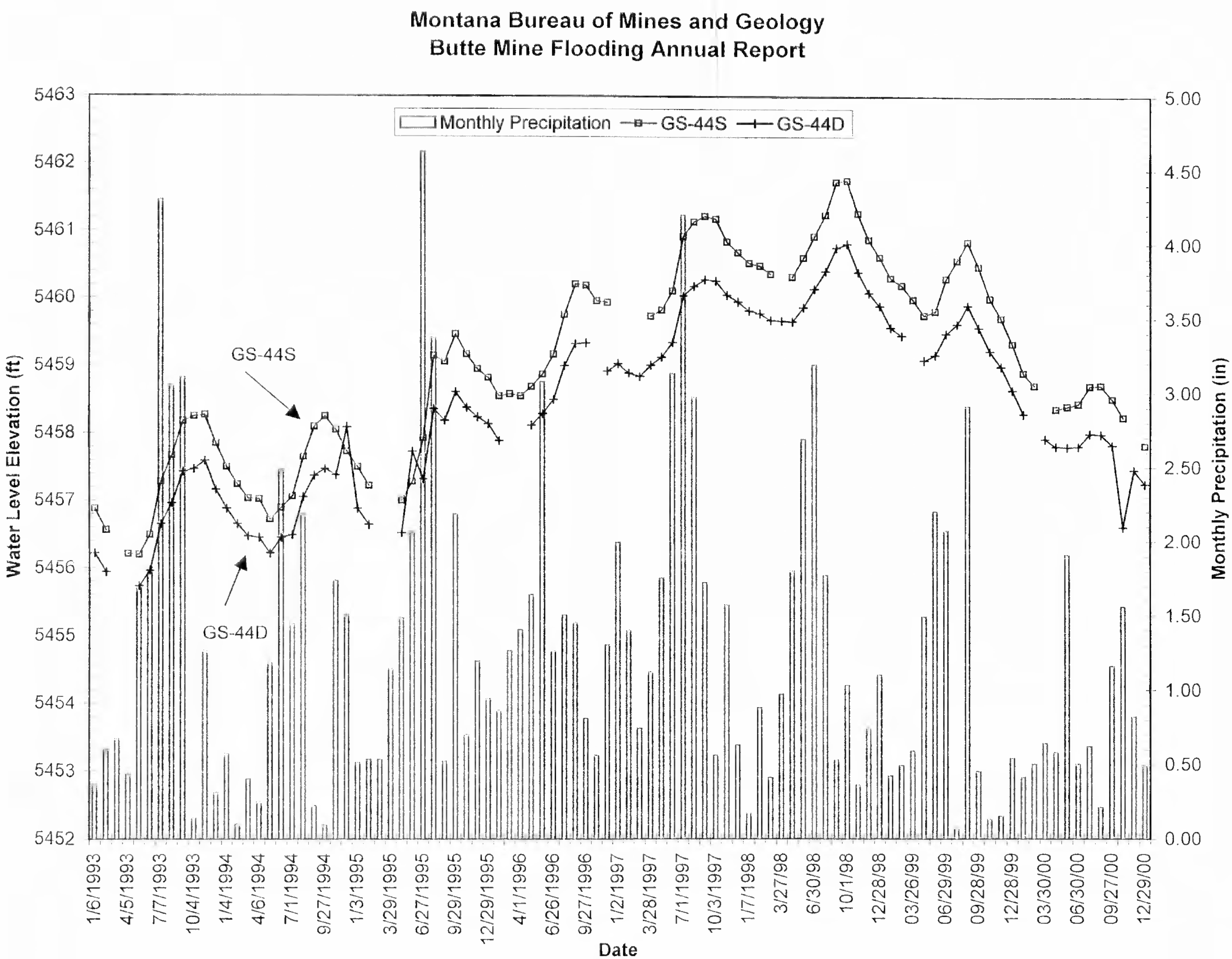

Figure 2-16. Water-level hydrograph for wells GS-44S and GS-44D.

Overall, water-level trends were similar during 2000 in wells GS-46S and GS-46D (figure 2-17), and followed the trends discussed previously for well series GS-41 and GS-44. Water levels declined from 1.21 ft in well GS-46S to 2.07 ft in well GS-46D during 2000. Total water-level increases in these two wells since 1993 are less than 2 ft. The seasonal trends are the same as those in the other GS series wells.

In both the GS-41 and GS-44 series 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 infers that water had the potential to move upwards in the aquifer and possibly discharge into a surface water body, such as Silver Bow Creek. However, the distance between these two wells makes it difficult to say with any certainty there is an upward gradient.

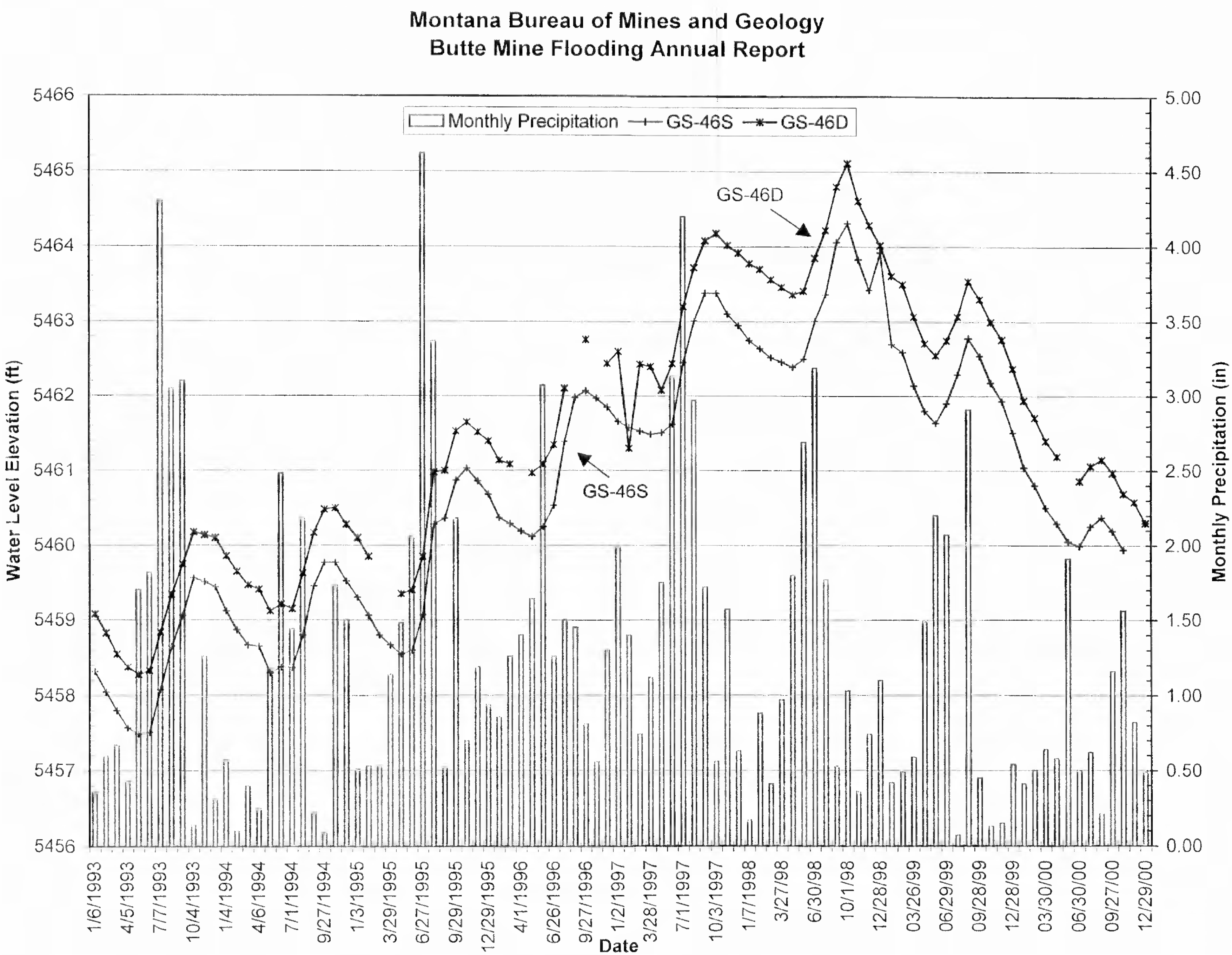

Figure 2-17. Water-level hydrograph for wells GS-46S and GS-46D.

2.1.5 Domestic Well Monitoring

Monitoring continued in the 14 domestic wells for the fourth year. The locations of these wells are shown on figure 2-18. Table 2.1.5.1 contains water-level summary data for these wells.

Table 2.1.5.1 Annual-water-level change and net change for domestic wells

Map Well ID	WL Change (ft) 1993-12/1997	WL Change (ft) 1998	WL Change (ft) 1999	WL Change (ft) 2000	Total WL Change (ft)
93-1					No Access
93-20	5.95	0.00	-1.81	0.02	4.16
93-22	6.35	0.24	-1.79	0.26	5.06
93-35					No Access
93-25	5.80	0.36	-1.55	-0.12	4.49
93-26	5.28	-0.01	-2.44	0.84	3.67
93-27					No Access
93-23	4.88	-0.06	-1.96	0.70	3.56
93-24	5.37	0.04	-1.65	-22.56*	-18.80
93-2	3.45	1.14	-2.43	-0.04	2.12
93-118	1.66	---	---	---	1.66
93-4	0.58	0.01	-0.03	-0.01	0.55
93-7	-0.04	-0.11	-0.41	-0.46	-1.02
93-8	-0.35	-0.05	-0.43	-0.49	-1.36
93-9	-1.08	-0.03	-0.34	0.17	-1.28
93-10	-0.21	0.04	-0.48	0.37	-1.02
93-12	1.58	-5.02	4.74	-0.06	-1.92
93-94					No Access
93-100					No Access
93-84					No Access
93-89					No Access
'MPC	-0.07	0.14	-0.13	-0.04	-0.10

* December water-level measured while pump was operating.

Water level changes were less than 1/2 (0.5) ft in 11 of the 14 monitored wells during 2000. The exceptions were wells 93-26, which had a rise of 0.84 ft, well 93-23, which had a rise of 0.70 ft, and well 93-24, which declined over 22.5 ft, based upon year-end measurements. It appears that the December 2000 water level in well 93-24 was measured either while the pump was operating or had been recently operated. If the November 2000 water level were used for this well's year-end measurement, its 2000 change would have been a rise of only 0.05 ft.

Figure 2-18. Domestic well location map.

The effects of precipitation are noticeable in wells 93-20, 22, 25, and 26 (figures 2-19 and 2-20). Water levels began to rise in the spring, one to two months after precipitation increased. They continued to rise through the fall before leveling off and falling during the winter. Water-level trends are very similar in each of these figures.

Total water-level changes vary from a decline of 1.92 ft to a rise of 5.06 ft, at wells 93-12 and 93-22 (excluding well 93-24). Similar to previous years, water levels have a net increase in wells to the east of Harrison Avenue and a decrease in areas west of Harrison Avenue. Figures 2-19 and 2-20 are hydrographs of domestic monitoring wells to the east of Harrison Avenue. The seasonal water-level changes are remarkably similar to those seen in other alluvial monitoring wells. Minimum water levels occur in early spring and maximum water levels occur in the late summer or early fall. No affects of the September 1998, Berkeley Pit landslide were seen in any of the domestic wells.

Figures 2-21 and 2-22 are hydrographs of selected domestic monitoring wells west of Harrison Avenue. One change was seen in these wells during 2000, that being at well 93-9 which had a water-level increase for 2000. The water level had declined in this well during the three previous years. The seasonal trends are similar to the other alluvial water levels, however, just not as pronounced

Based upon 4 years of data there are several things apparent from these figures. There is a delay (lag) period between precipitation increases and well responses south of the pit and east of Harrison Avenue. This is similar to trends seen in the GS series wells. Wells located east of Harrison Avenue have had a net water-level increase of several feet or more from 1993 through 2000, while water levels have a net decline between 0.1 and 2 ft west of Harrison Avenue.

Water-level response to increased precipitation in wells west of Harrison Avenue is nearly immediate. Increases in water levels are seen in the month precipitation levels increase, or the following month, and are short lived, with levels dropping the next month if precipitation levels decrease. These responses are similar to those noted earlier for wells AMC-23 and AMC-24.

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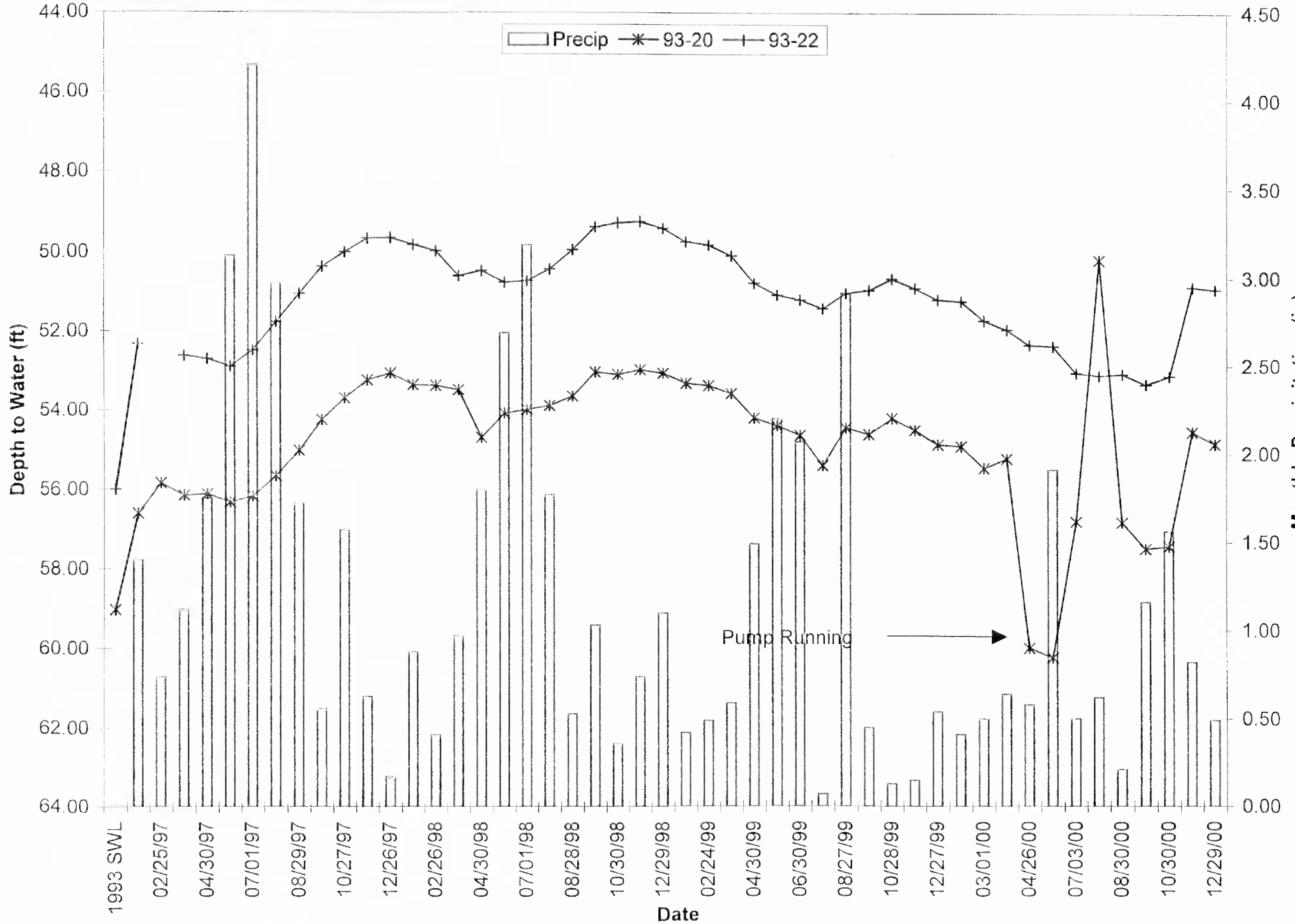

Figure 2-19. Water-level hydrograph for domestic wells 93-20 and 93-22.

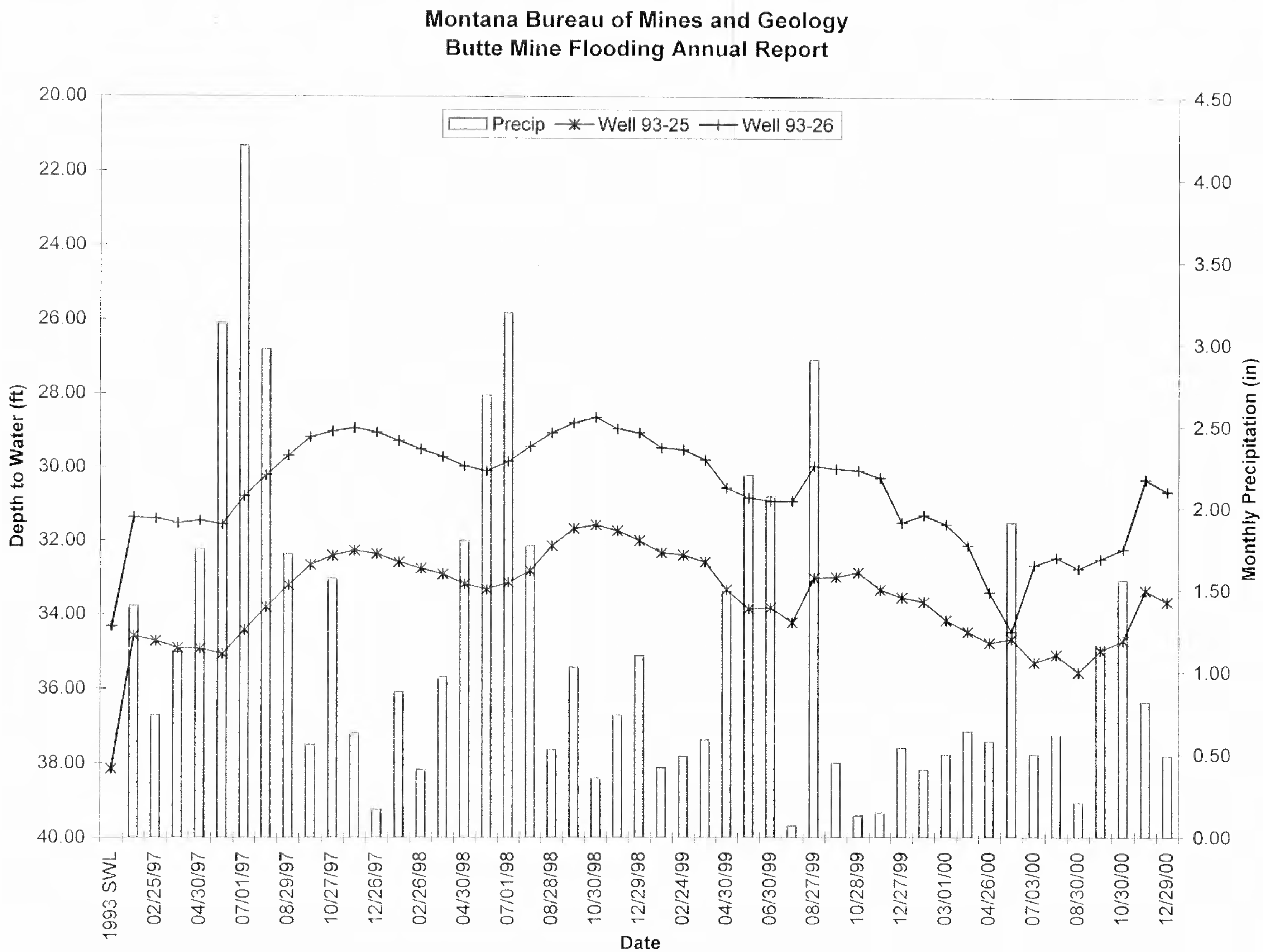

Figure 2-20. Water-level hydrograph for domestic wells 93-25 and 93-26.

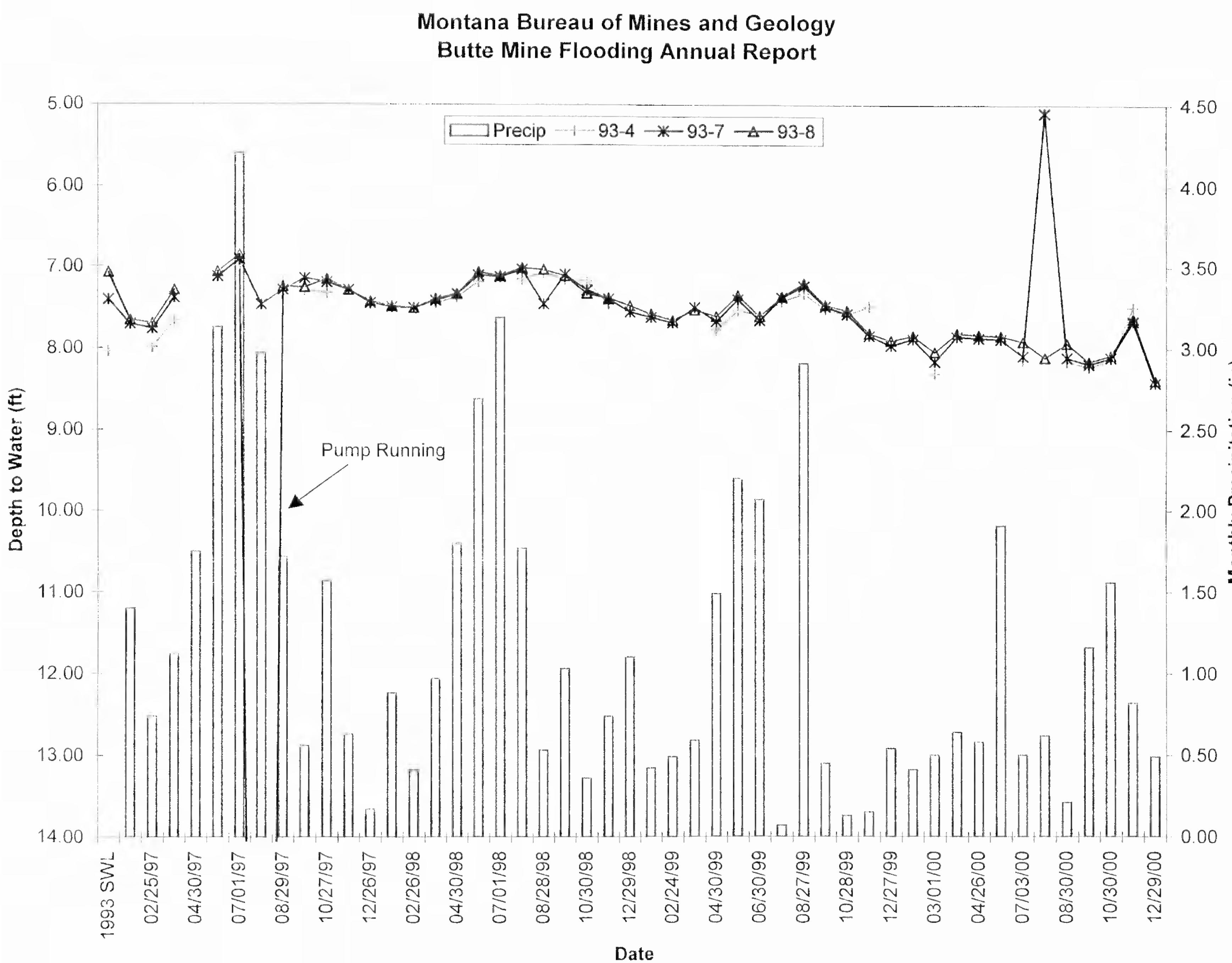

Figure 2-21. Water-level hydrograph for domestic wells 93-4, 93-7 and 93-8.

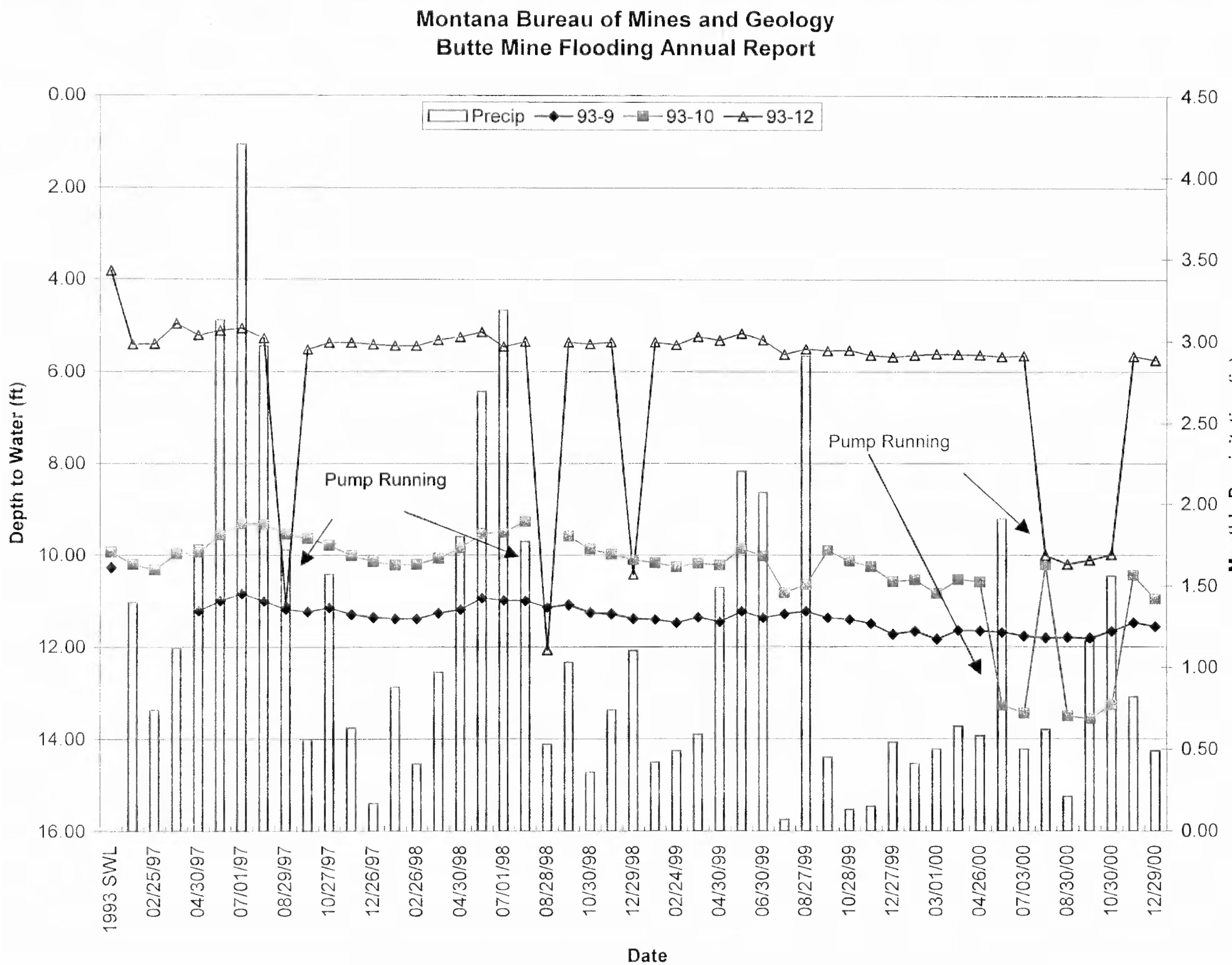

Figure 2-22. Water-level hydrograph for domestic wells 93-9, 93-10, and 93-12.

2.2 East Camp Underground Mines

Monitoring of water levels in the seven East Camp underground mines continued. Their locations are shown on figure 2-23. During the year 2000, water levels rose between 14 and 16 ft in the mines, while the Berkeley Pit water level raised 16.97-ft, Table 2.2.1. Figure 2-24 shows the annual water level changes graphically.

Table 2.2.1 Annual East Camp mine water-level change

Year	BERKELEY PIT	ANSELMO	KELLEY	BELMONT	STEWARD	GRANITE MOUNTAIN	LEXINGTON	PILOT BUTTE
1982			1304.00	117.00	85.00			
1983			877.00	1054.00	1070.00			
1984			262.00	269.00	274.00			
1985			122.00	121.00	123.00			
1986		56.00	96.00	102.00	101.00			
1987		77.00	84.00	77.00	79.00	67.00		
1988		53.00	56.00	53.00	52.00	57.00	8.10	
1989		29.00	31.00	31.00	29.00	31.00		
1990		32.00	33.00	34.00	33.00	34.00		
1991	12.00	29.00	33.00	30.00	29.00	31.00		
**Total 10 Year Change*	*12*	*276*	*2898*	*1888*	*1875*	*220*	*8.10*	
1992	25.00	22.00	24.00	24.00	23.00	25.00		
1993	26.00	24.00	25.00	26.00	25.00	26.00		
1994	27.00	25.00	26.00	25.00	25.00	27.00		
1995	29.00	28.00	27.00	18.00	28.00	30.00		
1996	18.00	16.00	19.00	4.15	18.00	18.00	1.19	3.07
1997	12.00	13.58	16.09	15.62	14.80	15.68	12.79	18.12
1998	17.08	13.23	14.73	13.89	14.33	14.24	13.71	11.26
1999	12.53	11.07	11.52	12.15	11.82	11.89	10.65	11.61
2000	16.97	14.48	14.55	15.66	14.60	15.09	14.01	14.11
***Total Change**	**196**	**443**	**3074**	**2041**	**2050**	**403**	**60**	**58**

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

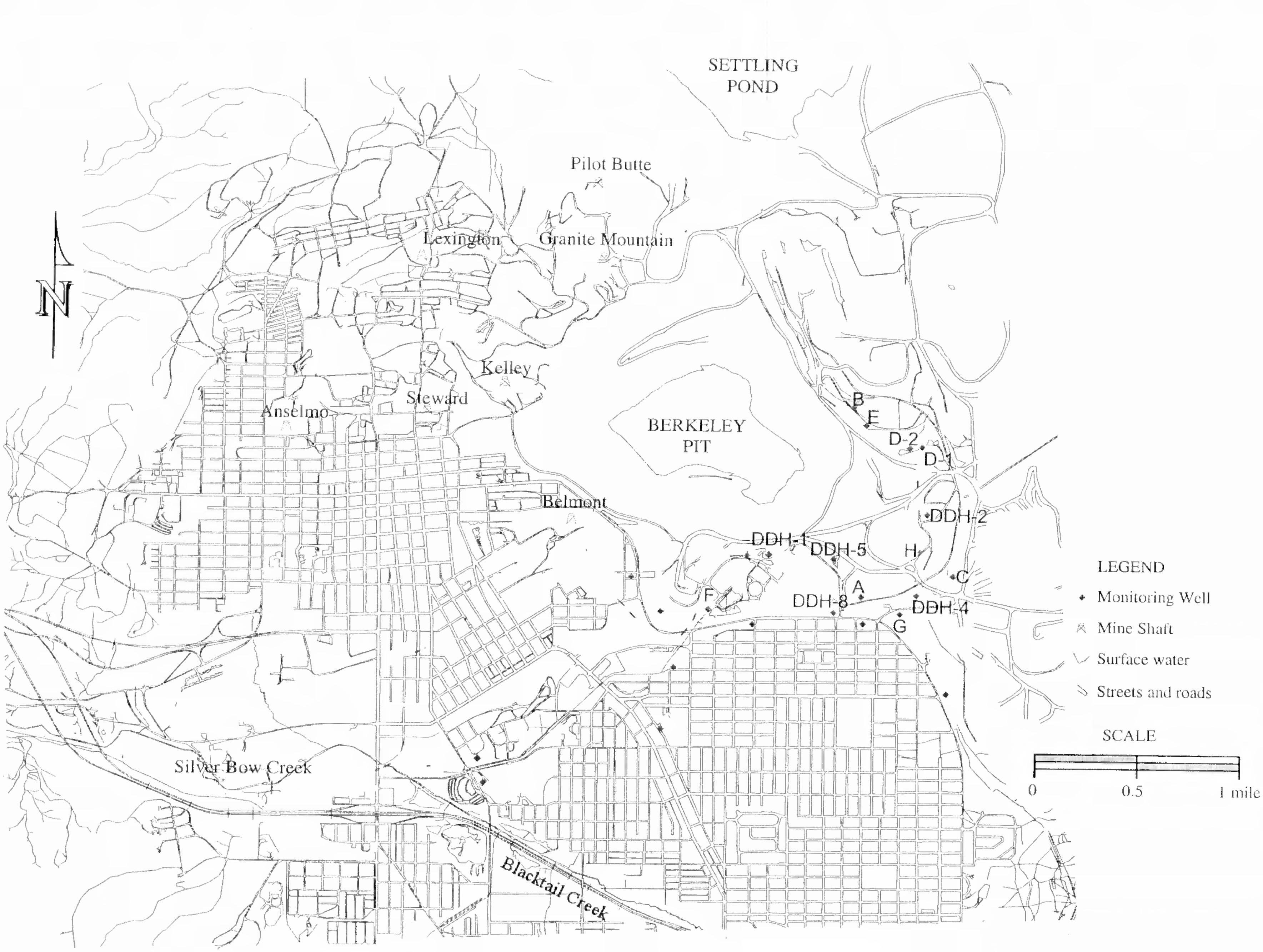

Figure 2-23. East Camp mines and RI/FS bedrock wells location map.

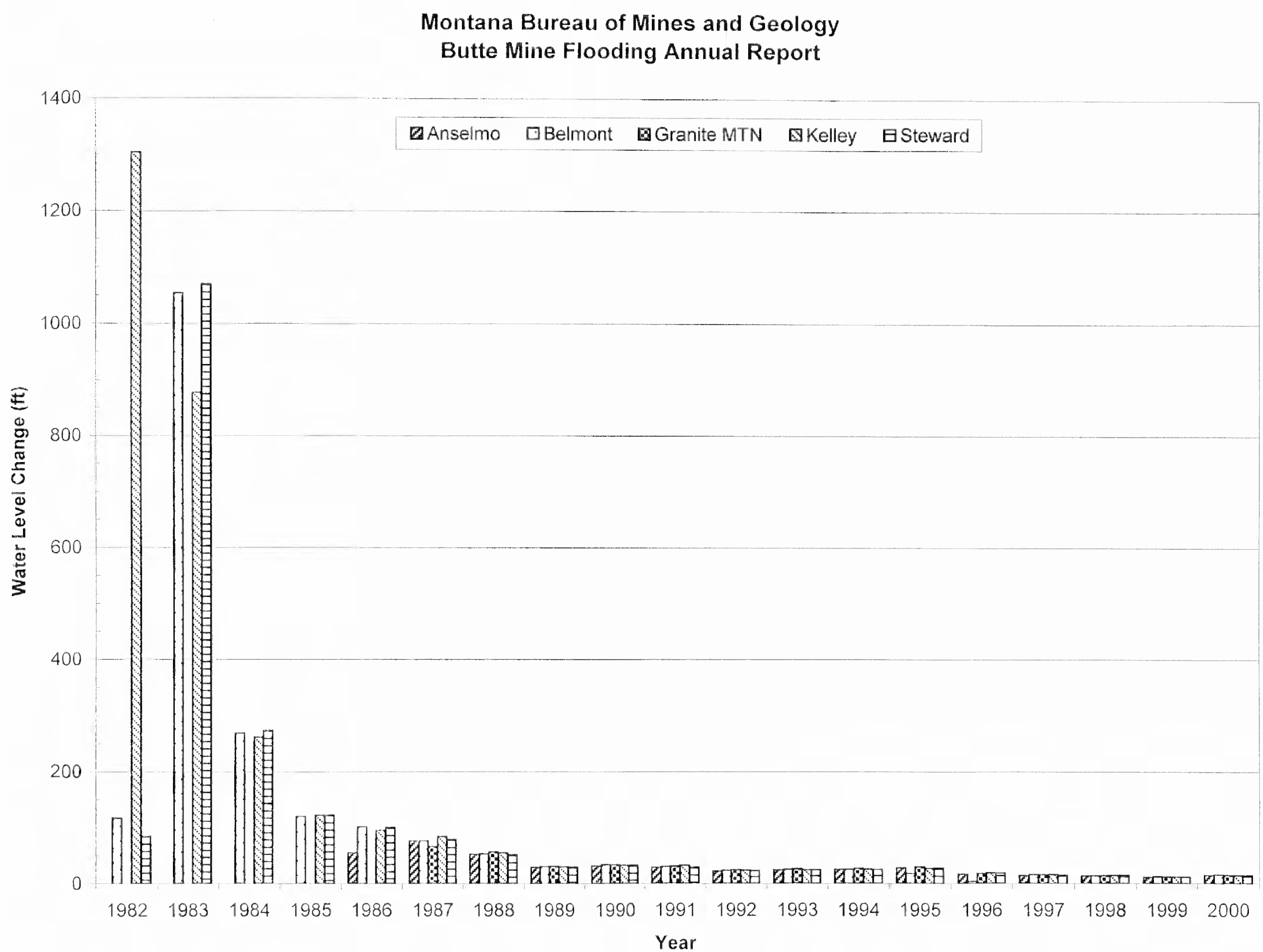

Figure 2-24. East Camp mines annual water-level changes.

Figure 2-25 is a hydrograph based upon water levels for the Anselmo Mine and Kelley Mine. There is no obvious change in water levels on this figure; however, changes are noticeable during the last 6 months of 2000 on a hydrograph based on water levels from 1995 through 2000 (figure 2-26). The addition of HSB drainage water into the pit is responsible for this change. Figure 2-27 shows monthly water-level changes in the Berkeley Pit during 2000. Water-level changes the last 6 months of 2000 were twice those of the first 6 months. A similar trend was seen in all the East Camp underground mines. Water levels remain the highest in the sites farthest from the Berkeley Pit. This continues to confirm that water is flowing towards the pit, thus keeping the pit the low point in this system.

Figure 2-28 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.

Water levels appear to have continued to rise in a similar trend. However, a hydrograph prepared using water levels from 1995 through 2000 shows both the 1996 and 2000 HSB operational changes (figure 2-26). The April 1996 diversion of HSB water is responsible for the flattening of the rise, while the 2000 addition of HSB is responsible for the increased rate of rise. This same trend is seen in the Berkeley Pit water-level rise (figure 2-27). The 1998 Berkeley Pit landslide is also noticeable on this figure.

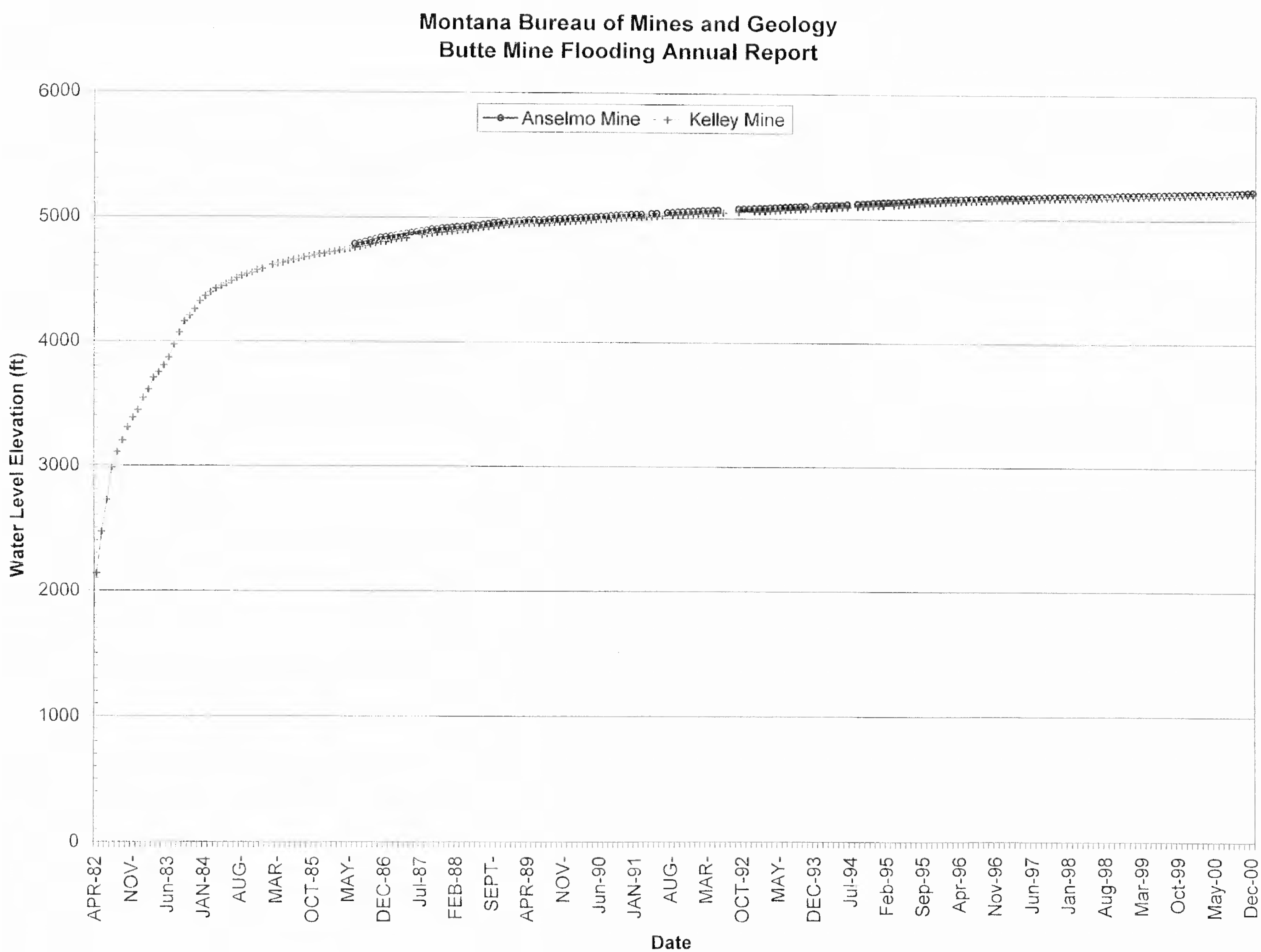

Figure 2-25. Water-level hydrographs for the Anselmo Mine and Kelley Mine.

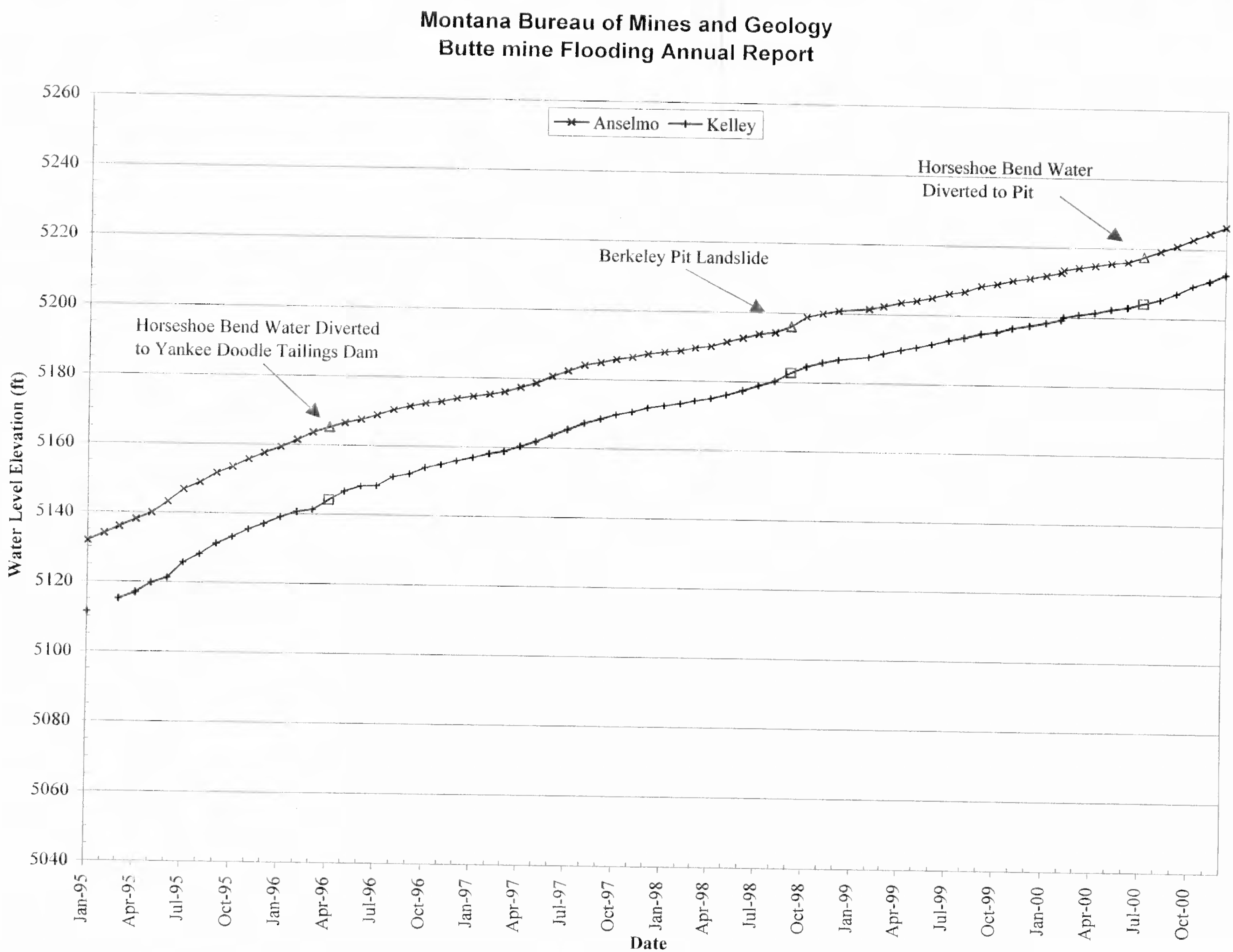

Figure 2-26. Water-level hydrograph, 1995-2000, Anselmo Mine and Kelley Mine.

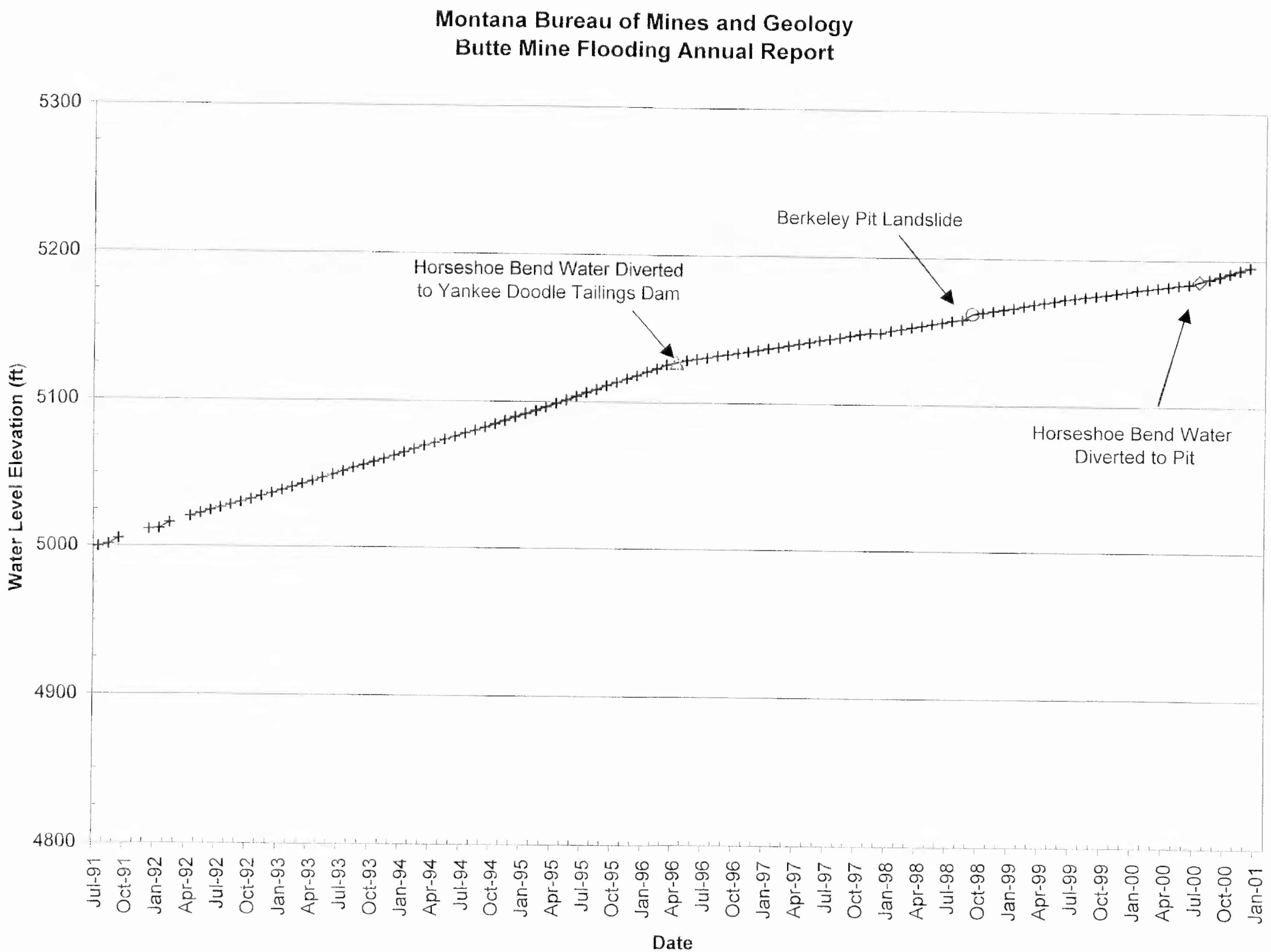

Figure 2-27. Water-level hydrograph for the Berkeley Pit.

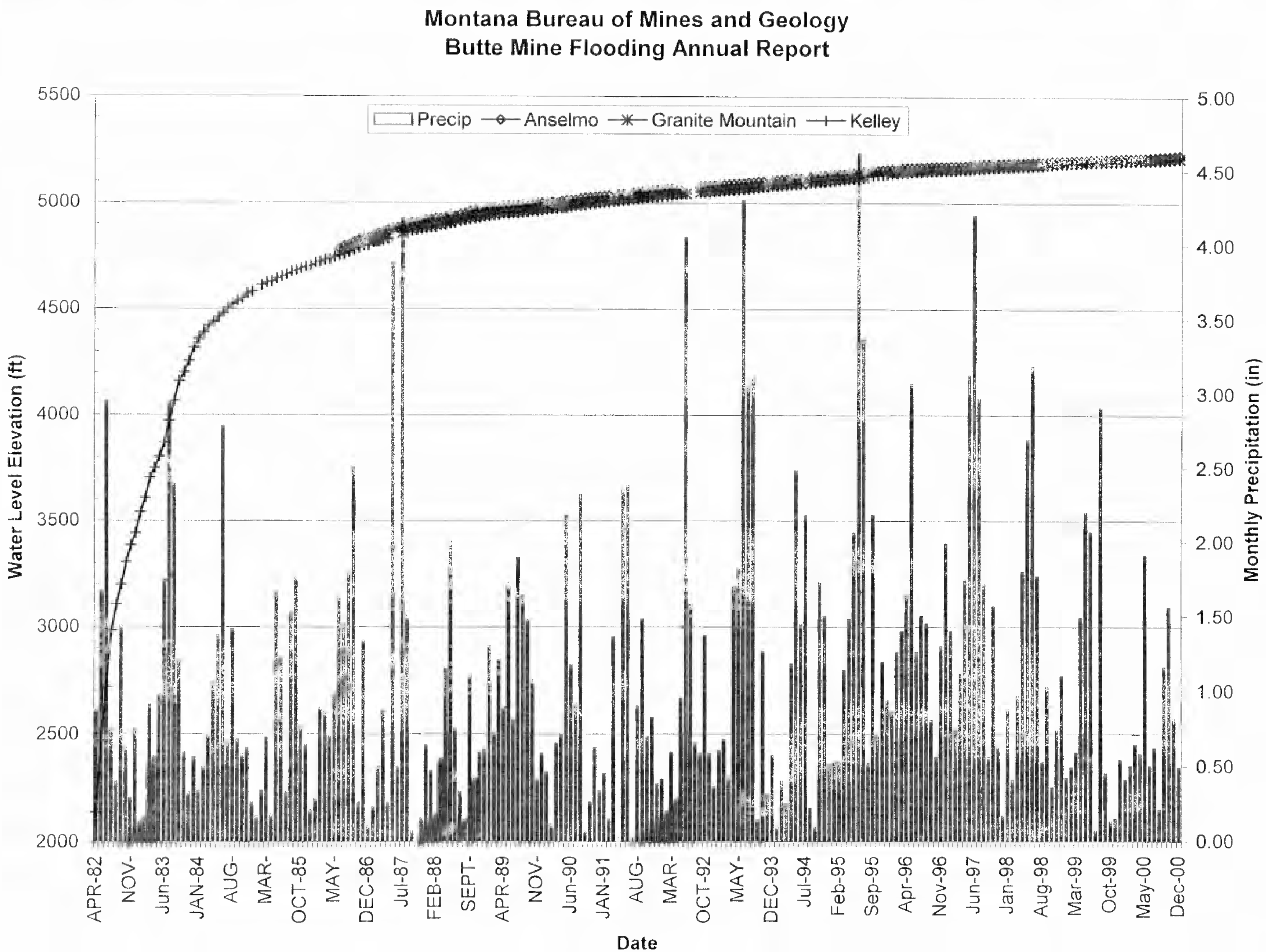

Figure 2-28. Water-level hydrographs for selected East Camp mine shafts, with precipitation.

2.2.1 RI/FS Bedrock Monitoring Wells

Monitoring of the nine RI/FS-and ROD-installed bedrock wells continued. Monitoring well locations are shown on figure 2-23. Water levels continue to raise in wells A, C, D-1, D-2, G and J at levels similar to those in the East Camp Mine system. Water levels in wells E, and F continue to follow patterns identified in earlier reports. Table 2.2.1.1 contains yearly water-levels changes and figure 2-29 shows those changes.

Table 2.2.1.1 RI/FS bedrock well annual water-level change

Year	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H	Well J
1989										
1990										
1991	33.18		22.38	24.20	22.68	1.73				
1992	39.22	8.78	26.53	27.89	25.04	0.47	-1.92			
1993	27.95	8.68	21.72	24.41	24.51	-0.37	1.09			
1994	25.65	7.90	23.88	25.12	25.21	0.27	0.11			
1995	28.69	13.41	29.55	26.99	27.50	0.44	1.65	28.74	30.37	
1996	19.31	14.56	26.22	18.77	18.92	0.48	-0.11	22.40	18.72	
1997	14.44	12.35	19.25	13.62	13.68	-0.64	1.41	15.67	3.76	
1998	15.96	11.30	16.68	16.41	16.39	0.44	1.03	15.56	15.44	
**Total 10 Year Change*	*204.4*	*76.98*	*186.21*	*177.41*	*173.93*	*2.82*	*3.26*	*82.37*	*68.29*	
1999	11.21	5.11	12.44	12.18	12.03	-0.78	-1.80	12.00	P&A	1.99
2000	15.12	8.20	13.39	14.66	15.79	-2.68	-2.49	12.84	P&A	16.19
***Total Change**	**230.73**	**90.29**	**212.04**	**204.25**	**201.75**	**-0.64**	**-1.03**	**107.21**	**68.29**	**18.18**

Year	DDH-1	DDH-2	DDH-4	DDH-5	DDH-8
1989	29.53			34.83	30.48
1990	36.24	30.99	5.44	27.61	35.96
1991	27.03	28.20	39.81	27.01	28.96
1992	28.25	26.09	37.66	31.07	26.16
1993	24.33	24.16	26.88	24.40	24.46
1994	25.00	25.65	28.34	19.78	15.97
1995	27.66	28.74	28.80	26.10	--
1996	18.53	18.97	20.24	12.41	55.68
1997	13.33	14.09	14.32	15.89	13.38
1998	15.03	16.20	16.25	16.50	16.50
**Total 10 Year Change*	*244.93*	*213.09*	*217.74*	*235.6*	*247.55*
1999	11.66	12.00	11.88	4.82	15.50
2000	14.64	16.11	14.77	P&A	10.42
***Total Change**	**271.23**	**241.20**	**244.39**	**240.42**	**273.47**

*Total change is the measured change. Access or obstructions have 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.

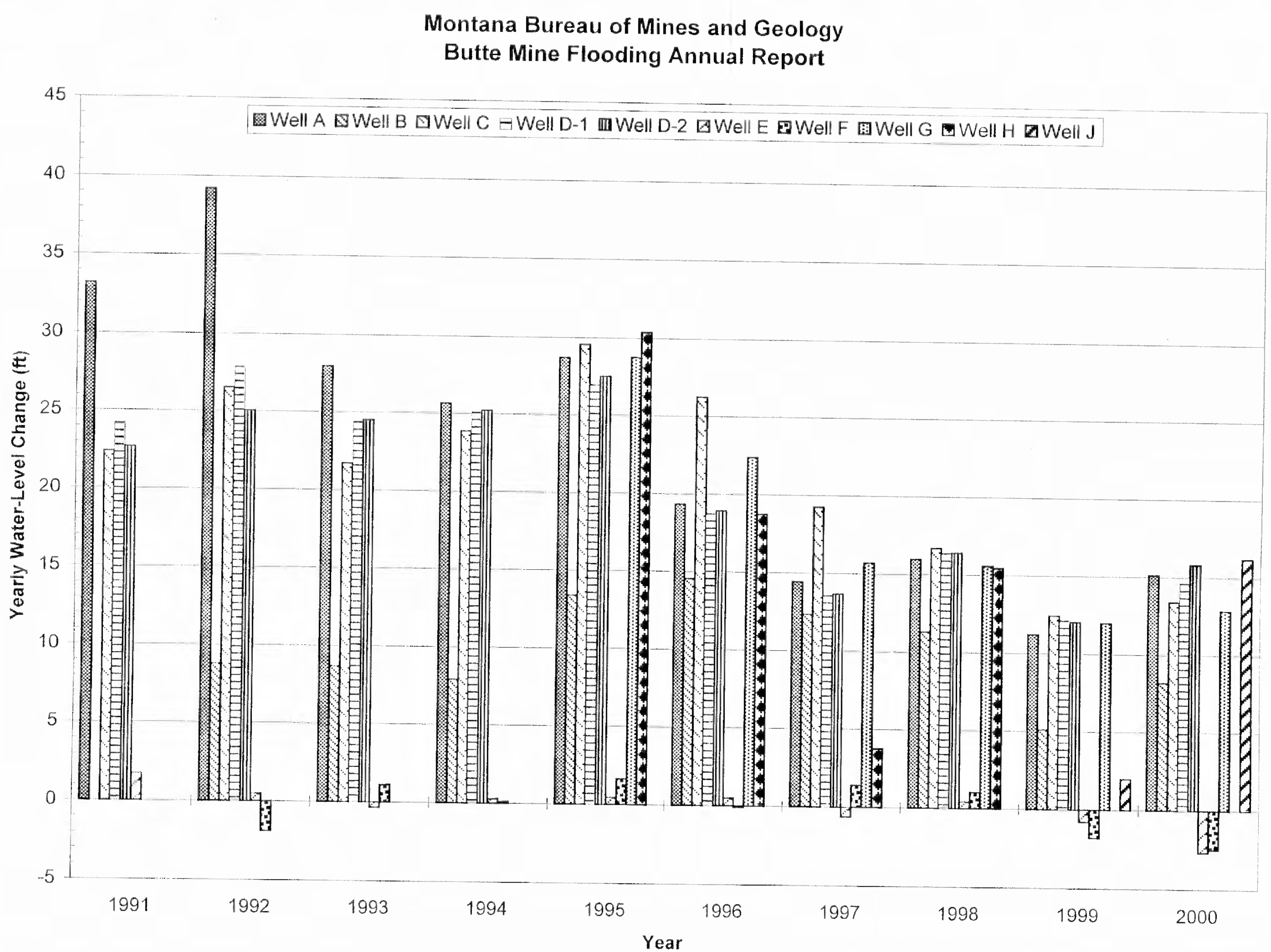

Figure 2-29. RI/FS bedrock wells annual water-level change.

As mentioned earlier, water-level trends in wells A, C, D-1, D-2, G and J followed those identified in last year's report. Figures 2-30 and 2-31 are hydrographs for wells A and 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 in response to precipitation. Unlike a number of the shallow alluvial wells, no variations in water levels are noted either seasonally or yearly as a result of precipitation. Water-level changes in the bedrock aquifer, which had been affected by historic underground mine dewatering, are responding to the cessation of pumping and show no apparent relationship to precipitation increases from 1982 through 2000. Instead, physical changes that affect the flow of water into the Berkeley Pit and underground mines, i.e. the 1996 HSB water diversion and the 2000 addition of the HSB drainage flow, are very apparent and are the major influences on water-level increases (figure 2-32). The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

Water levels measured in well J since its completion have been in the same range as those in other surrounding bedrock wells and are shown on figure 2-33. Historic water levels for well H are shown on this figure with a linear projection of water levels included. Water levels for well J plot very close to those projected for well H, verifying that well J was completed in the same bedrock zone as well H.

The water-level change in well B continues to increase at about one-half those of the above bedrock wells over the past two years. Since 1992 the rate of water-level rise in this well is about 46 percent that of the Berkeley Pit. Figure 2-34 is a hydrograph for wells A and B showing monthly water-level elevations. From this figure it is apparent that water level trend in well B is following those of the other bedrock wells (A, C, D-1, D-2, G, and J).

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (figure 2-35). They are considerably higher than those in the other bedrock wells, indicating a lack of dewatering from historic mining activities.

Water-level monitoring continues to confirm that the flow of water in the affected bedrock aquifer is towards the Berkeley Pit. Figure 2-36 is a potentiometric surface map for the East Camp bedrock aquifer showing the flow of water from all directions being towards the pit.

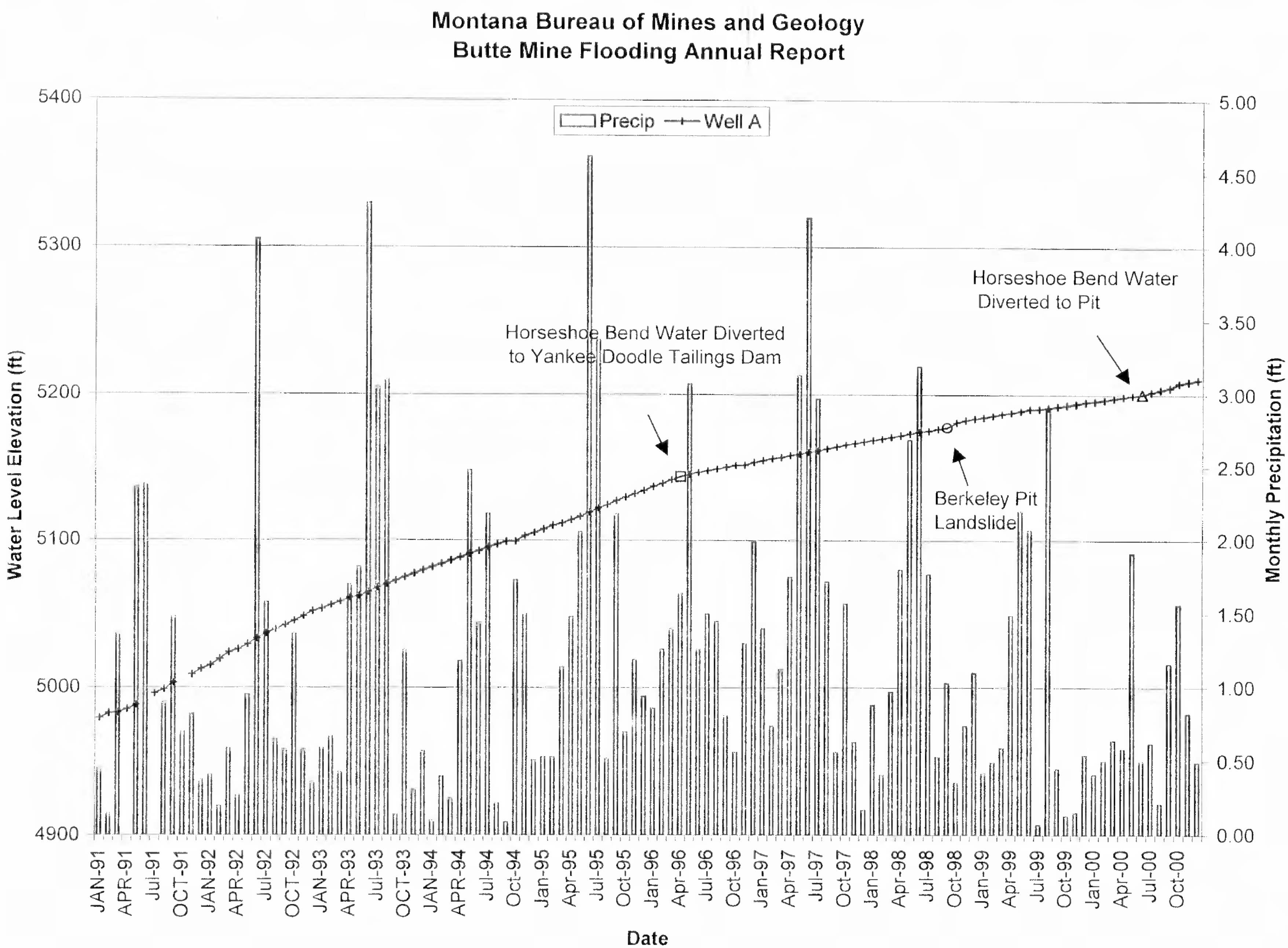

Figure 2-30. Water-level hydrograph for bedrock well A.

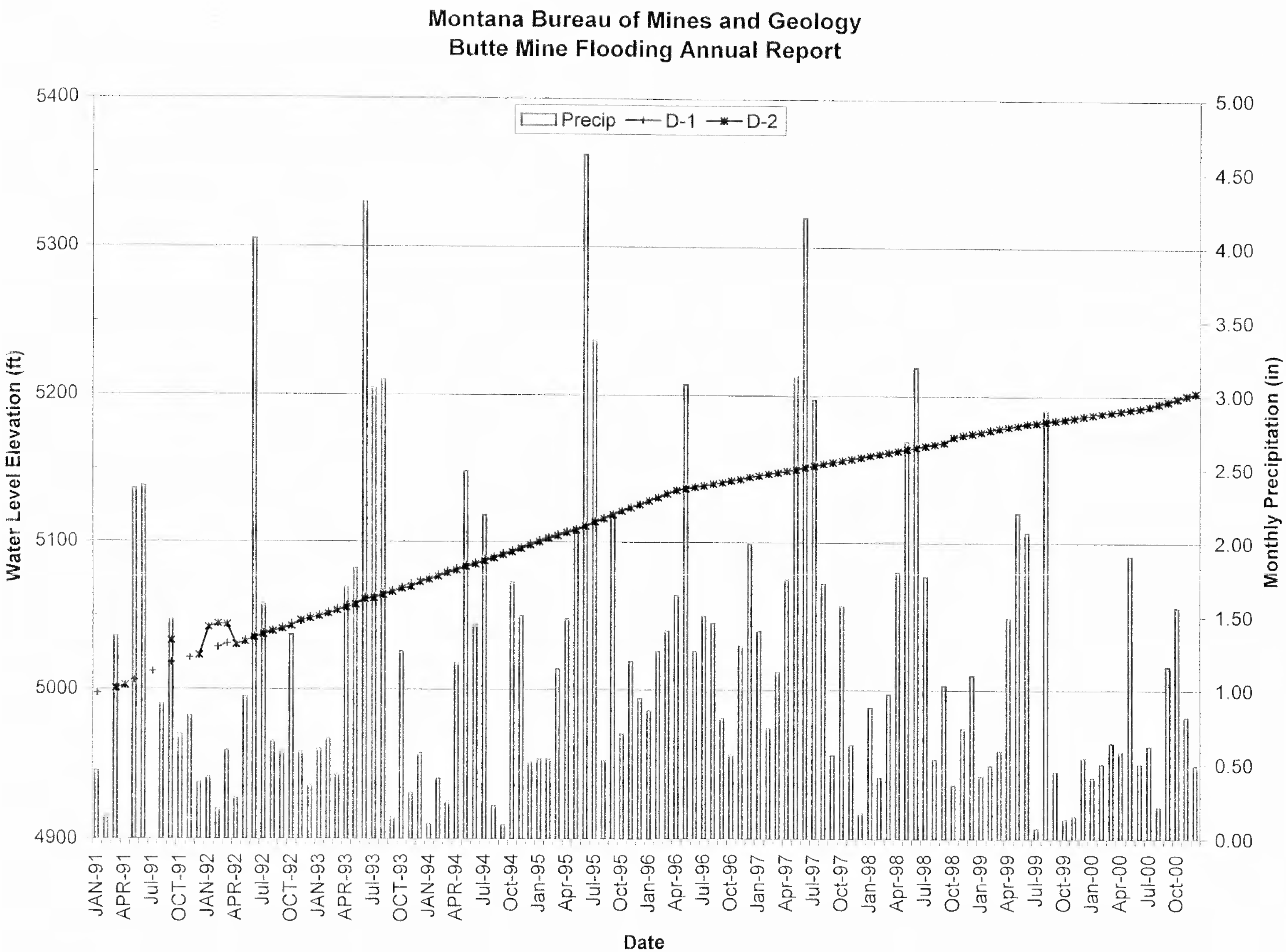

Figure 2-31. Water-level hydrographs bedrock wells D-1 and D-2.

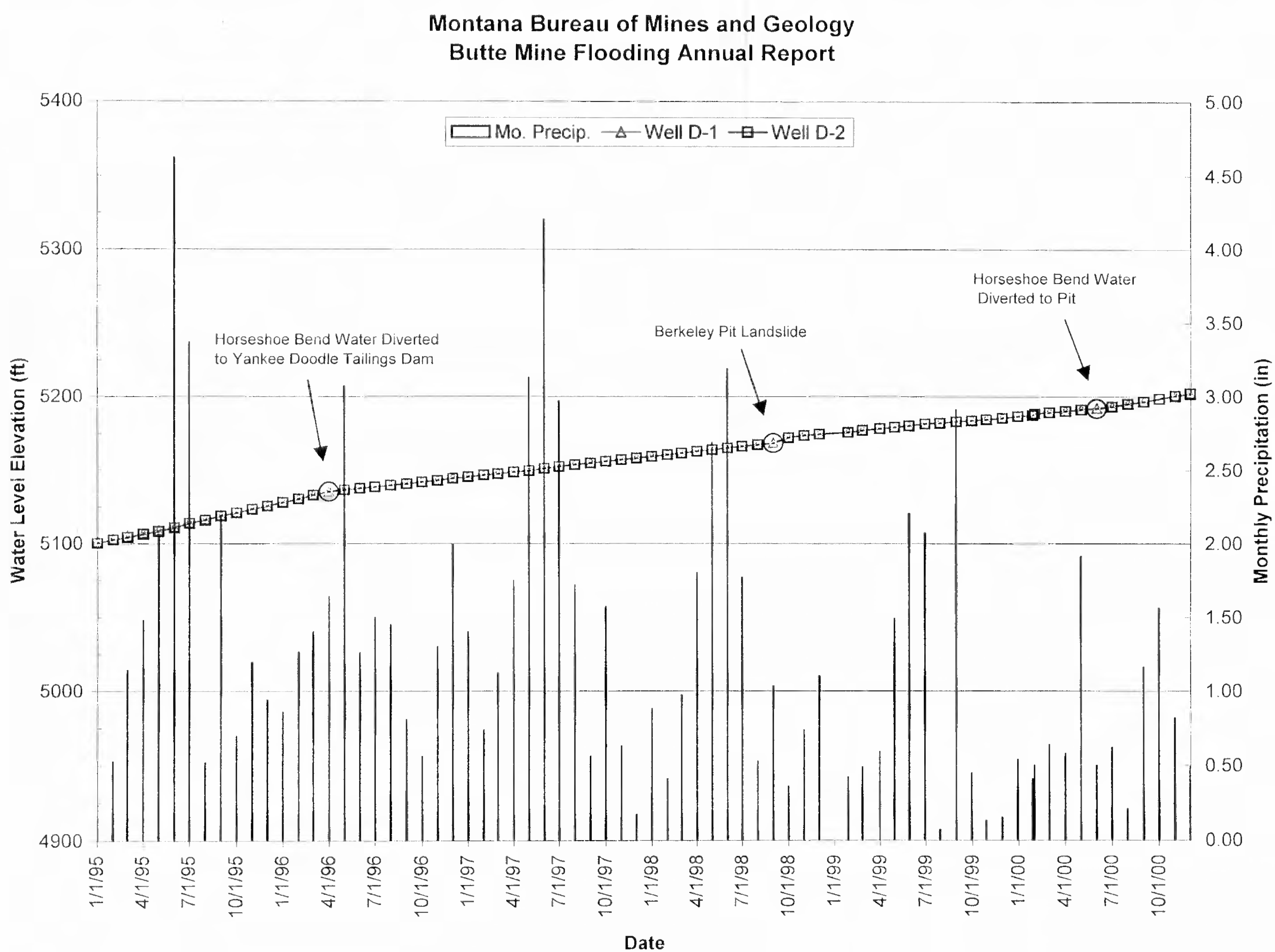

Figure 2-32. Water-level hydrograph, 1995-2000, wells D-1 and D-2.

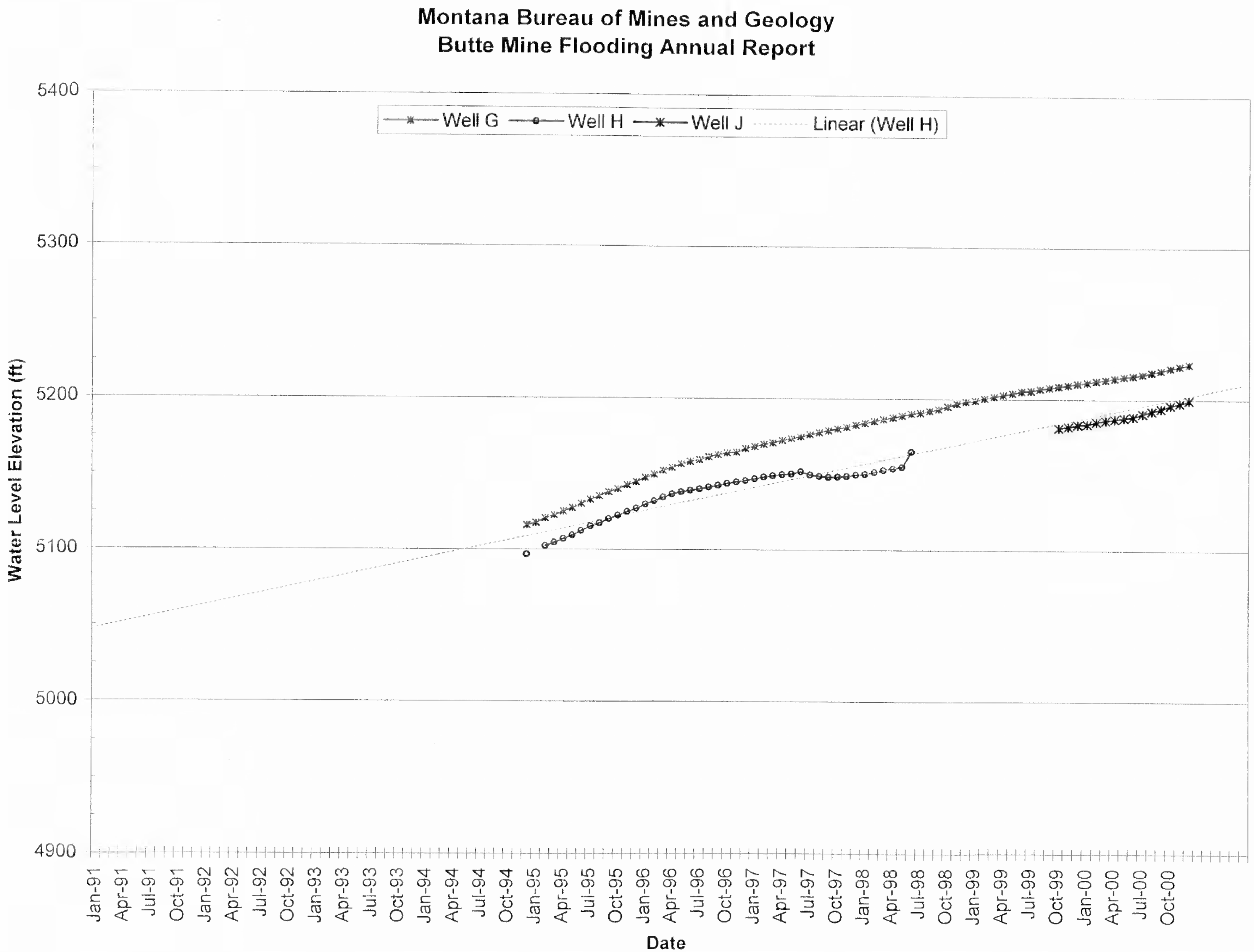

Figure 2-33. Water-level hydrograph for bedrock wells G, H, and J.

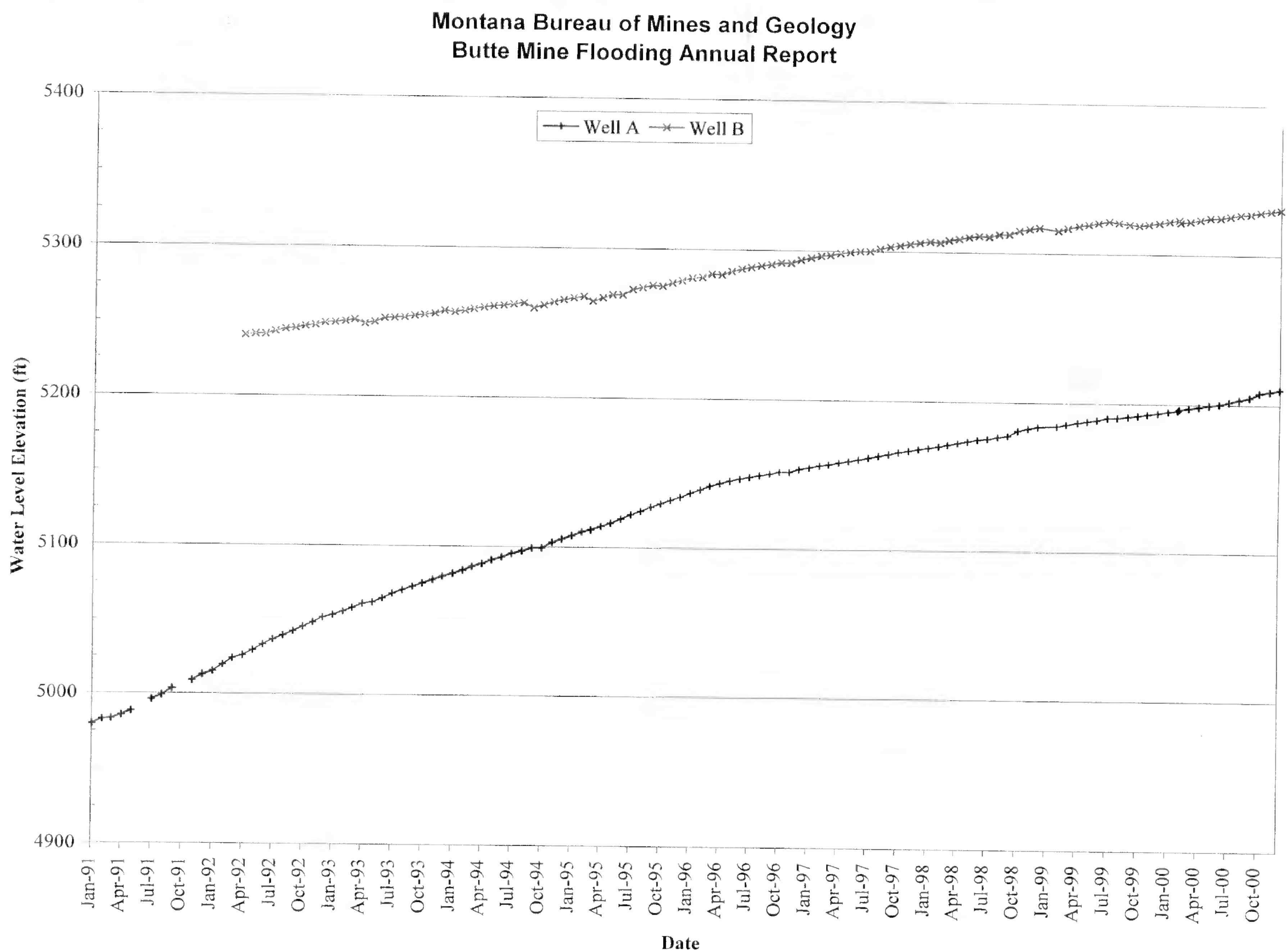

Figure 2-34. Water-level hydrograph for bedrock wells A and B.

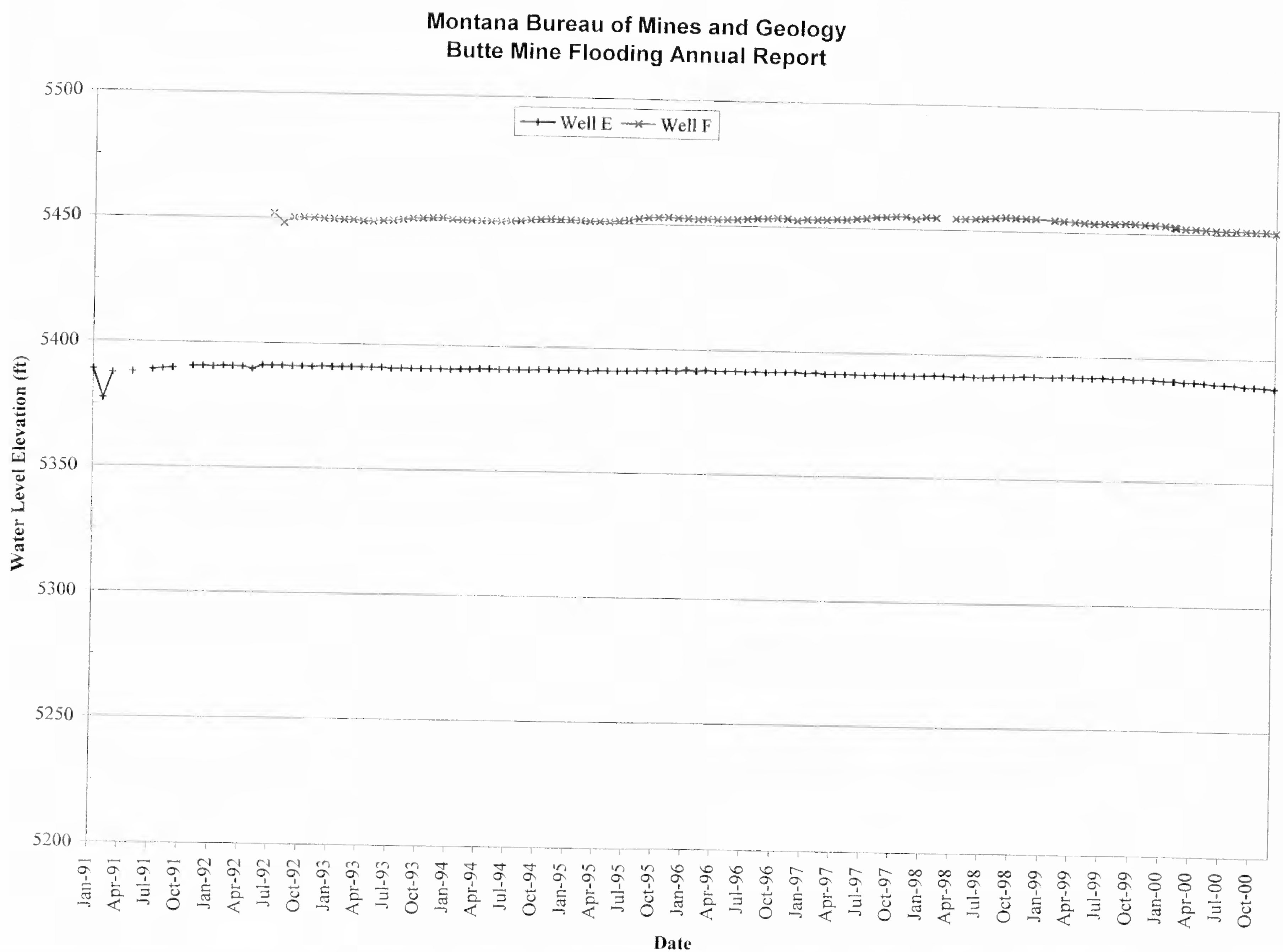

Figure 2-35. Water-level hydrograph for bedrock wells E and F.

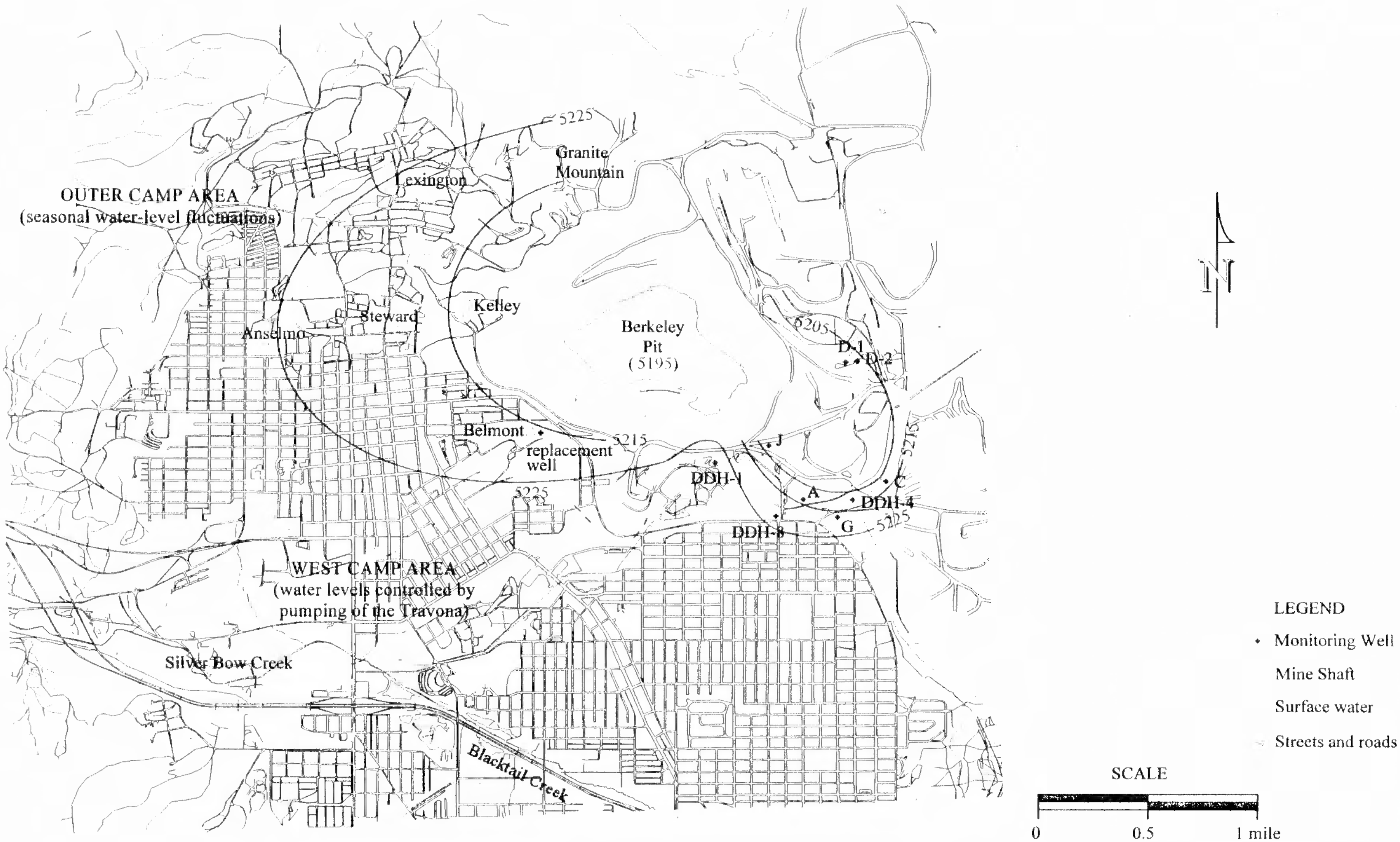

Figure 2-36. East Camp bedrock potentiometric map for December, 2000.

2.2.1.1 RI/FS Bedrock Well Rehabilitation

Well rehabilitation work was undertaken the latter part of 2000 on bedrock wells A, C, D-1, and D-2. Downhole camera surveys during 1998, 1999, and 2000 showed the presence of foreign objects in wells A and D-1. The surveys also showed encrustation inside the wells and excessive pitting of the casing for well D-1.

MR and MBMG developed a plan to refurbish these wells to ensure their continued reliability for water level monitoring and water quality sampling. The plan consisted of the following components:

1) Removal of objects in wells A and D-1;
2) Redevelopment of the wells by air injection, followed by pumping and surging until the water was clear;
3) Installation of 4-inch schedule 80 PVC inside well D-1; and
4) Re-inspection of wells using the downhole camera to verify success of work.

AK Drilling of Ramsay, MT was selected by MR to perform this work. AK and their subcontractor, Peak Groundwater Services, Butte, MT, began work in October 2000. The first activities were the removal of the objects in wells A and D-1.

The debris in Well A appeared to be pieces of broken PVC lying cross-wise in the well at the suspension ring. The suspension ring is where the larger diameter blank casing ends and the smaller diameter casing with the well screen starts. The bedrock wells had been installed by drilling a large diameter borehole through the alluvial and weathered bedrock. Blank steel casing was then installed in the borehole and cemented into place. Drilling of a smaller diameter borehole was continued through the inside of the cased hole until fractured, water-producing zones in the competent bedrock were encountered. A ring was then installed in the bottom of the solid casing into which the smaller casing was inserted. The smaller casing and well screen hang freely in the bottom part of the borehole.

Several pieces of broken 4-in PVC were retrieved from well A in just several hours. Figure 2-37 shows an example of the PVC removed. The location of the PVC in well A prevented additional camera work, as the camera could not get past the PVC and into the smaller diameter casing. Following the removal of the PVC from the suspension ring, additional camera work was attempted. However, the water in the smaller casing was very turbid, with considerable amounts of light-colored particles entrained in the water column, which prevented further identification of blockage or problems in this well with the camera until redevelopment work was completed.

AK used one of their drill rigs to blow the hole using air. Air was pumped into the well through a one and one-half inch (1-1/2) tremie pipe. Additional smaller pieces of broken PVC were removed from this well. The well was then pumped and surged. The pump was set deeper in the well in an attempt to remove the suspended material in the water column. Follow-up downhole camera inspections showed the presence of additional PVC pieces in the well. These will be removed during next year's redevelopment work.

The 1998 camera investigation showed what appeared to be a broken pipefitting lying in the sump (bottom) of well D-1. Various attempts to remove this object failed. Discussions with former employees of the contractor who installed the well casing indicated that the fitting seen in the video was welded to the bottom of the casing. The fitting was used during the casing installation for support of the well screen. No further attempts were made at removal of this object.

Well D-1 had extensive pitting throughout most of the blank steel casing that was very obvious in the downhole camera videos. The lower portion of the well (below the suspension ring) was in excellent condition. The lower portion had been completed using stainless steel casing and well screen. It was decided that installing a PVC liner above the suspension ring would extend this well's useful life and reduce further corrosion problems.

Well D-1 was cleaned first by injecting air into the well using the tremie pipe to remove any particles and allow for a final camera investigation to ensure the casing and well screen integrity prior to placing the liner in the well. Considerable amounts of fine particles were removed from the well. Once this was done and the camera survey showed the lower casing and well screen to be intact, work began on placing the liner in the well.

The original design for lining this well called for using 4-inch schedule 40 PVC resting on the suspension ring. However, the schedule 40 PVC broke during installation, therefore, 4-inch schedule 80 was used as the liner in this well. A series of three packers were installed on the bottom of the casing, which was allowed to set on the suspension ring. A concrete plug was poured on top of the packers to seal the PVC and packers in the hole above the stainless steel casing. The remainder of the well was grouted using bentonite to ground surface. Figure 2-38 shows the combination of packers used on the bottom of the PVC.

The well was pumped to remove any particles or debris that entered the well during placement of the liner. Following the pumping another downhole camera survey was performed to verify that the PVC liner was properly in-place and secured on the suspension ring and the PVC casing had no integrity problems. The camera survey showed the PVC casing to be intact and resting on top of the suspension ring.

Activities then shifted to cleaning and redevelopment of well D-2. This well is located near well D-1, figure 2-23. Wells D-1 and D-2 had been drilled as a nested pair, with D-2 being the deeper well. Initial cleaning of this well followed the same methods used for wells A and D-1 blowing with air, followed by pumping. Since this well was drilled deeper than D-1 a different design was used from that of the other wells. The stainless steel casing suspended from the suspension ring (540-ft) reduces to a smaller diameter casing at a depth of 660-ft below ground surface. The tremie pipe was too large to fit below this reduction in casing at 660-ft; therefore, no redevelopment took place in the screen interval of this well. Follow-up work with the downhole camera showed considerable encrustation below the point of redevelopment and within the screen interval. This encrustation of the well screen might explain why this well produces such small quantities of water during pumping and sampling. Additional redevelopment work to remove the encrustation is necessary for this well.

Well C was blown with air and cleaned up very quickly, with little sediment seen in the discharge water. The subsequent camera survey showed the casing to be in good shape, with little suspended sediment in the water, and the well screen to be clean. No additional redevelopment work was done on this well.

The rehabilitation and redevelopment work on these four wells was mostly successful. The only problems that will need follow-up work occurred in well D-2 where the tremie pipe would not fit below the second reduction in casing diameter. This prevented cleaning and breakup of encrustation in the screened intervals.

The driller did not have enough tremie pipe to get to the bottom of well A. This prevented the complete removal of the broken PVC in this well, noted in a follow-up camera survey. It should be noted that none of the remaining work in either of these two wells would affect water-level measurements or water-quality sample results.

Figure 2-37. Photo of broken PVC removed from well A.

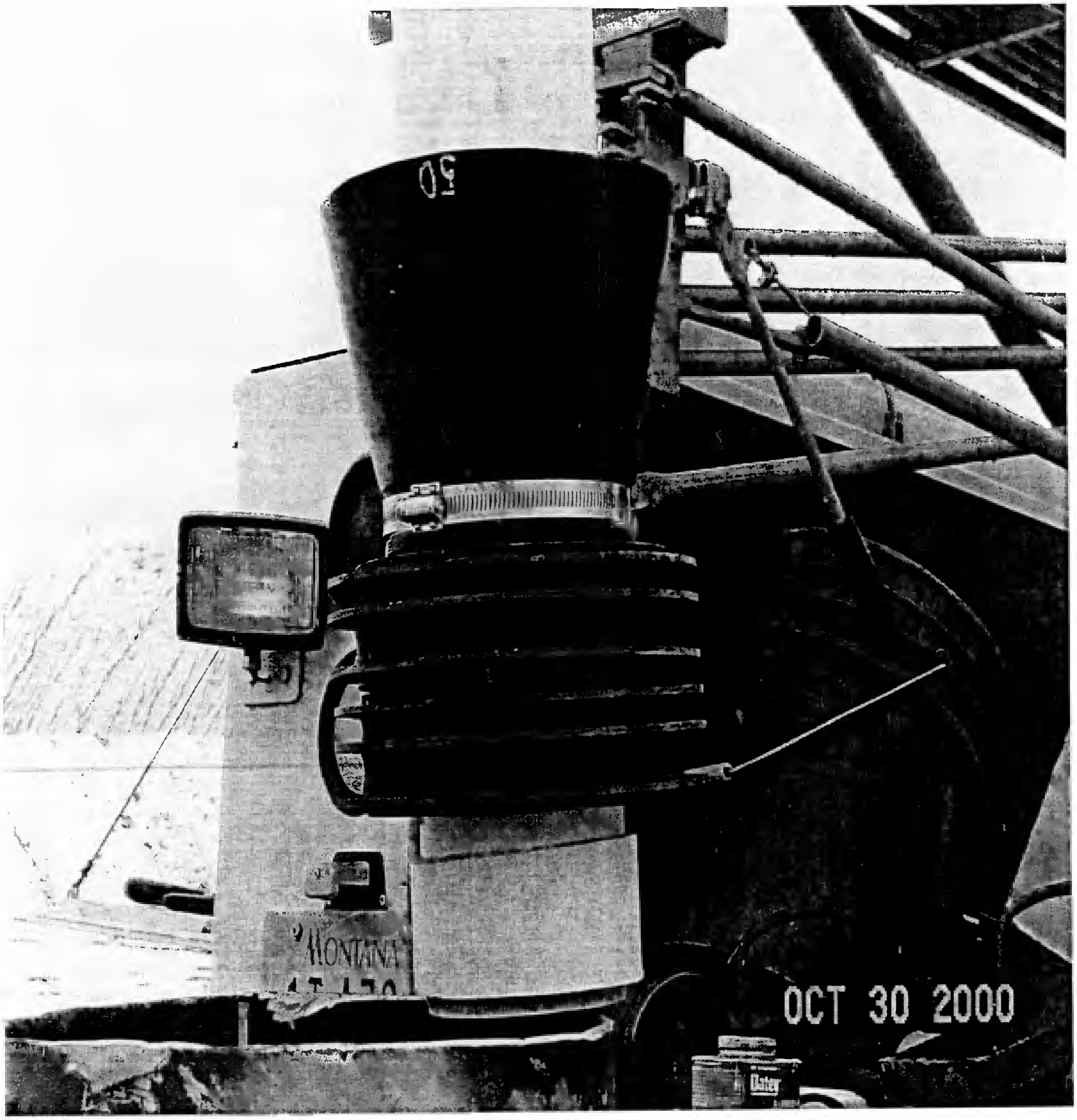

Figure 2-38. Photo of packers on bottom liner to be run into well D-1.

2.2.2 DDH Series Wells

Water-level monitoring of the DDH well series continued. Water levels have continued to rise in these wells following previous trends, with the exception of that in well DDH-5. The unexplained water-level variations in well DDH-5 seen in 1999, continued into 2000. Following a number of independent investigations, i.e. review of RI/FS geophysical data, downhole camera study, etc. it was decided that potential casing problems made this well unreliable for continued monitoring purposes and that it should be plugged and abandoned.

Well DDH-5 was plugged by placing an inflatable rubber packer inside the inner 3-in casing. The packer was set at a depth of 450-ft below ground surface, which is below the bedrock-alluvial contact, and inflated with air. The packer was also secured with a steel cable tied to the well casing at ground surface. A cement slurry was poured on top of the packer and allowed to cure. The remainder of the borehole was filled with a bentonite grout slurry to ground surface. The annular space between the inner 3-in and middle 5-in casing was filled with a cement slurry followed by a grout slurry to ground surface. A steel cap was welded over the top of the casing to secure this well.

Water-level rises in wells DDH-1, DDH-2, DDH-4, and DDH-8 varied from 10 to 16 feet in 2000. The rates of rise are consistent with those of the other bedrock wells and East Camp mine shafts. Figure 2-39 is a hydrograph for wells DDH-2 and DDH-4 showing water level increases. Once again precipitation does not show any affect on water level rises.

2.2.3 Berkeley Pit Water Level

Berkeley Pit water-level elevations were surveyed monthly to coincide with monthly water-level monitoring in wells. Figure 2-40 is a hydrograph showing water-level rise over time. The overall trend is similar to that of previous years. However, there are three noticeable changes on this figure. The first change represents the slowing of the filling rate when the HSB drainage diversion occurred in April of 1996, the second notes the increase in filling rate from the September 1998 landslide, and the third depicts the increase in filling rate following the June 2000 suspension of mining by MR and the subsequent inflow of water from the HSB drainage to the pit. Since April 1996 water from the HSB drainage was diverted and incorporated in the mining and milling process. Following MR's June 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 733 million gallons from July through December 2000 (figure 2-41). This represents an average flow of 2,750 gallons per minute. The overall Berkeley Pit water level rise for 2000 was 16.97 ft. (Note: It was observed during the spring of 2001 that the flume used to monitor the flow of water from the Horseshoe Bend drainage had a submergence problem. Through a series of direct measurements, correction factors were determined. The corrections were applied to flows for the year 2000 and are shown as the corrected flow on figure 2-41.)

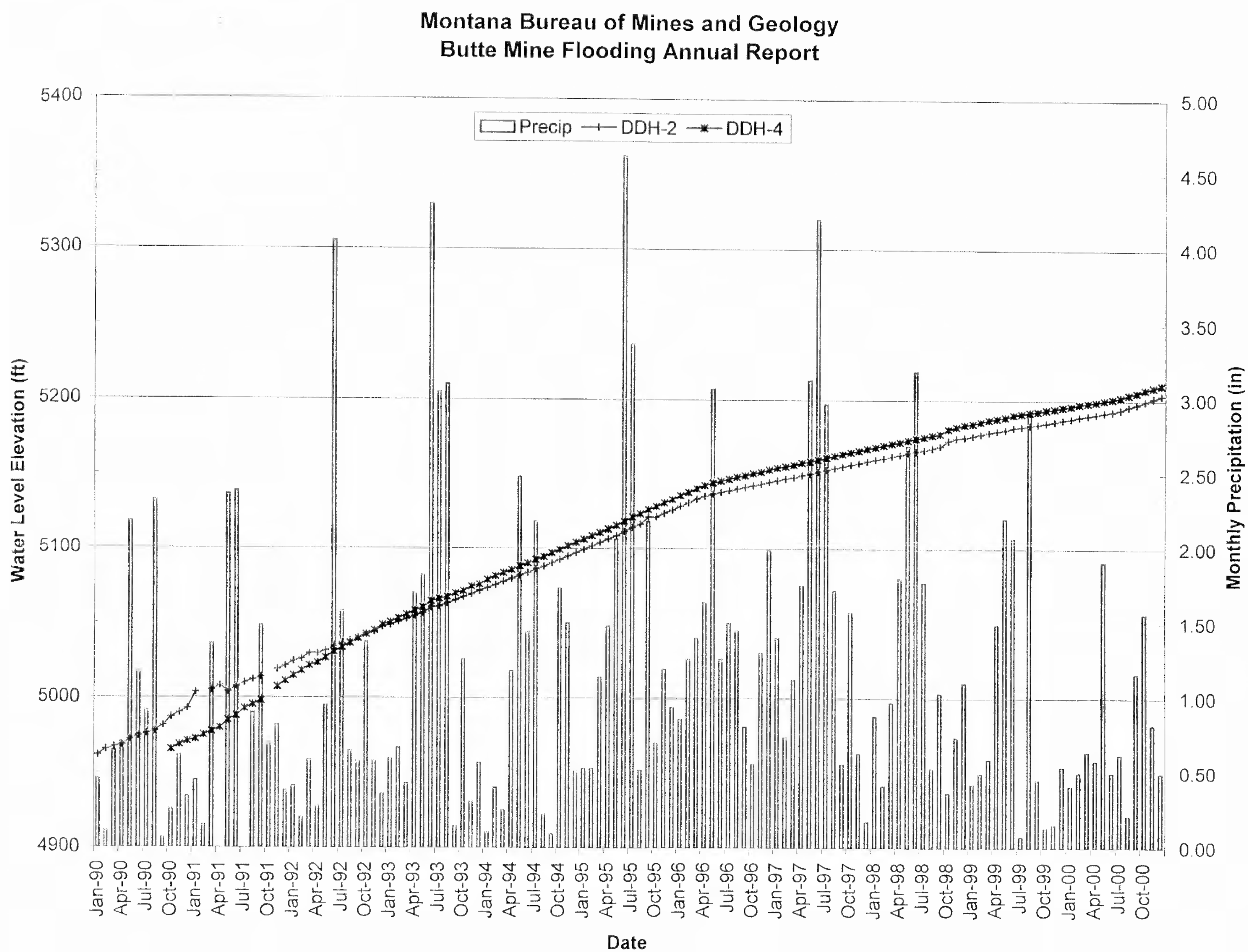

Figure 2-39. Water-level hydrograph for bedrock wells DDH-2 and DDH-4.

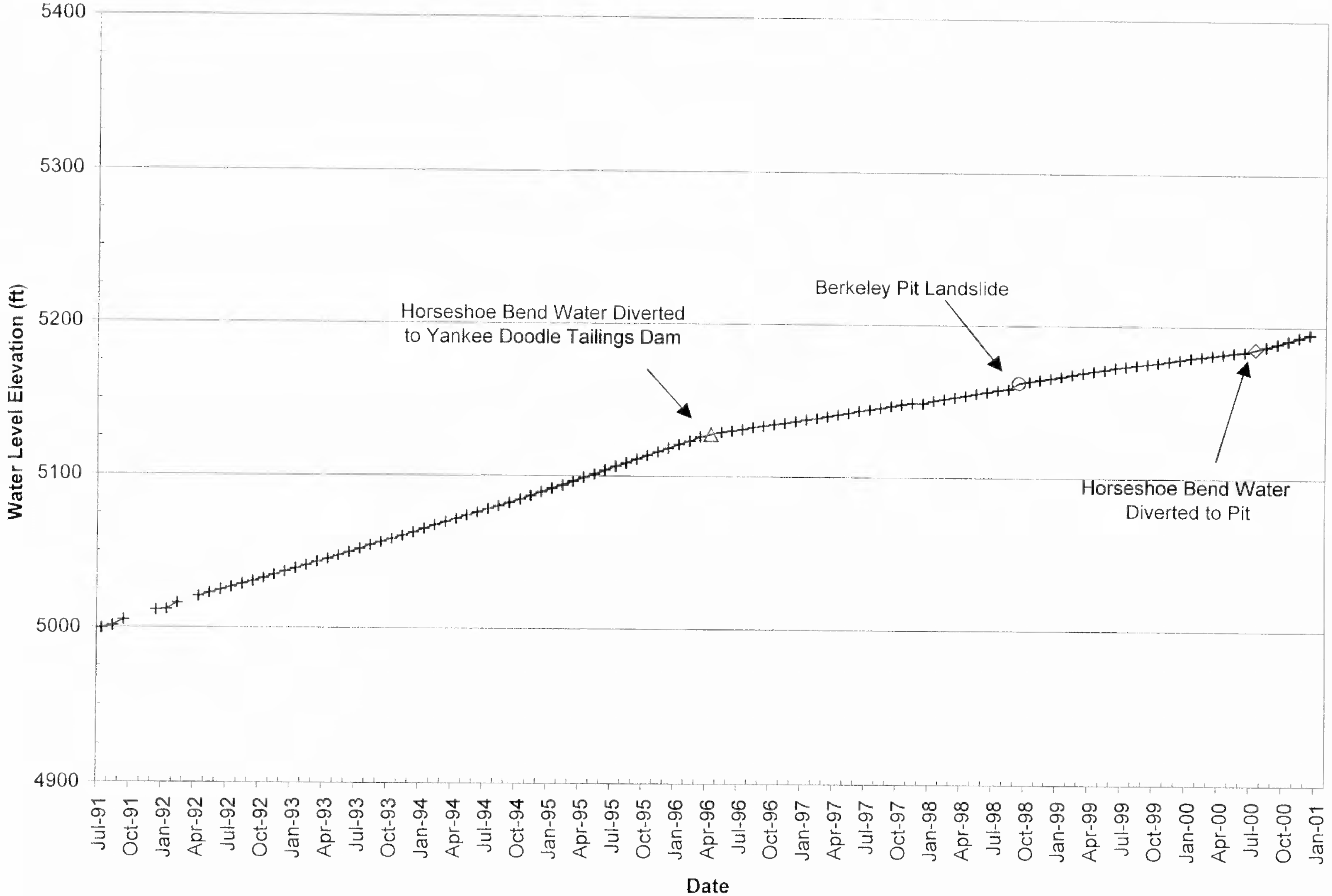

Figure 2-40. Water-level hydrograph for the Berkeley Pit.

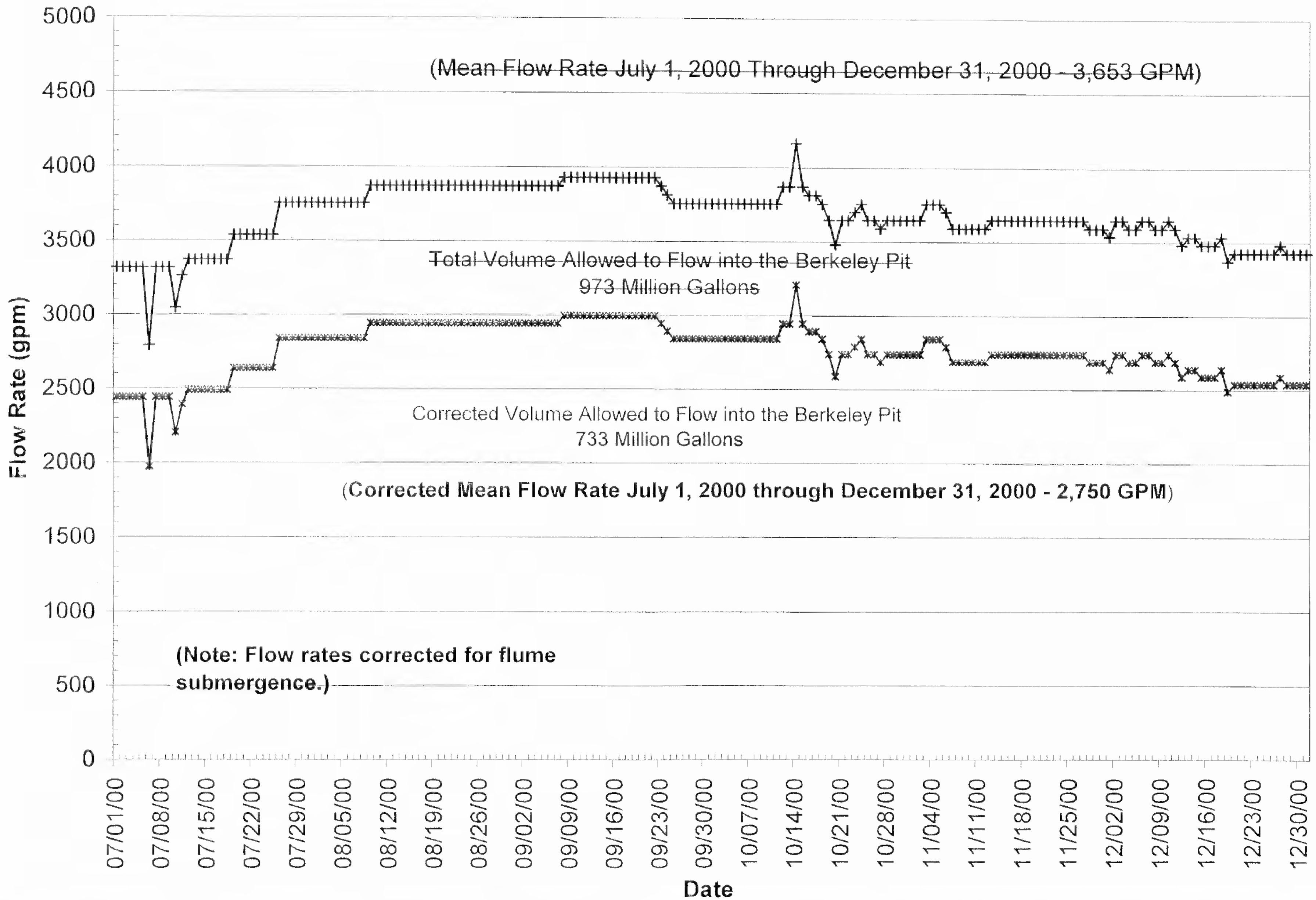

Figure 2-41. Horseshoe Bend drainage flow rate, July 1, 2000 through December 31, 2000.

Section 3.0 West Camp System

The West Camp System, which consists of the Travona, Emma and Ophir mines and the area adjacent to their underground mine workings is depicted on figure 3-1. Water-level monitoring was continued during 2000 in the mine shafts and six monitoring wells.

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 1S site. ARCO had a special well drilled for dewatering (pumping) purposes in the fall of 1997. This well is referred to as the West Camp Pumping Well (WCPW). Pumping activities were transferred from the Travona Mine to this site on October 23, 1998. However, the pump and pipeline were left intact at the Travona Mine. In case of any problems that might affect pumping activities at the WCPW site, the Travona Mine will serve as a backup pumping system.

The West Camp pumping system operated almost continuously during 2000, 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 270 acre-ft of water was pumped in 2000, compared to 326 acre-ft in 1998 and 370 acre-ft in 1999. Table 3.1.1 shows the annual amount of water pumped in acre-feet on a yearly basis, percent change from the previous year, and the percent change from 1996 (the first full year of continuous pumping). Figure 3-2 shows the annual amount of water pumped and the percent of annual precipitation since 1982.

Water-level changes in the West Camp mines reflect changes in pumping rates in the WCPW. The reduced pumping rate in 2000 allowed a net water level increase of 5.5 ft in the West Camp mines for 2000, table 3.1.2. Figure 3-3 shows annual water-level changes for the West Camp sites. Although water levels rose over 5 ft during 2000, the water level is still more than 10 ft below the West Camp action level of 5435 ft stipulated in the 1994 ROD.

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

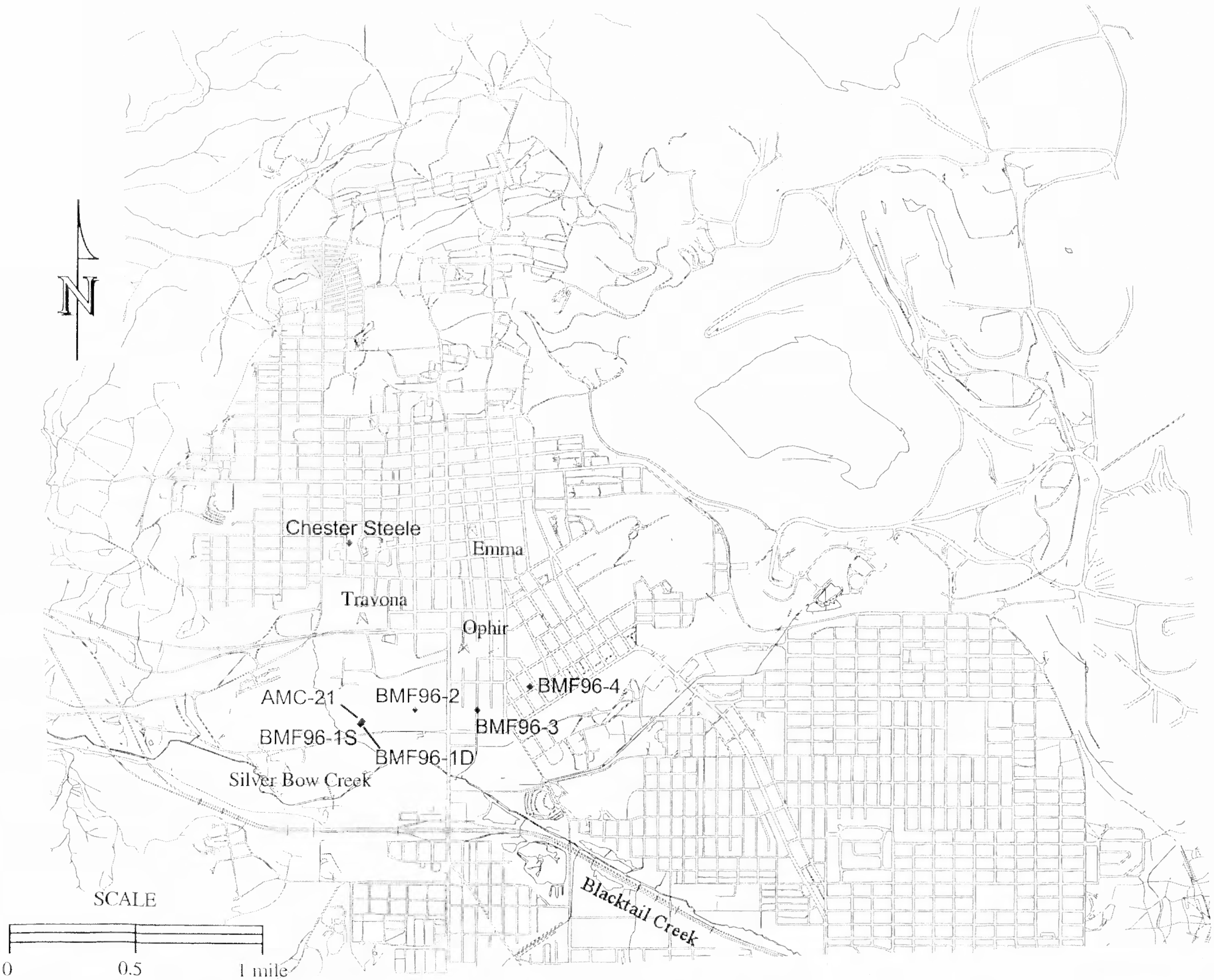

Figure 3-1. West Camp Monitoring Sites Location Map.

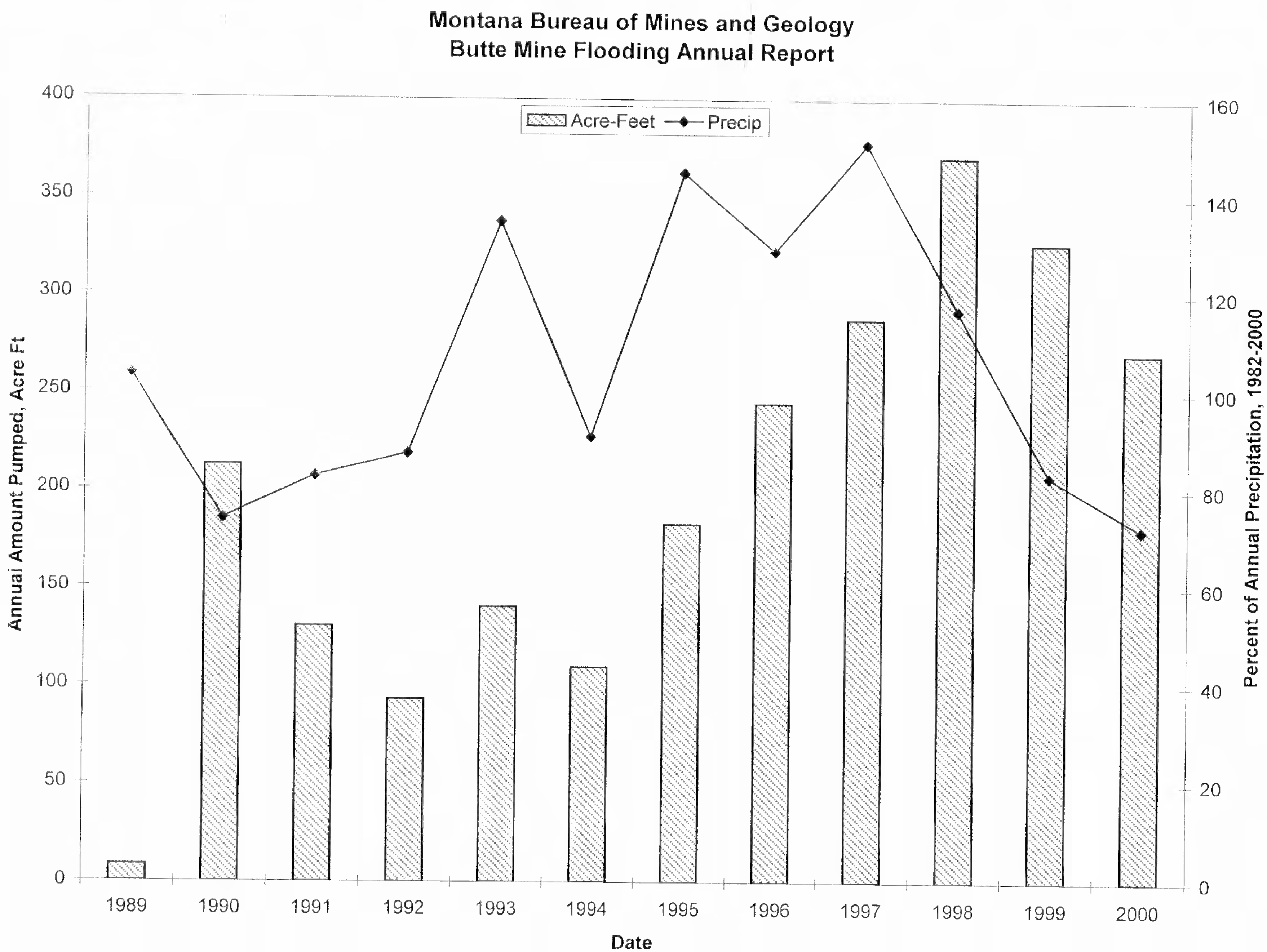

Figure 3-2. Annual amount of water pumped from the West Camp system.

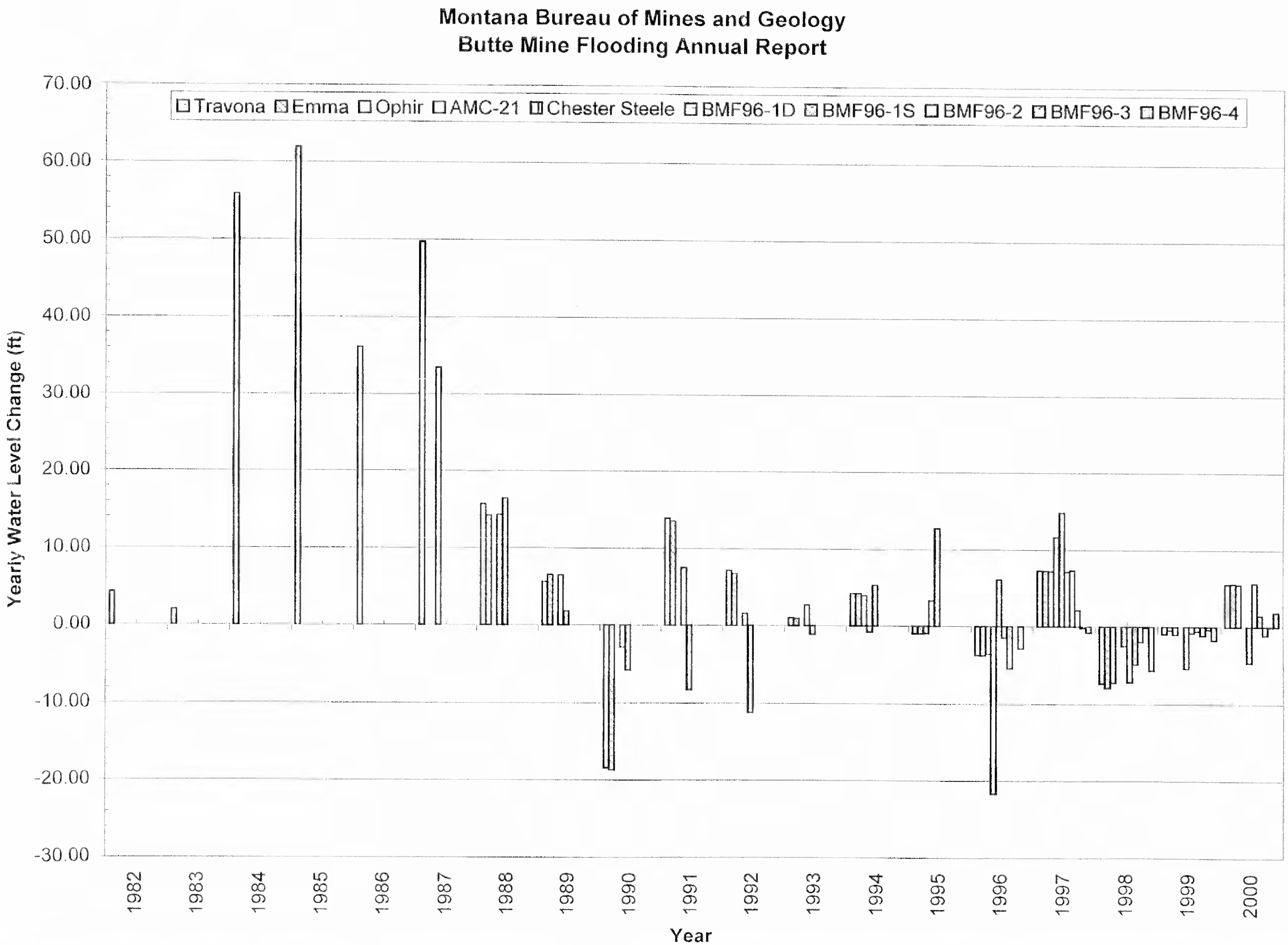

Figure 3-3. West Camp sites annual water-level change.

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

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

Pumping has been continuous since August 1995, with some minor exceptions

Table 3.1.2 West Camp Sites Annual Water Level Change

Year	Travona	Emma	Ophir	AMC-21	Chester Steele	BMF96-1D	BMF96-1S	BMF96-2	BMF96-3	BMF96-4
1982	4.30									
1983	2.00									
1984	55.90									
1985	61.90									
1986	36.10									
1987	49.70			33.48						
1988	15.69	14.20		14.32	16.42					
1989	5.67	6.60		6.52	1.79					
1990	-18.42	-18.66		-2.84	-5.77					
1991	13.88	13.52		7.57	-8.28					
**Total 10 Year Change*	*226.72*	*15.66*		*59.05*	*4.16*					
1992	7.21	6.79		1.55	-11.20					
1993	1.01	0.93		2.71	-1.11					
1994	4.24	4.26	4.00	-0.78	5.36					
1995	-0.98	-1.00	-0.96	3.32	12.72					
1996	-3.72	-3.76	-3.56	-21.69	6.14	-1.50	-5.41	0.00	-2.85	
1997	7.29	7.28	7.22	11.66	14.82	7.20	7.36	2.13	-0.19	-0.80
1998	-7.31	-7.88	-7.20	NA	-2.51	-7.14	-4.87	-1.97	-0.13	-5.64
1999	-0.97	-0.47	-1.03	NA	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	NA	-4.64	5.70	1.45	-1.13	-0.07	1.86
***Total Change**	**239.42**	**27.42**	**4.00**	**55.82**	**18.37**	**3.44**	**-2.08**	**-2.12**	**-3.62**	**-6.34**

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

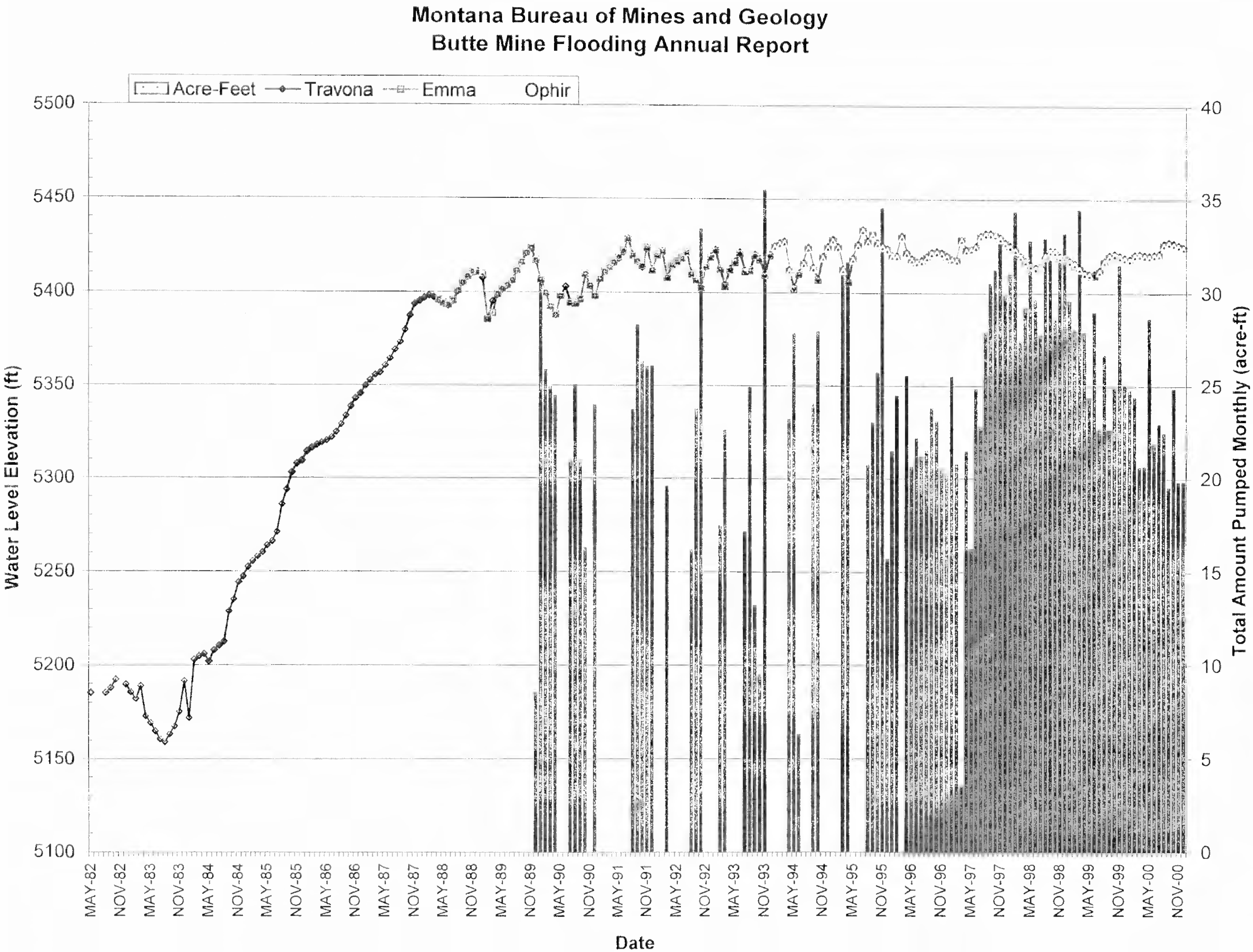

Figure 3-4. West Camp water-level hydrographs and total amount of water pumped monthly.

3.2 West Camp Monitoring Wells

Water levels rose in 3 of the 5 BMF96 West Camp wells during 2000. Well BMF96-1D, which is completed into the Travona Mine workings had water level changes similar to the three West Camp mines, rising over 5.5 ft. The water levels in wells BMF96-1S and BMF96-4 rose 1.45 ft and 1.86 ft, respectively. These changes are shown in Table 3.1 and on figure 3-3.

Figure 3-5 is a water-level hydrograph for wells BMF96 1D, 1S and 4. Water levels in wells 1D and 4 respond similar to one another, reflecting the influence pumping has on the system. This is an important trend since well BMF96-4 is not completed into mine workings. It is, however, in the area of the historic 1960's flooding problems that led the Anaconda Company to install well AMC-21 for control of water levels in the West Camp. (See MBMG 1998 Open-File Report 376 for a greater discussion of historic flooding problems in the West Camp System.) During periods of continued water level rise in wells 1D and 4 there does appear to be some similarity in water level change in well 1S. Well BMF96-1S is located adjacent to well 1D, but is completed at a shallower depth, in the weathered bedrock of the Missoula Gulch drainage. This well also shows response to pumping rates in the WCPW. There was no change in longer-term trends in any of these wells from those described in the 1998 and 2000 reports.

Water levels in wells BMF96-2 and BMF96-3 are 20 to 50 ft higher than those in wells BMF96-1D and BMF96-4, and when plotted with the other BMF96 wells appear to show very little change, figure 3-6. However, when these wells are plotted separately (figure 3-7), there is considerable variation in monthly water levels, and water levels in both wells respond similarly. Monthly precipitation is shown on these figures and water levels respond very quickly to precipitation events. Although these wells are completed at depths of 175 ft below ground surface, there water levels are less than 20 ft below ground surface. Water-level trends during 2000 in these wells were similar to those seen in previous years.

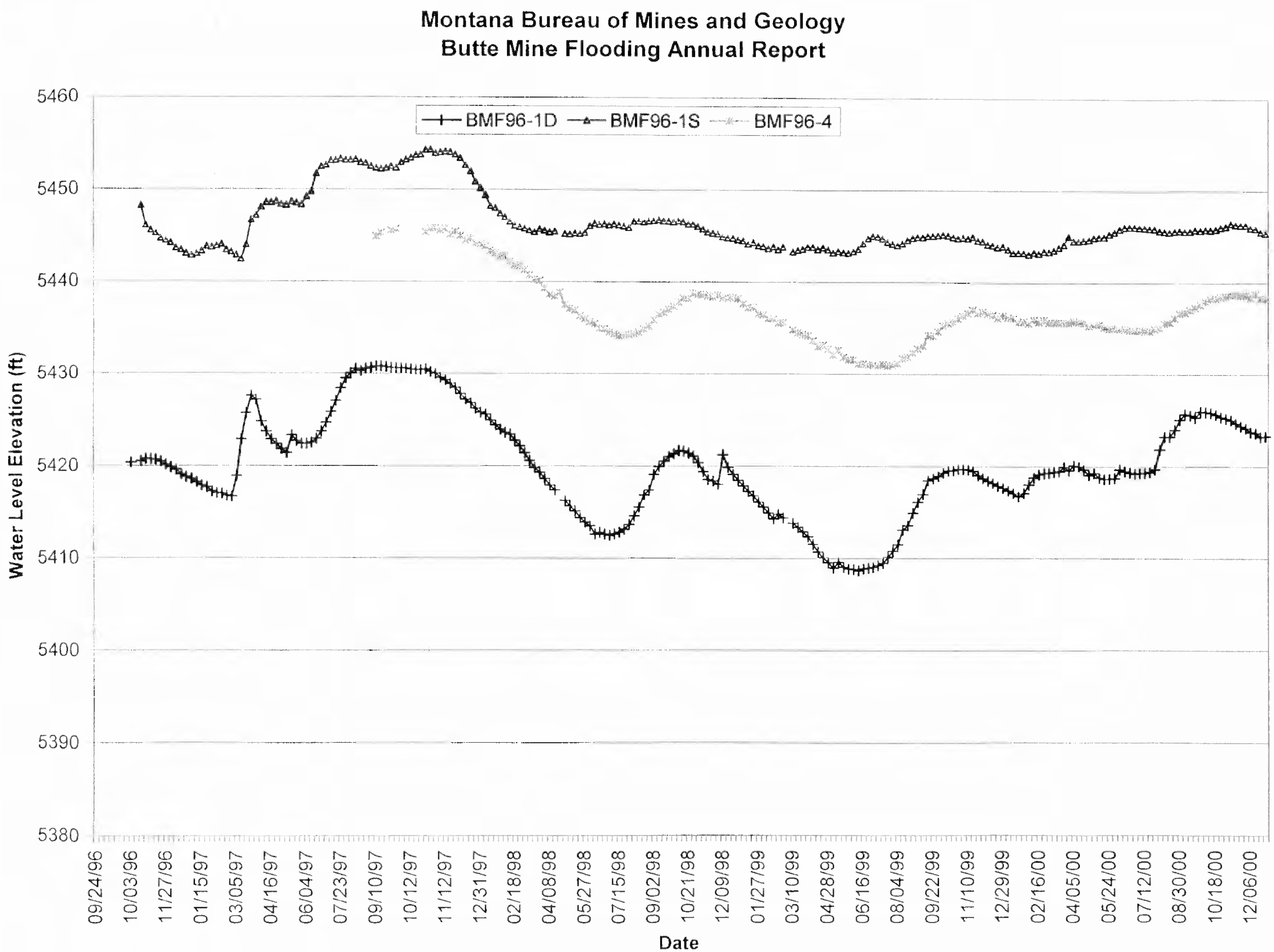

Figure 3-5. Water-level hydrograph for West Camp wells BMF96-1D, BMF96-1S, and BMF96-4.

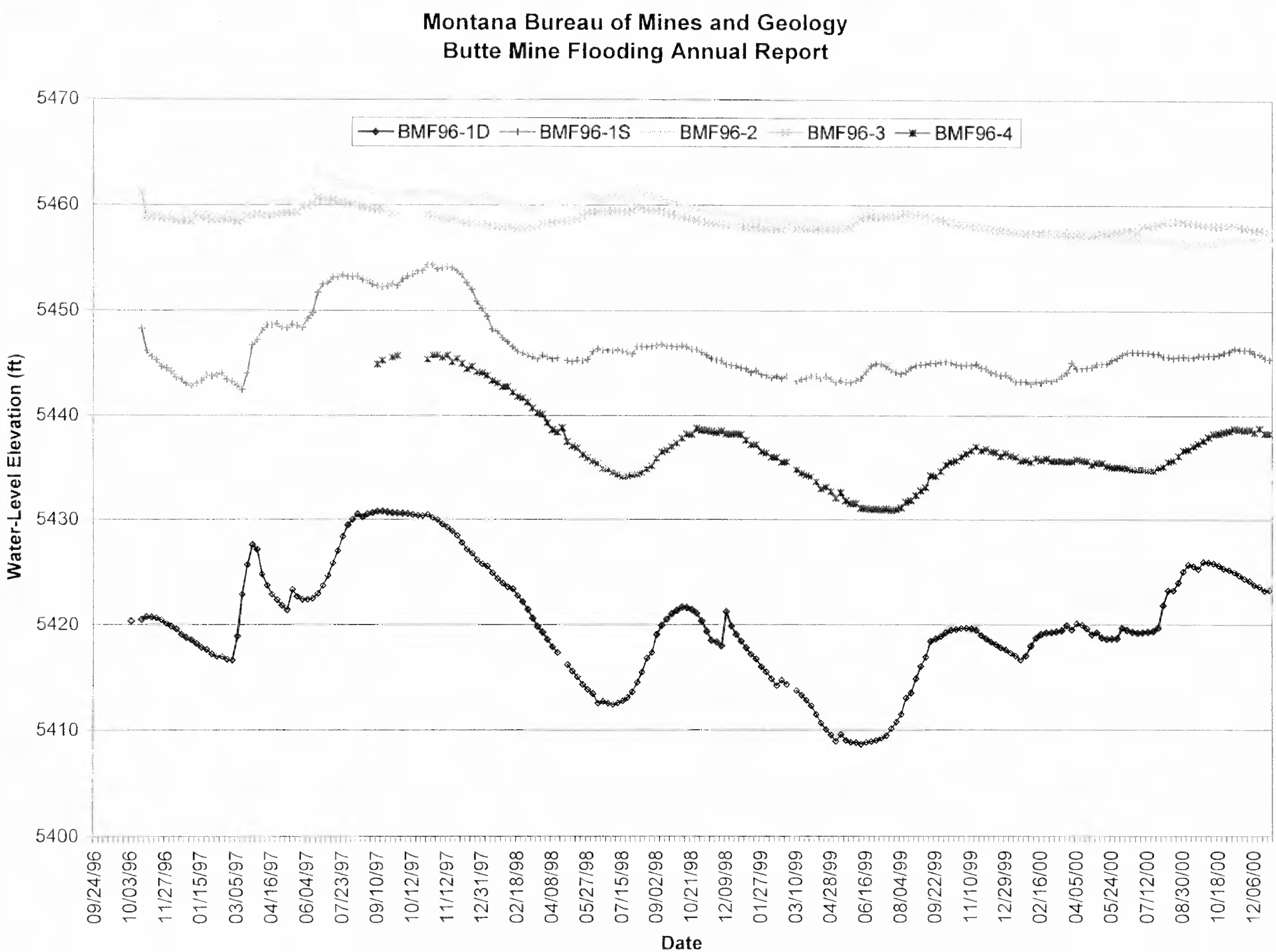

Figure 3-6. Water-level hydrograph for BMF96 series wells

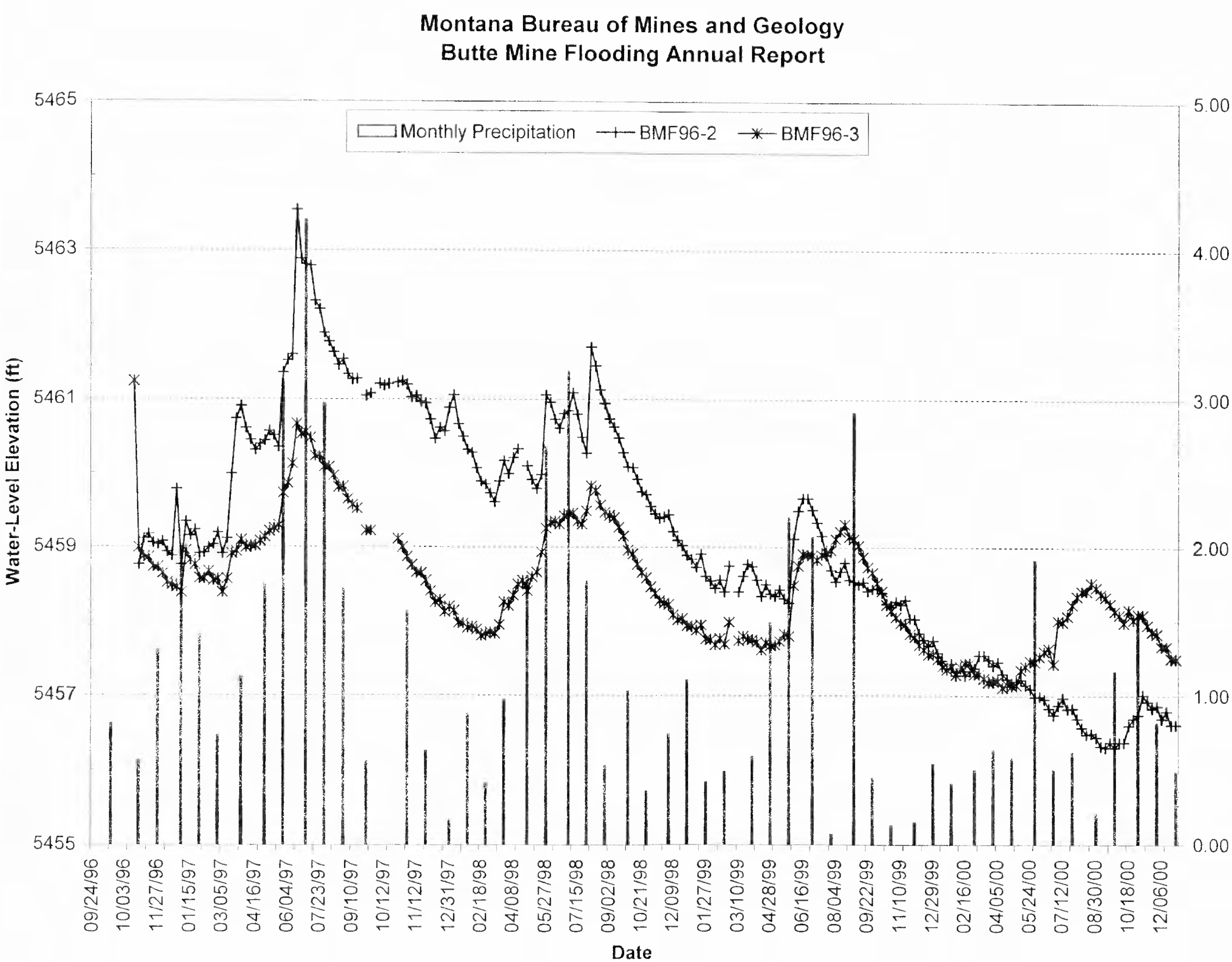

Figure 3-7. Water-level hydrograph for wells BMF96-2 and BMF96-3.

Section 4.0 Outer Camp System

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

Outer Camp water levels continued to decline in 2000, following the trend seen in 1999. Table 4.0.1 contains yearly water level change data, while figure 4-2 shows these changes graphically.

Table 4.0.1 Annual Outer Camp Sites Water-Level Change

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	-1.10	-3.56	-3.56	
1989		-1.34	-4.23	
1990				
1991				
1992	1.41			
1993	5.49			0.36
1994	-0.72	4.66		2.51
1995	5.44	12.41		6.48
1996	-0.96	10.44	18.41	-1.47
**Total 10 Year Change*	*11.96*	*22.61*	*17.74*	*7.88*
1997	7.56	14.50	16.42	7.76
1998	-2.79	0.59	2.17	-2.72
1999	-1.94	-2.87	-2.32	-1.57
2000	NA	-0.95	-1.31	-4.24
***Total Change**	**14.79**	**33.88**	**25.58**	**7.11**

*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 observations between this site and the Tech well, water levels probably continued to decline throughout 2000.

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

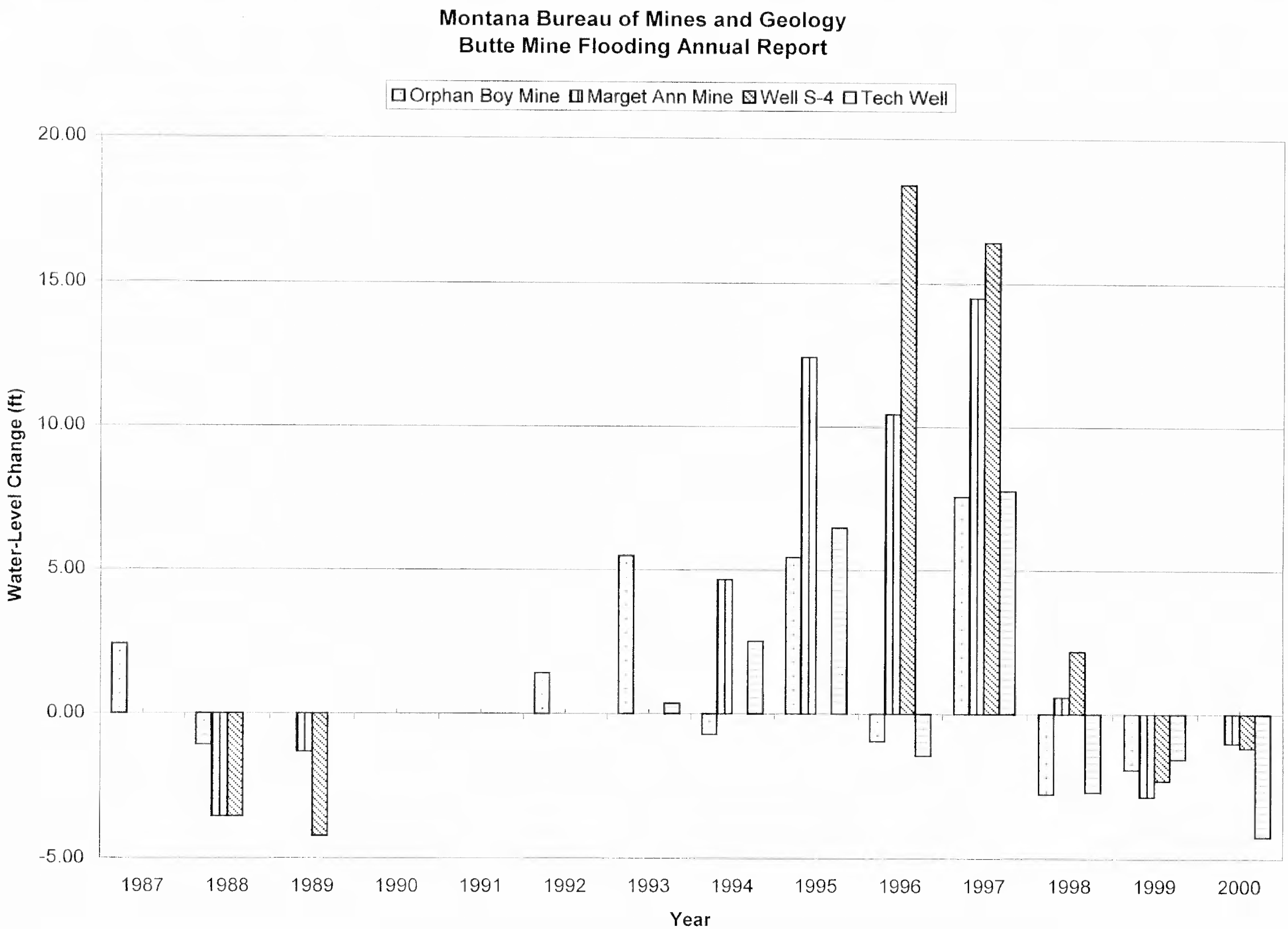

Figure 4-2. Outer Camp sites annual water-level change.

Figure 4-3 shows water levels for the Orphan Boy Mine and the Montana Tech water well along with monthly precipitation amounts. Water levels in the Tech well did not show the same response to precipitation events as seen in previous years, rising in the spring and then declining throughout the winter.

Water levels in the Marget Ann Mine and well S-4 fell between 0.95 ft and 1.31 ft during 2000. Figure 4-4 is a water level hydrograph for these two sites, with monthly precipitation totals shown. Water levels from 1994 through 1997 showed a consistent increase throughout this time period regardless of precipitation amounts. Since then water levels have fallen, but still appear to have little influence from precipitation. Water levels in the Marget Ann Mine dropped throughout 2000 regardless of precipitation trends. A similar trend occurred in well S-4.

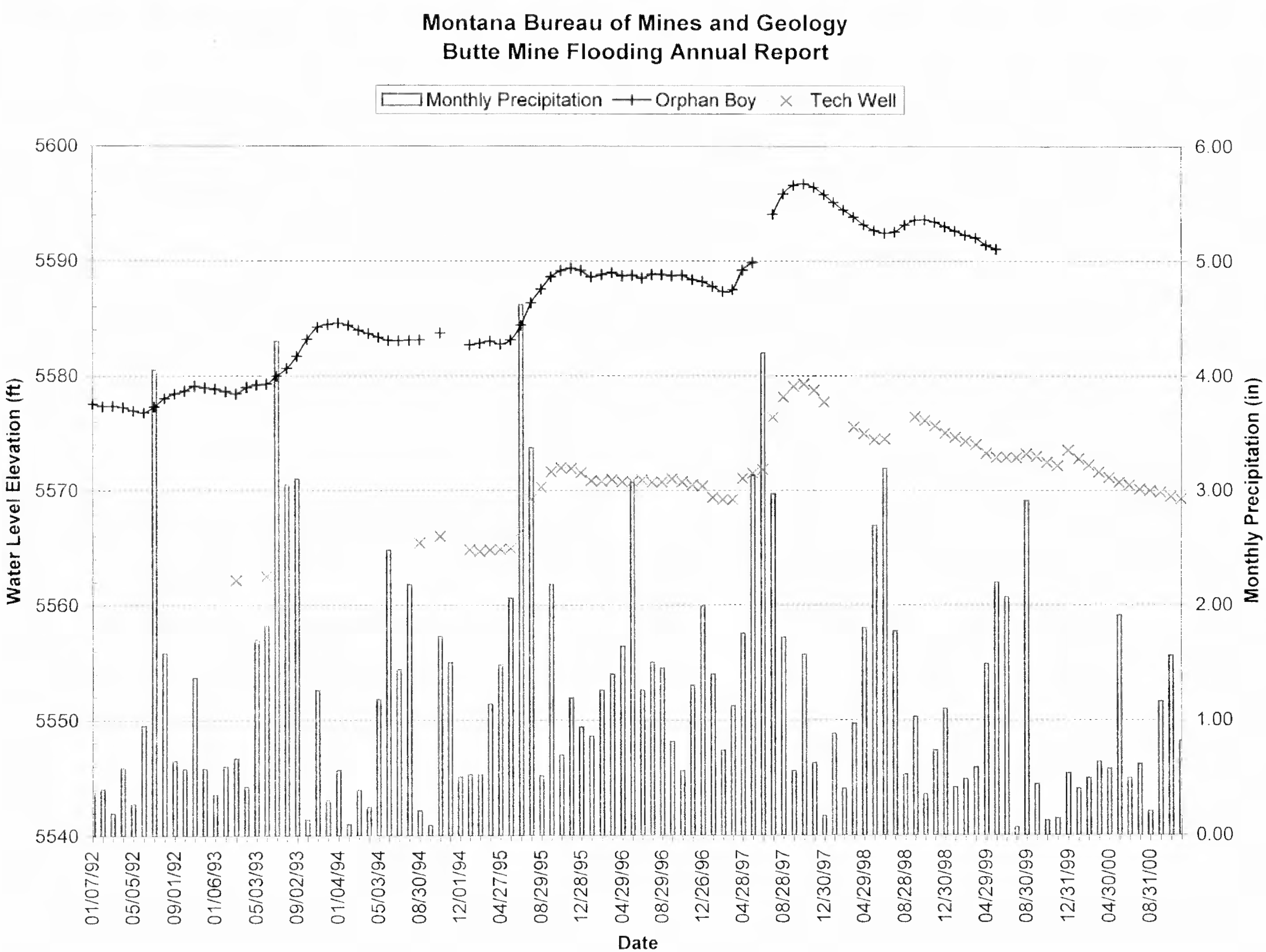

Figure 4-3. Water-level hydrograph of the Orphan Boy Mine and Montana Tech well.

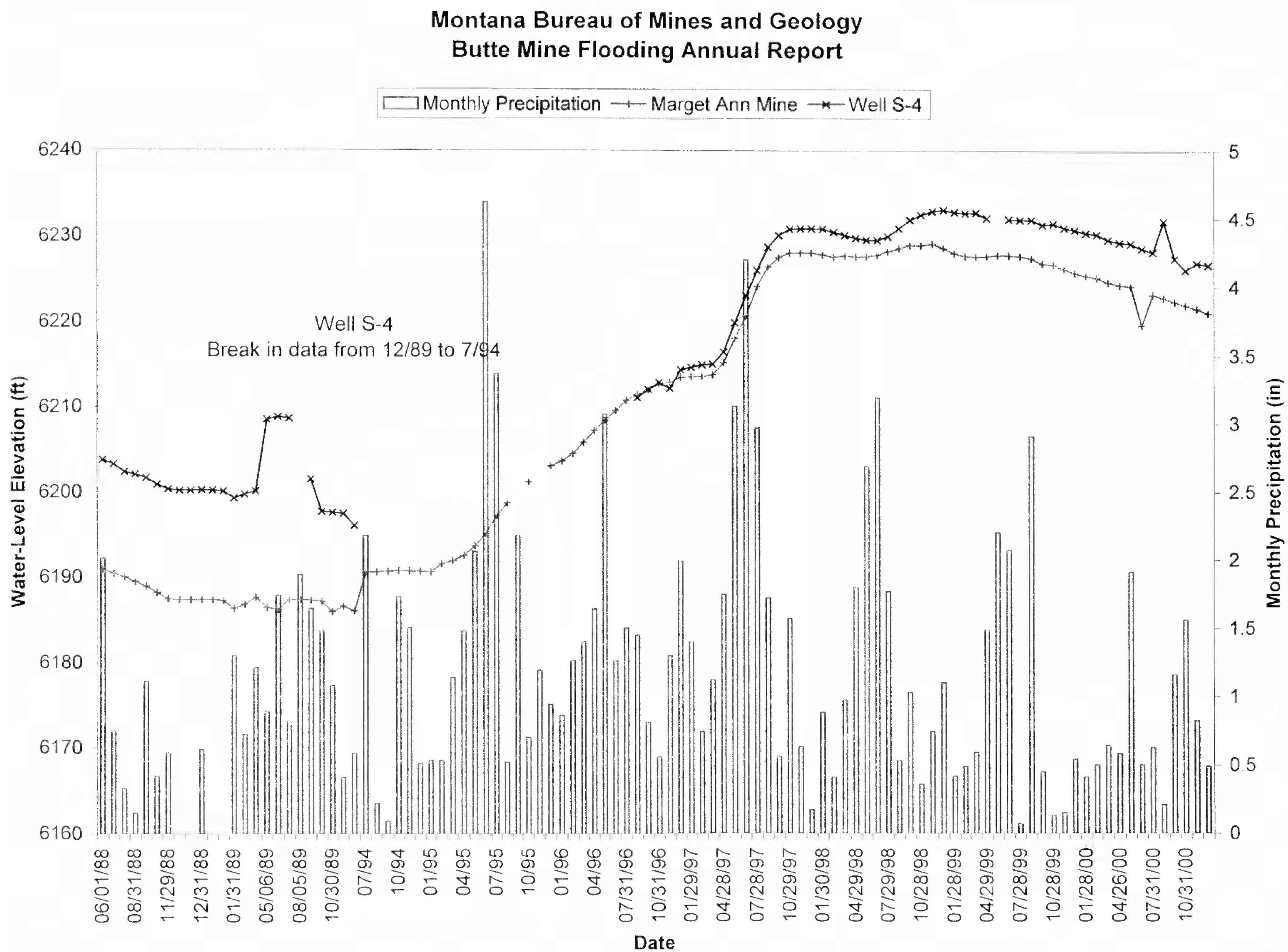

Figure 4-4. Water-level hydrograph for Marget Ann Mine and Well S-4.

5.0 Miscellaneous Wells

The location of the miscellaneous monitoring wells is shown on figure 5-1. These sites consist of 11 shallow alluvial monitoring wells (MF) and 2 bedrock-monitoring wells. Two of the alluvial wells have been damaged and are no longer monitored.

Water levels fell in all 9 of the remaining alluvial wells during 2000, following the trend seen in 1999. Annual water level changes are listed in Table 5.0.1. Total water-level changes since 1983 are a foot or less (up or down) in most of these wells.

Figures 5-2, 5-3, and 5-4 are water level hydrographs for alluvial wells MF-1, MF-05, and MF-10, showing monthly water-level variations along with monthly precipitation totals. Water levels respond to precipitation events very quickly in all of these wells. Water-level variations are greater in wells MF-05 and MF-10 then those seen in well MF-01. Water levels gradually increased in those two wells from 1993 through 1998 before declining most of 1999 and 2000. All three of these wells showed a water-level rise in September and October followed by a decline the remainder of the year. The decline in water levels could be due in large part to below-average precipitation during 1999 and 2000.

Water levels fell in the Hebgen Park bedrock well during 2000, while having a net rise in the Parrott Park well, table 5.0.1.

Figure 5-5 is a water-level hydrograph for the Hebgen Park well. Water levels declined throughout the first six months of 2000, before leveling off the remainder of the year. Water levels did not appear to respond to precipitation as consistently as seen in previous years. The lack of, or decrease, in precipitation, however, could account for the water level decline in this well.

The water-level hydrograph for the Parrott Park well is shown on figure 5-6, along with monthly precipitation totals. Water levels continued their decline from 1998 through the first eight months of 2000. However, from September and into early December, water levels rose over 7-ft. As a result this well had a net water-level rise of 1.5-ft for 2000, compared to a net decline the previous two years. It is probable that irrigation of the park lawn has more of an affect on water level increases and extends these increases into the fall. Precipitation did not have any noticeable influence on water levels in this well during 2000.

Table 5.0.1 Miscellaneous Well Annual Water Level Change

Year	MF-1	MF-2	MF-3	MF-4	MF-5	MF-6	MF-7	MF-8	MF-9	MF-10	MF-11	Hebgen [1]	Parrott
1983	-0.24	-0.13	-0.64	-0.20	-0.09	-0.09	-0.93	0.53	-0.65	-0.41	-0.59		
1984	1.02	-0.09	-0.03	0.89	-0.25	-0.14	0.37	0.09	-0.28	0.57	-0.23		
1985	-1.00	-0.02	0.19	-0.21	-0.33	0.59	-1.17	-0.01	-0.10	-0.60	-0.29		
1986	0.00	0.10	0.22	0.29	0.40	0.08	1.01	0.13	-0.10	0.00	-0.35		
1987	-0.12	-0.05	-0.37	-0.88	-0.10	-0.99	-0.01	-0.03	-0.41	-0.11	0.45		
1988	-0.54	-0.05	0.08	0.38	-0.18	-0.13	-0.01	-0.05	0.17	0.01	-0.31	1.54	1.43
1989	0.34	0.18	0.20	0.38	0.86	0.24	0.10	0.08	0.21	0.03	0.13	-2.18	0.42
1990	0.09	0.13	0.26	0.08	0.10	0.14	0.16	0.14	-0.01	0.15	1.17	-1.90	5.23
1991	0.16	0.13	0.19	0.79	0.03	0.00	-0.13	0.52	0.84	2.15	-0.84	3.09	-6.10
1992	-0.18	-0.06	-0.12	-0.68	-0.47	0.00	-0.69	-0.50	-0.65	-1.94	-0.31	-1.40	0.63
**Total 10 Year Change*	*-0.47*	*0.14*	*-0.02*	*0.84*	*-0.03*	*-0.30*	*-1.30*	*0.90*	*-0.98*	*-0.15*	*-1.17*	*-0.85*	*1.61*
1993	0.13	0.06	0.13	0.77	0.60	0.00	0.13	0.20	0.38	0.07	0.52	6.27	1.39
1994	-0.06	-0.02	0.21	-0.11	0.15	0.00	0.31	0.07	-0.22	0.00	0.03	-0.25	5.96
1995	-0.10	-0.01	-0.99	0.32	0.66	0.00	0.46	0.05	-0.78	0.12	0.03	NA	2.67
1996	0.16	0.15	1.12	-0.01	0.27	0.00	0.22	-0.81	0.81	0.22	-0.70	2.75	-1.50
1997	0.05	0.16	-0.89	0.20	0.35	0.00	0.00	0.90	1.92	0.30	1.17	4.22	4.75
1998	0.65	P&A	0.46	-0.04	-0.04	P&A	0.28	0.34	-1.87	0.16	0.10	-0.62	-0.33
1999	-0.21	P&A	0.05	-0.79	-0.91	P&A	-0.33	-0.48	0.06	-0.45	-0.42	-2.93	-5.34
2000	-0.26	P&A	-0.14	-0.54	-1.01	P&A	-0.36	-0.25	-0.60	-0.24	-0.52	-5.98	1.50
***Total Change**	**-0.11**	**0.48**	**-0.07**	**0.64**	**0.04**	**-0.30**	**-0.59**	**0.92**	**-1.28**	**0.03**	**-0.96**	**2.61**	**10.71**

(1) Hebgen Park Well – No data from June 1992-Jan 1993, Jan1995-Sept 1996, and Jan 1998-Jan 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.

Figure 5-1. Miscellaneous monitoring wells location map.

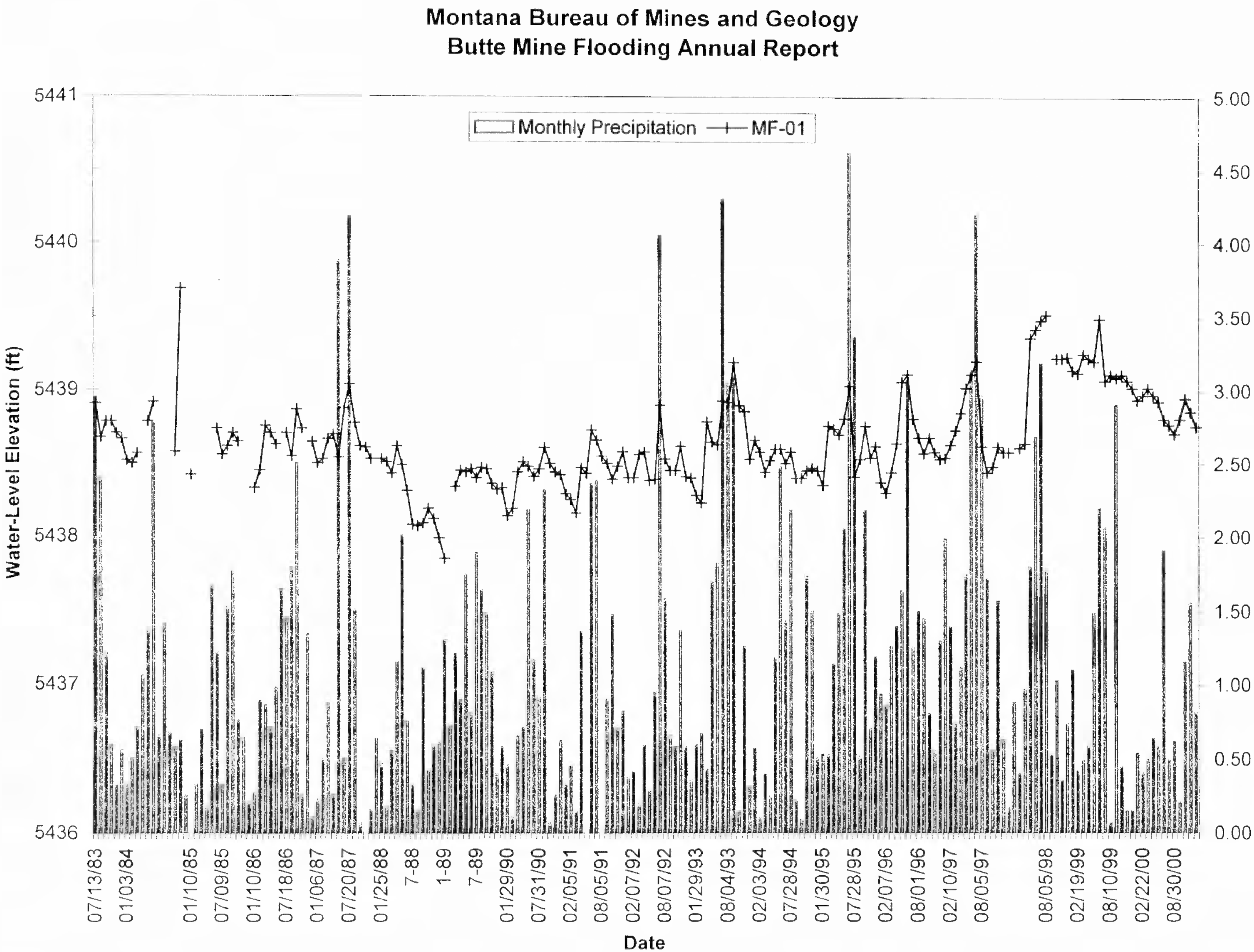

Figure 5-2. Water-level hydrograph for well MF-01.

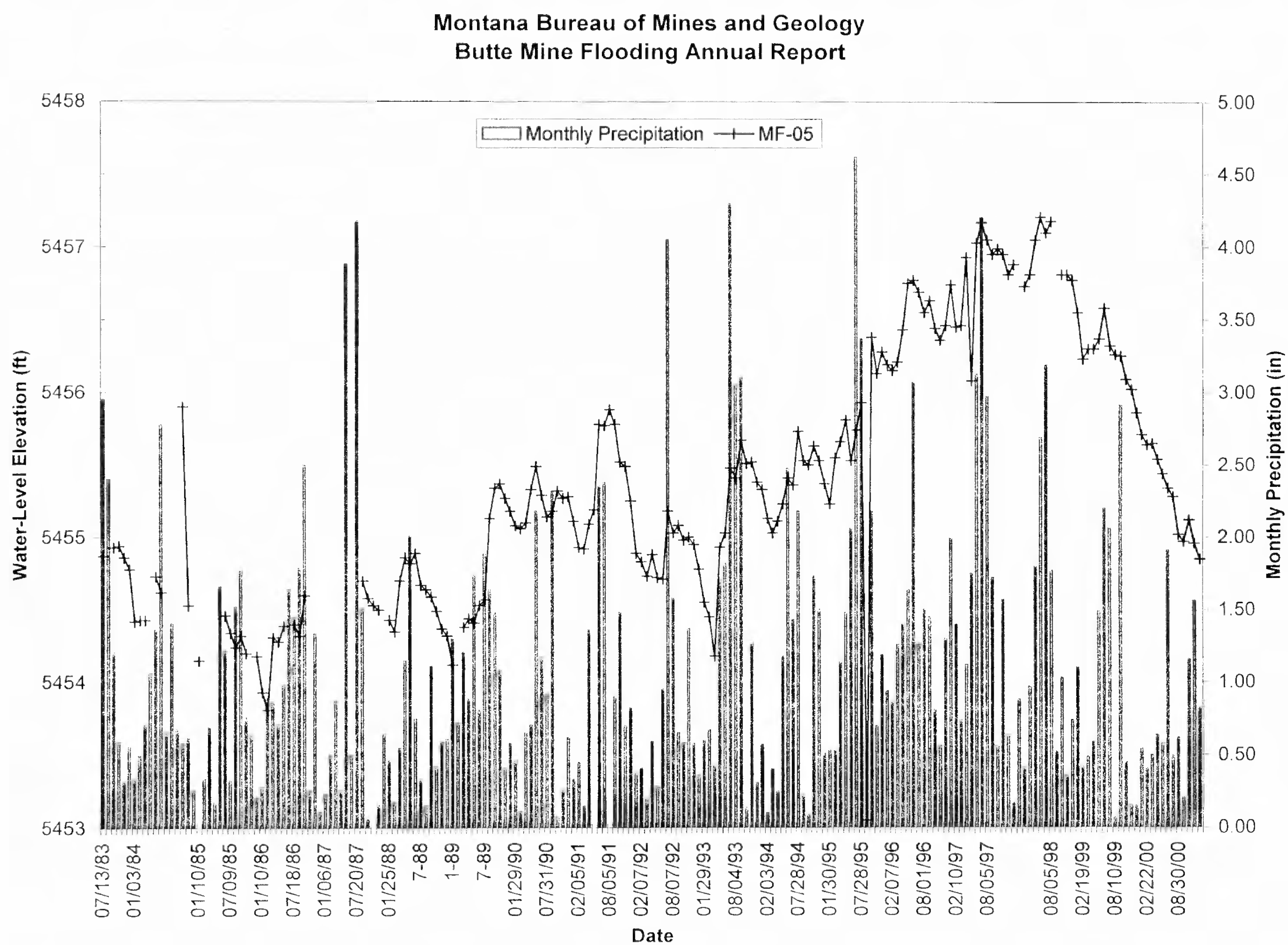

Figure 5-3. Water-level hydrograph for well MF-05.

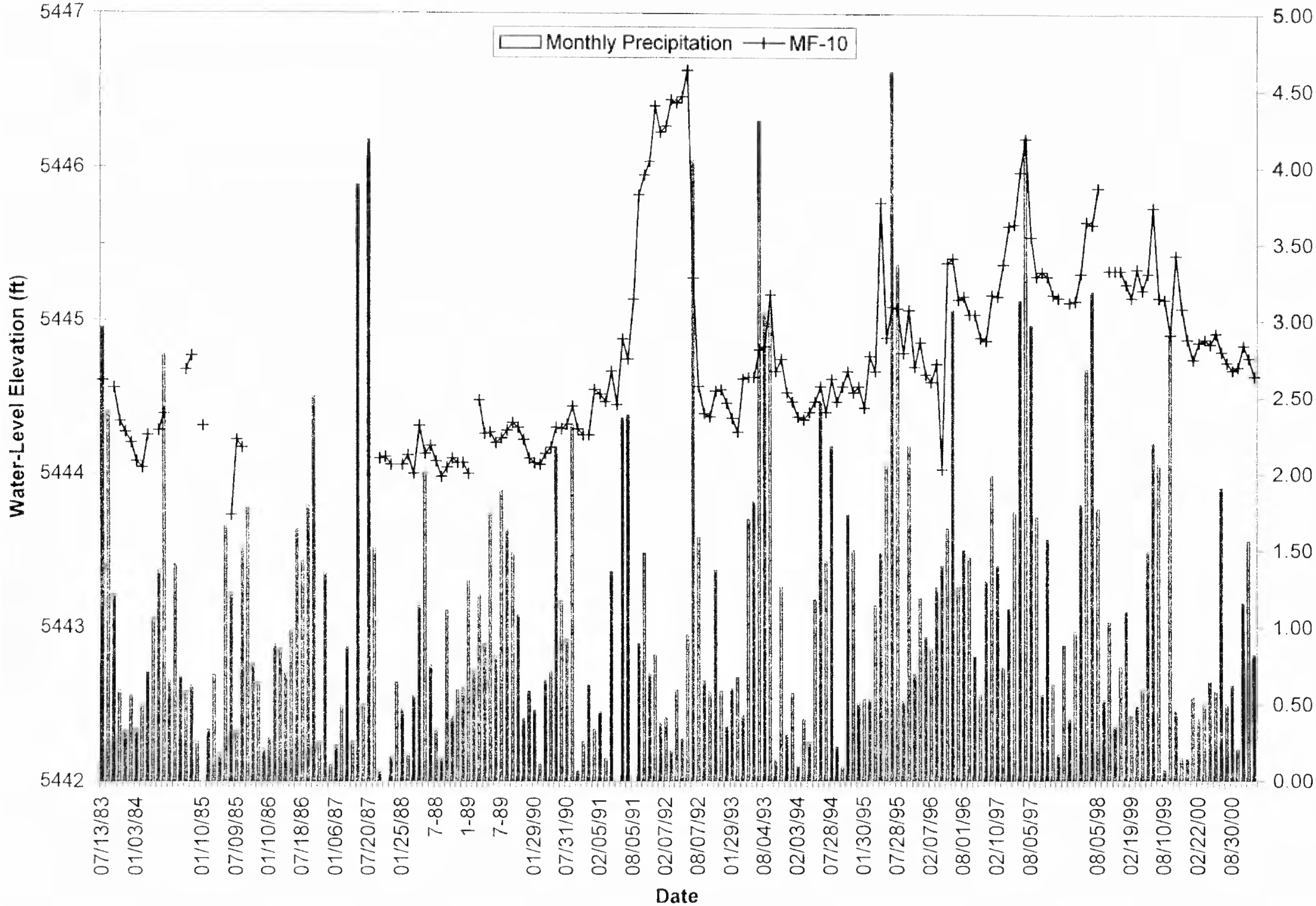

Figure 5-4. Water-level hydrograph for well MF-10.

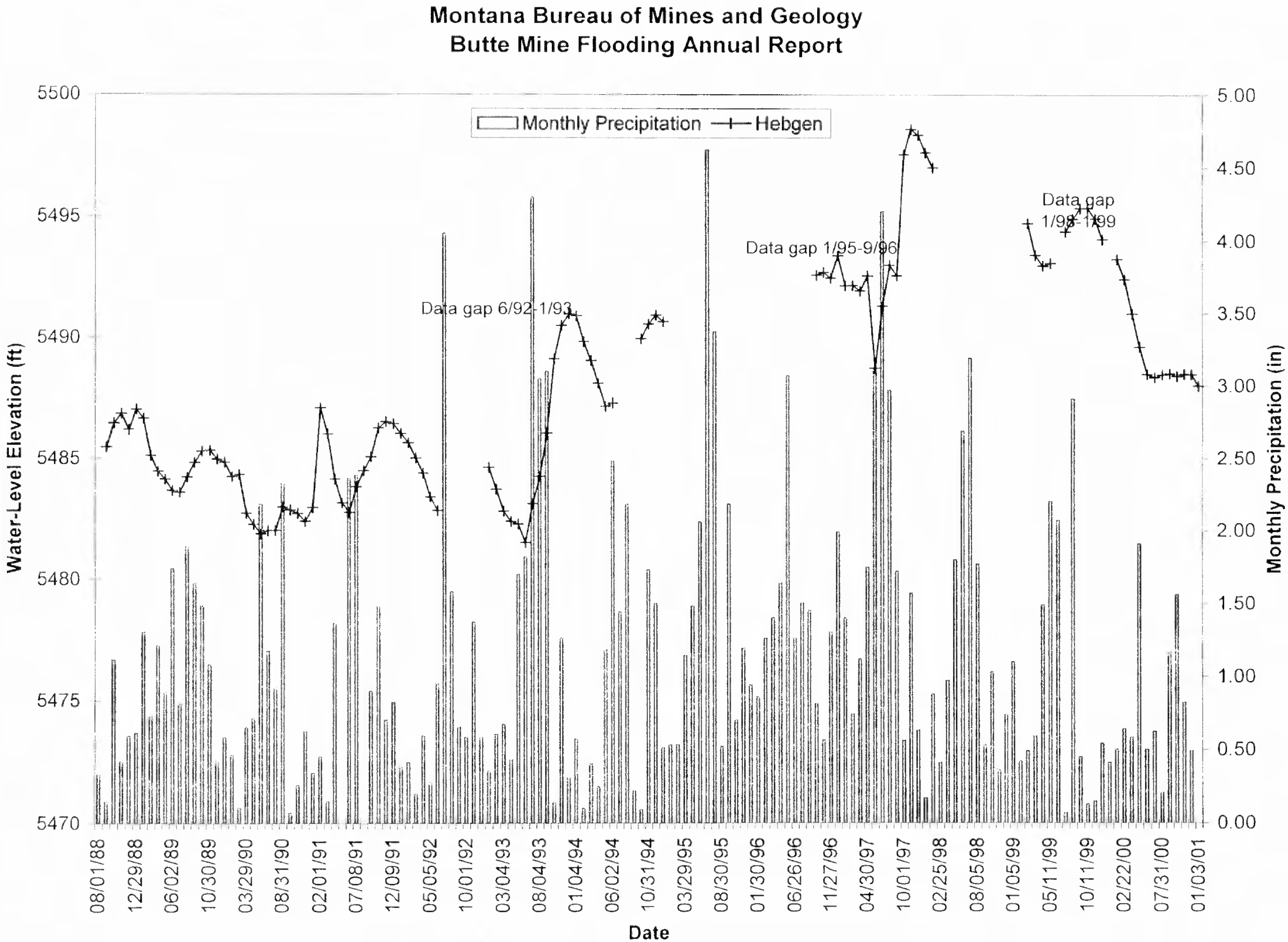

Figure 5-5. Water-level hydrograph for the Hebgen Park Well.

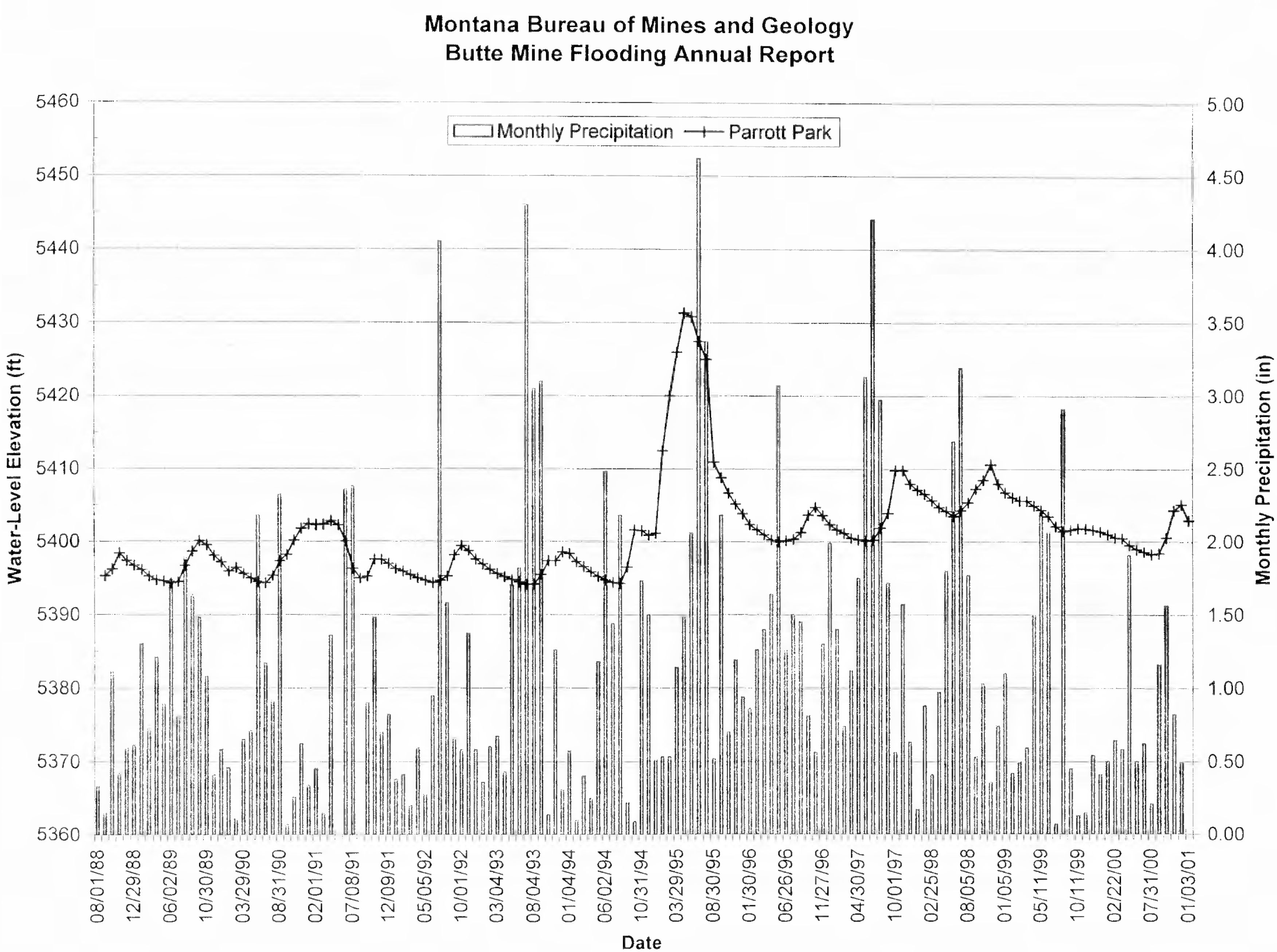

Figure 5-6. Water-level hydrograph for Parrott Park well

Section 6.0 Review of the Berkeley Pit Model

MR updated the Berkeley Pit water-level model based upon actual 2000 water-level measurements. The model update included water-level increases resulting from the suspension of mining and milling operations by MR. The suspension of mining activities resulted in the input of water from the HSB drainage into the Berkeley Pit the last six months of 2000.

Based upon the model updates, it is projected that the water level of 5410-ft (critical water level) will be reached at the Anselmo Mine in 2018, three years earlier than that predicted in the 1999 model (MR 2001). The model update assumes the continued input of HSB drainage water through June 2003, when the HSB water treatment plant is scheduled for completion. Water from the HSB drainage will then be diverted away from the pit and into the treatment plant. The treated water will be discharged to Silver Bow Creek. The review of treatment technologies will begin in 2003 with construction of the treatment plant scheduled to begin in 2010. The treatment technology and plant construction time frame are based upon the schedule listed in the EPA 1994 ROD for the Butte Mine Flooding Operable Unit (EPA, 1994). If mining were to resume, or the treatment plant came on-line sooner, the dates listed above would be extended.

Water level trends in the alluvial monitoring system were similar to those noted in previous reports at most of the monitored sites. A decrease in water levels continued in a majority of the alluvial wells during 2000. The decline in water levels in alluvial monitoring wells to the south and southeast of the September 1998 Berkeley Pit landslide continued.

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

Water levels in a majority of the alluvial monitoring wells, located outside the mine area, show a response to seasonal precipitation events. The response time varies from immediate, to a 2-3 month lag-time. Therefore, the decrease in annual precipitation in the Butte Basin during 1999 and 2000 probably accounted for a good portion of the overall water-level decrease seen in a number of monitoring wells.

No notable precipitation influence was seen in any of the East Camp bedrock wells or underground mines. The water level changes (increases) are independent of precipitation and are a result of the cessation of long-term mine dewatering activities in 1982. However, the addition of HSB drainage water into the Berkeley Pit did have a substantial influence on East Camp bedrock water levels. Water levels rose an average of 0.89-ft per month the first six months of 2000, while rising an average of 1.93-ft the remainder of the year. This increase doubled the amount of the monthly rise, which means for every month the HSB drainage water is allowed to flow into the Berkeley Pit, the date for eventual treatment of Berkeley Pit water is shortened by a month.

The date the East Camp system water level was predicted to reach the Critical Water Level (CWL) elevation of 5410-ft was reduced by three years from 2021 to 2018. This new date reflects the assumed three years of HSB drainage water entry into the pit, until a water treatment plant is built to treat the HSB water. The CWL date is assumed to be the date the 5410-ft elevation would be reached at the Anselmo Mine. The Anselmo Mine is the anticipated compliance point in order to keep the Berkeley Pit the low point in the East Camp bedrock-mine system. This will ensure that all water in the historic underground mine system will continue to flow towards the Berkeley Pit.

The pumping of groundwater in the West Camp System continues to control water levels in this system. The volume of water pumped during 2000 was less than that of previous years, resulting in over a 5-ft increase in water levels in this system. This occurred even though 2000 precipitation amounts were below normal.

The rehabilitation work performed on bedrock well D-1 demonstrated that PVC liners could be successfully installed in the deep bedrock wells, thus extending their useful life.

The redevelopment work performed on four of the bedrock wells also shows the need for constant review of monitoring well integrity and occasional maintenance of these wells.

Results of the 2000 water level monitoring continue to show that the current monitoring program is adequate for ensuring that contaminated bedrock groundwater is flowing into the Berkeley Pit, and that West Camp water levels are being sufficiently controlled by West Camp pumping operations. These are two of the main environmental concerns associated with the flooding of Butte's historic underground mines and the Berkeley Pit.

Continued long-term water-level monitoring throughout the entire Butte Hill mine system (East Camp, West Camp and Outer Camp) and the associated shallow alluvial aquifer should continue to enable better recognition, prediction and interpretation of trends seen to date. Water-level changes caused by the September 1998 Berkeley Pit landslide act to verify this need for continued monitoring. The influence on water levels continue to be seen a considerable distance to the south of the pit, extending into areas outside the active mine area. This shows considerable interconnection of the shallow alluvial system previously not seen, or thought to occur, as the result of discontinuous clay lenses in the alluvial system. (Canonie, 1993).

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