Butte Mine Flooding Operable Unit
Water-Level Monitoring and Water-Quality Sampling
2013 Consent Decree Update
Butte, Montana
1982–2013

prepared for

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

October 2014

Prepared by

Terence E. Duaime
Nicholas J. Tucci
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1300 West Park Street
Butte, MT 59701-8997

Contract No. 400022-TO-35

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Montana Bureau of Mines and Geology Open File Report 650

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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 existing information. This report presents data collected during the year 2013, combined with data collected since 1982, when the Anaconda Company suspended underground mine dewatering and mining in the Berkeley Pit.

Major observations and developments discussed in this report are:

1. A rotational slump occurred in the southeast corner of the Berkeley Pit on February 8, 2013, resulting in a water-level rise of about 0.60 ft This slump occurred while Montana Resources was attempting to stabilize the area where two slumps occurred in 2012, by pushing waste rock from the Pittsmont Dump into the pit. The slump increased the volume of material that entered the pit. The area adjacent to the slump continued to be a concern for further slumps and a safety concern for personnel sampling within the pit. As a result, no monitoring/water-quality sampling was undertaken on the pit water surface during 2013; Montana Resources suspended Berkeley Pit copper recovery activities.
2. The annual Berkeley Pit model was updated, taking into account the continued diversion of Horseshoe Bend drainage water away from the pit, discharge of sludge from the treatment plant into the pit, waste material from the February 2013 slump, and the addition of storm water flow from the Butte Hill. The projected date when the 5,410-ft water-level elevation would be reached at the Anselmo Mine was modified from July 2023 (2012 Report) to May 2023, <u>a change of 1.3 months;</u>
3. A constriction was noted in well LP-17 during spring sampling activities, preventing water-quality sampling. The well was plugged and abandoned and a replacement well (LP-17R) was drilled nearby. The new well was sampled during the fall 2013 sampling event.
4. Water-quality variations in East Camp alluvial well LP-16 continued. Well LP-16 was sampled twice with moderate increases in sulfate, copper, and zinc continuing;
5. West Camp pumping activities were discontinued from July 8, 2013 to September 17, 2013 to allow water levels to rise as part of a study to review the system's critical water level. The

Environmental Protection Agency and Montana Department of Environmental Quality provided a temporary waiver of the 1994 Record of Decision and 2002 Consent Decree to allow this test. Additional water-level monitoring and water-quality sampling were undertaken to ensure that no problems occurred in the shallow groundwater system during the test period. The volume of water pumped in 2013 was 74 percent of the 2012 volume (164.5 acre-ft vs. 223.6 acre-ft). Water levels increased between 11.5 and 12.59 ft throughout the West Camp underground system; and

6. Montana Resources continued to use water from the Horseshoe Bend drainage in leach pad operations. Flows from 1,200 to 2,500 gallons per minute were diverted.

Total and yearly water-level changes for all sites are presented along with hydrographs for <u>selected</u> sites. Water-quality data follow the presentation of water-level data in each section where water-quality data are available. All sites are not sampled for water quality.

Monitoring and sampling activities performed during 2013 reflect the long-term program outlined in the 2002 Consent Decree. Therefore, some monitoring sites that were part of the early monitoring program have been deleted, while others have been added.

List of acronyms used in text

ACM	Anaconda Copper Mining Company
AMC	Anaconda Mining Company
ARCO	Atlantic Richfield Company
BABCGWA	Butte Alluvial and Bedrock Controlled Groundwater Area
ARCO	Atlantic Richfield Company
BMFOUButte Mine Flooding Operable Unit	
BPSOU	Butte Priority Soils Operable Unit
BSB	Butte–Silver Bow
COC	Contaminants of Concern
CD	Consent Decree
CWL	Critical Water Level
DEQ	Montana Department of Environmental Quality
DNRC	Montana Department of Natural Resources and Conservation
DO	Dissolved Oxygen
EPA	U.S. Environmental Protection Agency
fbs	Feet below Ground Surface
gpm	Gallons per Minute
GWIC	MBMG Ground Water Information Center
HSB	Horseshoe Bend Drainage
HSB Falls	Horseshoe Bend Falls
MBMG	Montana Bureau of Mines and Geology
MCL	Maximum Contaminant Level
MGD	Million Gallons per Day
MPTP	Montana Pole and Treatment Plant NPL Site
MR	Montana Resources
MSD	Metro Storm Drain
MSL	Mean Sea Level
NAVD29	North American Vertical Datum of 1929
NAVD88	North American Vertical Datum of 1988

ORP	Oxidation-Reduction Potential
POC	Points of Compliance
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SBC	Silver Bow Creek
SC	Specific Conductance at 25^{0}C
SMCL	Secondary Maximum Contaminant Level
SWL	Static Water Level
WCPW	West Camp Pumping Well

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SECTION 1.0 SITE BACKGROUND

Butte has a long history of mining dating back to 1864, with the development of gold placers in Missoula and Dublin gulches and along Silver Bow Creek (Miller, 1978). Placer mining only lasted for a short period of time. It was followed by the development of silver mining in 1866 (Miller, 1978). The major silver deposits were developed in the early 1870s and consisted of such mines as the Alice, Travona, Lexington, and Colusa. However, with the repeal of the Sherman Silver Purchase Act in 1893, and the presence of high-grade copper outcrops, Butte mining shifted its focus to the development of copper deposits.

Mining expanded and mines deepened as mining companies followed the rich copper veins. With the expanded mining, improved methods to handle groundwater became a major concern; therefore, the mining companies began interconnecting mines to drain water to central pump stations to improve efficiency (Daly and Berrien, 1923). The Anaconda Copper Mining Company (ACM), which would eventually control a majority of the underground mines, began interconnecting selected mine levels for draining water to a central pump station as early as 1901. The High Ore Mine and Kelley Mine served as central pump stations collecting water and pumping it to the surface (figures 1-1 and 1-2). This water, which was acid in nature and contained high concentrations of dissolved minerals, necessitated specialized pumps and piping to transport the water. The pumps in the High Ore Mine were made of a phosphor-bronze alloy, whereas the discharge pipes (water column) were made of cast iron and lined with either lead or wood (Febles, 1913). The first common drain level was the 2,800 level; this was followed by the 3,800 level. The High Ore Mine served as the central pump station from 1901 until 1967, when the pump station was moved to the Kelley Mine. Once the water reached the surface it was routed to a precipitation plant for recovery of copper (figure 1-3). Once the copper was removed from the water, the water was discharged to Silver Bow Creek. This practice of discharging untreated, acidic, metal-laden water to Silver Bow Creek continued until the late 1950s when the Anaconda Company began adding lime to the water to raise the pH and reduce the mineral content of the water (Spindler, 1977).

The recovery of copper precipitate from underground mine water had been a common practice on the Butte Hill since the 1890s (Febles, 1913). Leaching of copper from old mill tailings and upper portions of underground mine workings occurred on the Butte Hill to various degrees. Some of the leaching was a by-product of water introduced into the underground workings to fight mine fires. As water percolated through the underlying workings, it was found to contain substantial quantities of copper and was pumped to precipitation plants for processing (Gillie, 1943). At various times precipitation plants were associated with the High Ore, Leonard, and Silver Bow mines for copper recovery. Febles (1913) reported that about 1,200 gallons per minute (gpm) of water was delivered to the High Ore precipitation plant; he also stated that the plant produced approximately 2,200,000 pounds of pure copper annually from this water.

The cost of mining increased as the mines deepened and the ore grades lessened. Therefore, the Anaconda Company began open-pit mining operations in the Berkeley Pit in July 1955. As the open-pit mining expanded, it consumed some of the primary underground mines (figure 1-4) that were important to Butte's early development. Figures 1-5 and 1-6 show a comparison of Butte's topography between 1904 and 2012 using digital elevation models. The impacts of open pit mining and associated waste facilities are very noticeable to the north and northeast of the Berkeley Pit (figure 1-6).

Figure 1-1. High Ore Mine pump station, 2800-ft level. (Photo courtesy World Museum of Mining, Butte, MT.)

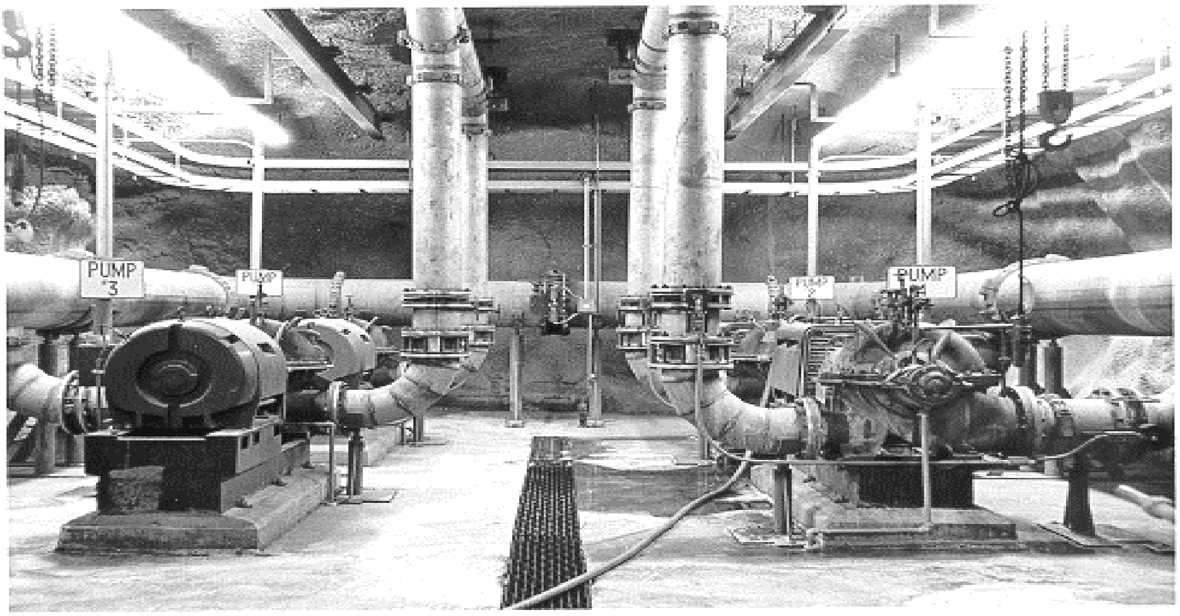


Figure 1-2. Kelley Mine pump station, 3900-ft level. (Photo courtesy World Museum of Mining, Butte, MT.)

Figure 1-3. Flume conveying water pumped from Butte underground mines to precipitation plant. (Photo courtesy World Museum of Mining, Butte, MT.)

Figure 1-4. Location of selected underground mines engulfed by development and expansion of the Berkeley Pit.

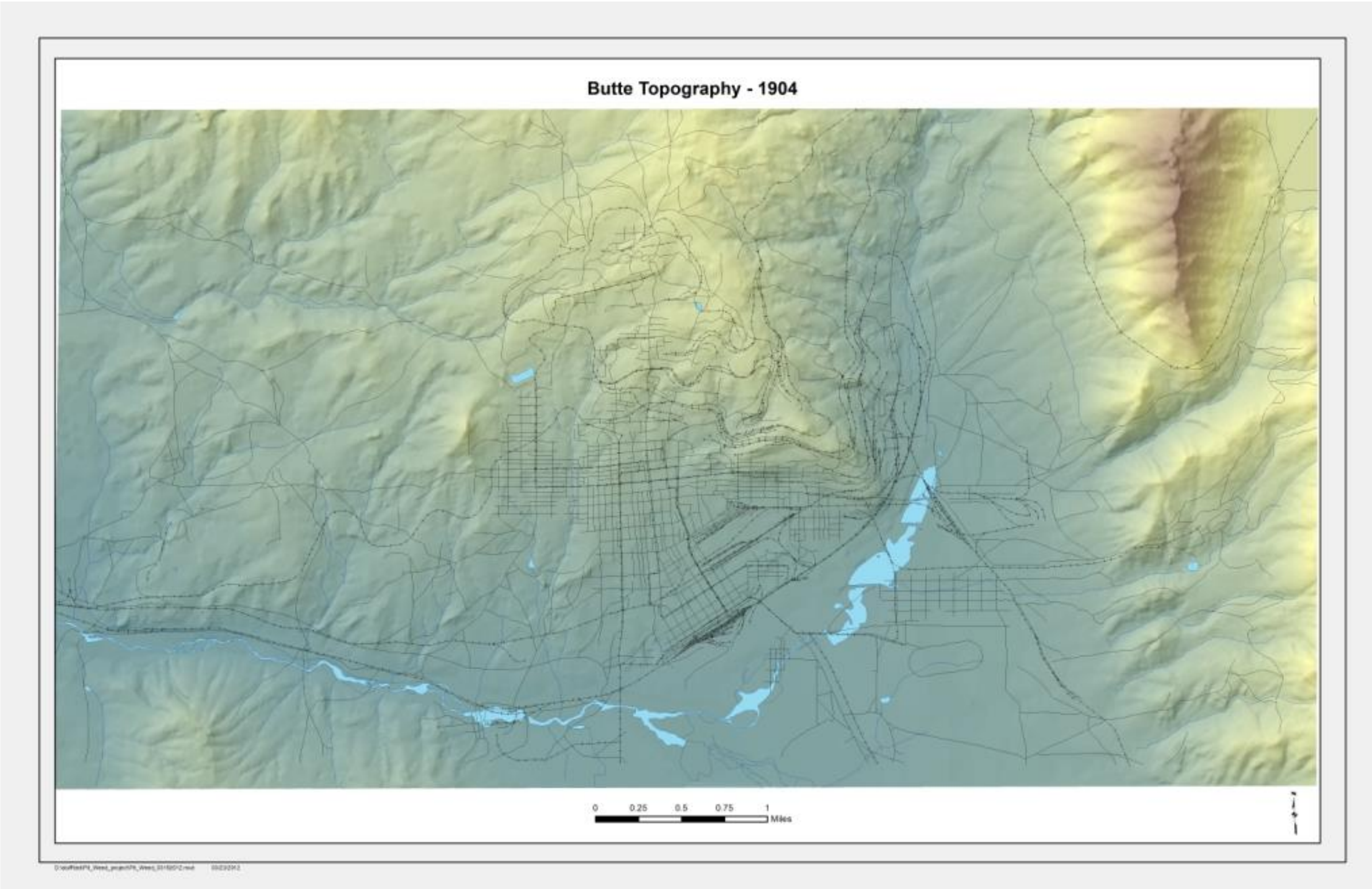


Figure 1-5. Digital elevation model showing Butte topography, 1904.

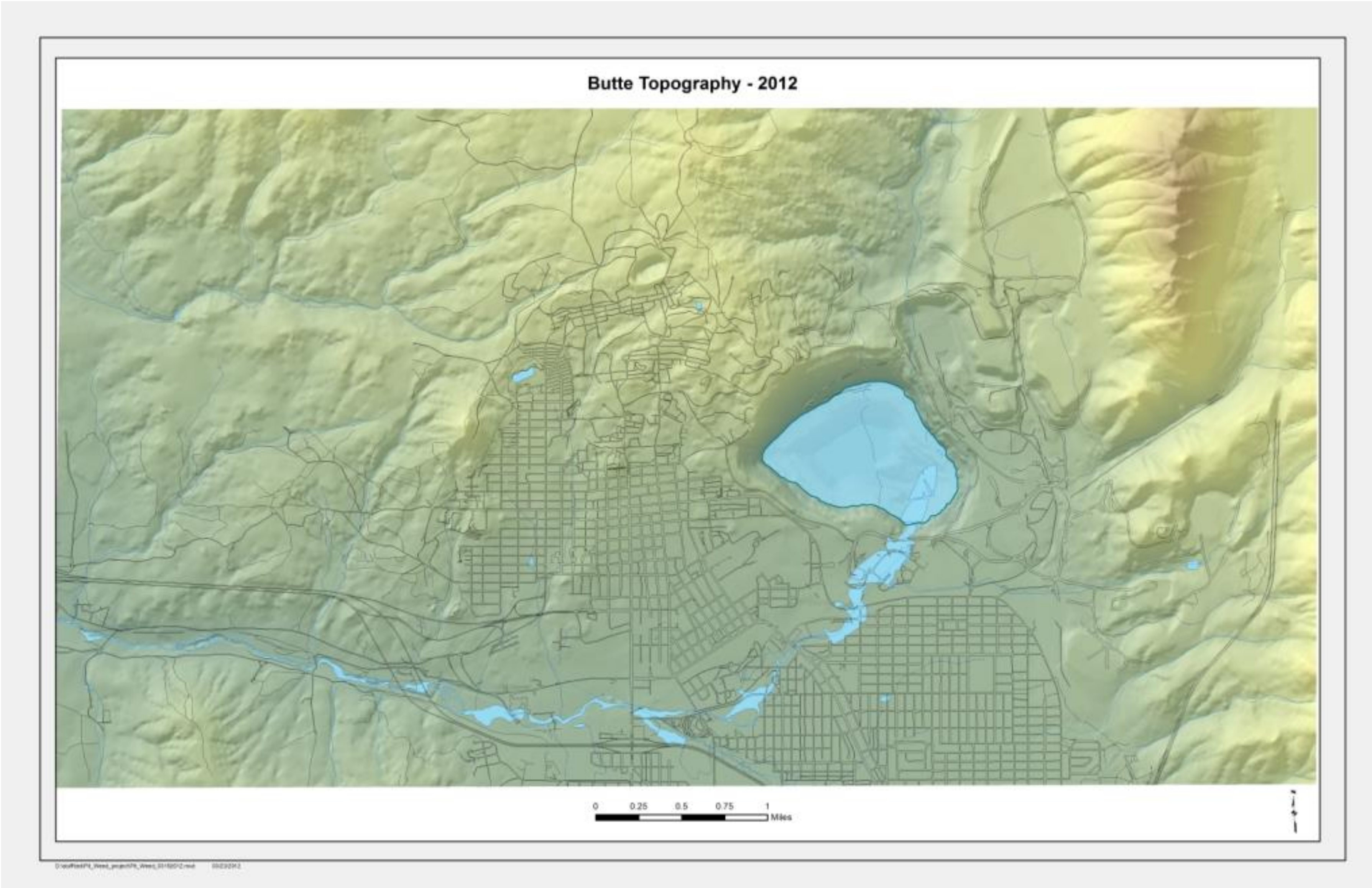


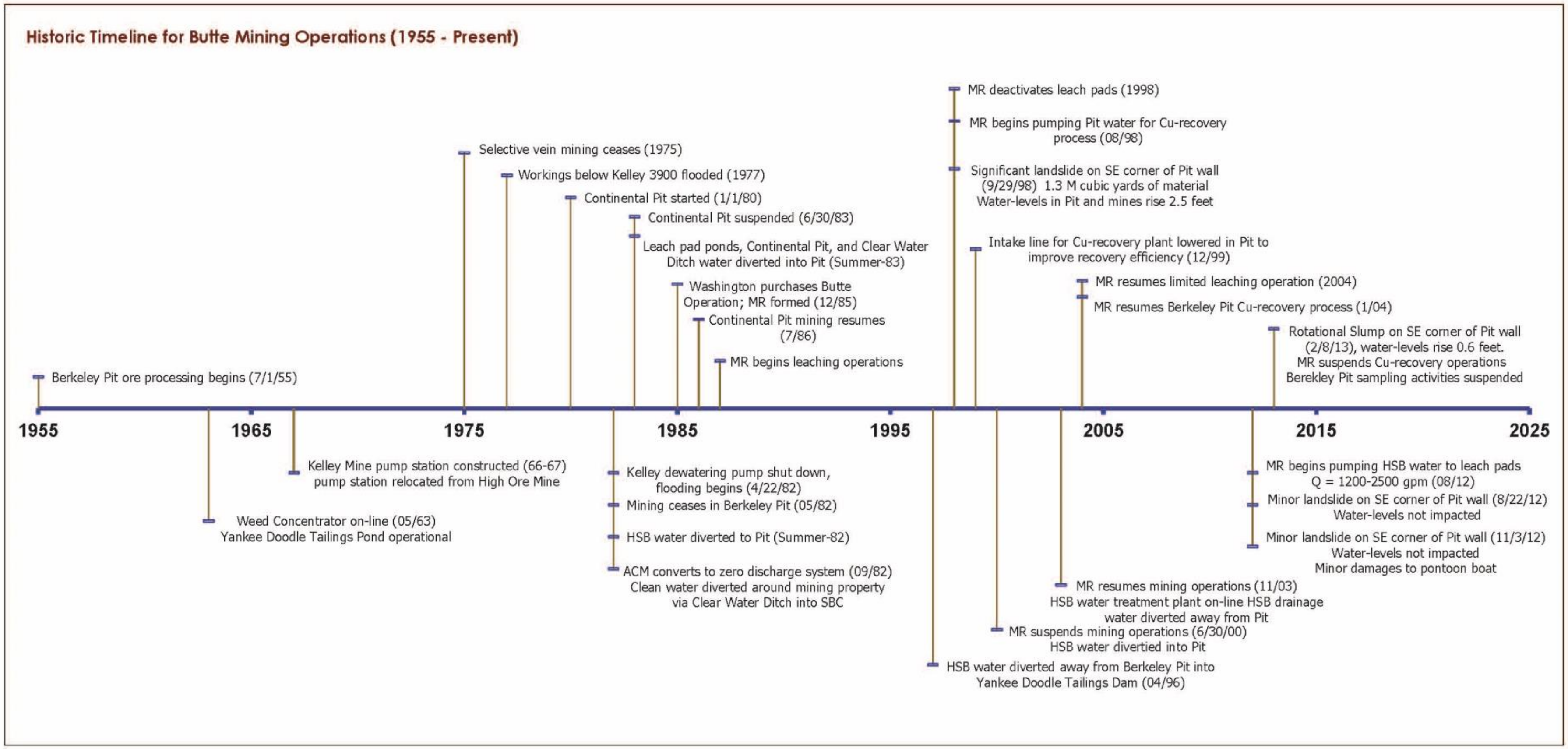
Figure 1-6. Digital elevation model showing Butte topography, 2012.

Active underground mining continued in the Kelley and Steward Mines until 1975 (Burns, 1994) when the Anaconda Company ceased underground mining operations; however, they continued to operate the underground pumping system, which not only kept the mines dewatered, but also did the same for the Berkeley Pit. When the Anaconda Company discontinued selective underground vein mining, they eventually allowed the lower-most mine workings to flood to a level just below the 3,900-level pump station in 1977.

Open-pit mining expanded to east of the Berkeley Pit with the development of the East Berkeley Pit in 1980 (Burns, 1994). This open-pit mine was developed to remove both copper and molybdenum reserves. The Berkeley Pit continued to operate until shortly after the Anaconda Company's announcement in April 1982 that they were no longer going to operate the Kelley Mine pump station. When the pumping suspension was announced, the pump station was removing up to 5,000 gpm of water. The East Berkeley Pit continued to operate until June 30, 1983, when the Anaconda Company closed all its Butte mine operations.

The Anaconda Company, which had been purchased by the Atlantic Richfield Company (ARCO) in 1977, sold its Butte operations to Dennis Washington in December 1985, who then formed Montana Resources (MR; Burns, 1994), renaming the East Berkeley Pit the Continental Pit. MR resumed mining in the Continental Pit in July 1986. Table 1.0.1 presents a timeline of selected activities relating to Butte mining operations, including the Berkeley Pit, Continental Pit, concentrator, underground mining, and ancillary activities from 1995 through 2013.

Table 1.0.1 Timeline for Butte operations, 1955–2013.



Section 1.1 Introduction

The Anaconda Company announced on April 23, 1982 the suspension of pumping operations at the Kelley Mine pump station, located at the 3,900-level of the mine. (The 3,900-level pump station was located at a depth of ~3,600 ft below ground surface.) At the same time, the Anaconda Company also announced the suspension of mining in the Berkeley Pit, beginning May 1982. However, they continued to operate the East Berkeley Pit (now referred to as the Continental Pit) until June 30, 1983, when they announced a suspension of all mining operations in Butte.

The Anaconda Company developed and implemented a groundwater monitoring program following the 1982 suspension of mining. This program included a number of mine shafts, alluvial dewatering wells, existing domestic and irrigation wells, along with a number of newly installed alluvial monitoring wells. Monitoring included water-level measurements and water-quality sampling. This monitoring program continued until changes were made as part of the Butte Mine Flooding Operable Unit (BMFOU) Superfund investigation.

The U.S. Environmental Protection Agency (EPA) and the Montana Department of Environmental Quality (DEQ) approved and oversaw the BMFOU Remedial Investigation/Feasibility Study (RI/FS) that ran from the fall of 1990 through the spring of 1994. Major tasks of the RI/FS included the installation of a number of new monitoring wells, both bedrock and alluvial. Access was also gained into several previously capped underground mines for monitoring purposes. The 1994 Record of Decision (ROD) included a monitoring program that included portions of the 1982 Anaconda Company monitoring network, portions of the RI/FS monitoring network, and portions of a supplemental surface-water and groundwater network operated by the Montana Bureau of Mines and Geology (MBMG) since the summer of 1983.

The ROD included provisions for: 1) continued monitoring and sampling of both groundwater and surface water, 2) diversion of the Horseshoe Bend Drainage (HSB) water away from the Berkeley Pit (to slow the pit-water filling rate), 3) incorporation of the HSB water in the MR mining operations for treatment, 4) construction of a water treatment plant if changes in mining operations prevent treatment of HSB water (e.g., mine shutdown), and 5) establishment of a maximum water 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 ROD monitoring program consisted of 73 monitoring wells, 12 mine shafts, and 3 surface-water-monitoring sites, which can be broken down into the following categories:

1) East Camp bedrock wells—18;

2) East Camp Mines—7;

3) East Camp alluvial wells within active mine area—19;

4) East Camp alluvial wells outside active mine area—31;

5) West Camp mines—3;

6) West Camp monitoring wells—5; and

7) Outer Camp mines—2.

The final monitoring network described in the 2002 Consent Decree (CD) replaced the ROD monitoring network; minor changes have been made to the 2002 CD Program and are shown in Table 1.1.1. The current (2013) monitoring program consists of 78 sites and includes: 61 monitoring wells, 11 mine shafts, and 6 surface-water sites. The monitoring network can be broken down into the following categories:

1) East Camp bedrock wells—12;
2) East Camp mines—6;
3) East Camp alluvial wells within active mine area—20;
4) East Camp alluvial wells outside active mine area—17;
5) Bedrock wells outside active mine area—4;
6) West Camp mines—3;
7) West Camp wells—6;
8) Outer Camp mines—2;
9) Outer Camp wells—2; and
10) Surface-water sites —6 (Berkeley Pit, Continental Pit (as appropriate), Horseshoe Bend, Blacktail Creek, Silver Bow Creek, and Outer Camp seep).

Table 1.1.1 Current Approved Monitoring Program,(comparison to 2002 CD Program).

Butte Mine Flooding Monitoring Sites		Water Level 2002 Consent Decree Monitoring Frequency	**Current Program (2013) WL Monit. Frequency**	Water Quality 2002 Consent Decree Monitoring Frequency	**Current Program (2013) Water Quality Frequency**
East Camp Mines[1]	Anselmo	M	**M**	Annual	**Annual**
	Belmont Well #2	1/4ly	**M**	NS	**NS**
	Granite Mountain	1/4ly	**M**	NS	**NS**
	Kelley	M	**M**	Annual	**Annual**
	Lexington	1/4ly	**M**	NS	**NS**
	Pilot Butte	1/4ly	**M**	NS	**NS**
	Steward	M	**M**	Annual	**Annual**
	Berkeley Pit	M	**M**	Twice/3Depths	**Twice/3Depths**
	HSB[2]	C/M	**C/M**	M	**M**
	Continental Pit[2]	M	**Inactive**	Twice/yr.	**Inactive**
RI/FS Wells - Bedrock	A	C/M	**C/M**	Semi-A	**Semi-A**
	B	M	**C/M**	Semi-A	**Semi-A**
	C	C/M	**C/M**	Semi-A	**Semi-A**
	D-1	1/4ly	**M**	Annual	**Annual**
	D-2	1/4ly	**C/M**	Annual	**Annual**
	E	Annual	**M**	2yrs	**2yrs**
	F	Annual	**M**	2yrs	**2yrs**
	G	C/M	**C/M**	Annual	**Annual**
	J	1/4ly	**C/M**	Annual	**Annual**
DDH Wells	DDH-1	1/4ly	**M/Plugged**	NS	**NS**
	DDH-2	1/4ly	**C/M**	NS	**NS**
	DDH-8	1/4ly	**M**	NS	**NS**
LP Wells	LP-01	1/4ly	**M**	NS	**NS**
	LP-02	1/4ly	**C/M**	NS	**NS**
	LP-03	1/4ly	**P&A**	NS	**NS**
	LP-04	1/4ly	**M**	NS	**NS**
	LP-05	1/4ly	**M**	NS	**NS**
	LP-06	1/4ly	**P&A**	NS	**NS**
	LP-07	1/4ly	**M**	NS	**NS**
	LP-08	M	**M**	Annual	**Annual**
	LP-09	1/4ly	**C/M**	Annual	**Annual**
	LP-10	M	**M**	Semi-A	**Semi-A**
	LP-11	P&A	**P&A**	NS/P&A	**NS/P&A**
	LP-12	M	**C/M**	Semi-A	**Semi-A**
	LP-13	M	**C/M**	Semi-A	**Semi-A**
	LP-14	C/M	**C/M**	Semi-A	**Semi-A**
	LP-15	M	**M**	Semi-A	**Semi-A**

Butte Mine Flooding Monitoring Sites		Water Level 2002 Consent Decree Monitoring Frequency	Current Program (2013) WL Monit. Frequency	Water Quality 2002 Consent Decree Monitoring Frequency	Current Program (2013) Water Quality Frequency
	LP-16	M	C/M	Semi-A	Semi-A
	LP-17	1/4ly	P&A	Annual	P&A
	LP-17R	1/4ly	C/M	Annual	Semi-A
	MR97-1(3)	1/4ly	M	NS	NS
	MR97-2(3)	1/4ly	M	NS	NS
	MR97-3(3)	1/4ly	M	NS	NS
	MR97-4(3)	1/4ly	M	NS	NS
AMC Wells	AMC-5	1/4ly	M	Annual	Annual
	AMC-6	C/M	C/M	Semi-A	Semi-A
	AMC-8	C/M	C/M	Semi-A	Semi-A
	AMW-8	1/4ly	C/M	NS/Annual	Annual
	AMC-10	1/4ly	M/Dry	Semi-A	Semi-A/Dry
	AMC-12	1/4ly	M	Annual	Annual
	AMC-13	1/4ly	M	NS	NS
	AMC-15	1/4ly	M	2yrs	2yrs
	AMW-22	1/4ly	M	NS	Annual
GS Wells	GS-41S	C/M	C/M	Annual	Annual
	GS-41D	C/M	C/M	Annual	Annual
	GS-44S	C/M	C/M	Annual	Annual
	GS-44D	C/M	C/M	Annual	Annual
	GS-46S	C/M	C/M	Annual	Annual
	GS-46D	C/M	C/M	Annual	Annual
BMF05 Wells	BMF05-1	M	C/M	Semi-A	Semi-A
	BMF05-2	M	C/M	Semi-A	Semi-A
	BMF05-3	M	C/M	Semi-A	Semi-A
	BMF05-4	M	C/M	Semi-A	Semi-A
Park Wells	Chester Steele	1/4ly	M	Annual	Annual
	Hebgen	1/4ly	M	NS	NS
	Belmont #1	1/4ly	M	NS	NS
	Parrott	1/4ly	C/M	Annual	Annual
West Camp Mines	Emma	1/4ly	M	Annual	Annual
	Ophir	1/4ly	C/M	Annual	Annual
	Travona	1/4ly	C/M	Annual	Annual
West Camp Wells	WCPW-1	No	No	1/4ly-Pumping	1/4ly-Pumping
	BMF96-1D	C/M	C/M	NS	NS
	BMF96-1S	C/M	C/M	NS	NS
	BMF96-2	1/4ly	C/M	NS	NS
	BMF96-3	1/4ly	C/M	NS	NS
	BMF96-4	C/M	C/M	Annual	Annual
Outer Camp Mines	Orphan Boy	Replace	C/M	Annual	Semi-A

Butte Mine Flooding Monitoring Sites		Water Level 2002 Consent Decree Monitoring Frequency	**Current Program (2013)** **WL Monit. Frequency**	Water Quality 2002 Consent Decree Monitoring Frequency	**Current Program (2013)** **Water Quality Frequency**
Outer Camp Wells	Orphan Girl(4)	M	**Drop**	Annual	**Drop**
	Marget Ann	1/4ly	**M**	2yrs	**2yrs**
	S-4	1/4ly	**M**	NS	**NS**
	Tech Well	1/4ly	**M**	2yrs	**2yrs**
	Seep	Semi-A	**M**	Semi-A	**Semi-A**

Green Highlighted Cells- identifies increased level of monitoring/sampling from that specified in CD.

(1) The safety of each mine will be reviewed and if unsafe conditions exist, repairs will be made, or another site will be substituted for the unsafe location.

(2) MBMG monitoring and sampling will occur only when pumping and treatment is not taking place. Otherwise, monitoring and sampling will be part of the water treatment plant operations.

(3) MR97 series wells will be monitored until steady state conditions occur. A review of continued monitoring will be undertaken at that time.

(4) 2002 CD proposed replacing the Orphan Boy Mine due to access problems with the Orphan Girl Mine. Access was re-established at the Orphan Boy Mine; therefore, plans for monitoring using the Orphan Girl Mine were dropped.

M- Monthly

C/M- Continuous and monthly

NS- No Sampling

P&A- Plugged and Abandoned

SA=Semi-A=Semi-Annual

1/4ly- Quarterly

The 1994 ROD and 2002 CD established separate critical maximum water levels (CWLs) for the East Camp bedrock system and West Camp bedrock system, while the 2002 CD specified compliance points that groundwater levels could not exceed. In the East Camp bedrock system, the maximum water level cannot exceed an elevation of 5,410 ft (mean sea level, msl, USGS NAVD29 datum) at any of the eight compliance points, while in the West Camp bedrock system, the maximum water level cannot exceed an elevation of 5,435 ft msl (USGS NAVD29 datum) at well BMF96-1D. The compliance points in the East Camp consist of the following mine shafts and bedrock monitoring wells:

1) Anselmo Mine
2) Granite Mountain Mine
3) Kelley Mine

4) Pilot Butte Mine
5) Belmont Well #2
6) Bedrock Well A
7) Bedrock Well C
8) Bedrock Well G

In addition to the compliance point stipulations, water levels in the East Camp bedrock system must be maintained at a level lower than that of the West Camp water levels. (Refer to the CD and Explanation of Significance Differences to see the entire scope of activities addressed in the CD and an explanation of differences from items contained in the 1994 ROD.)

The CD addressed all current and future activities relating to the BMFOU and reimbursed EPA and DEQ for past costs associated with the site. Funding for the continuation of the long-term groundwater, surface water, and Berkeley Pit/Continental Pit monitoring program were included in the CD. The monitoring program performed by the MBMG is under the direction of DEQ and EPA. 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.

The present study is the 17th such report, summarizing 32 years of data collection. Notable changes and a comparison of trends for water levels and water quality are discussed. This report does not present a detailed overview of the history of mining on the Butte Hill, nor the Superfund processes that have been 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 376 for greater detail and information about the site.

Monitoring activities continued in 2013 in the East Camp, West Camp, and Outer Camp systems (fig. 1-7). 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 mines and underground 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. The MBMG developed a Sampling and Analysis

Plan based upon the requirements of the 2002 CD that identifies how the monitoring program is carried out (MBMG, August 2002, updated April 2011). Groundwater monitoring and water-quality sampling follow closely the methods described in the Clark Fork River Superfund Site Investigations Standard Operating Procedures (ARCO, 1992).

By the time water levels in the underground mines reached the elevation of the bottom of the Berkeley Pit in late November 1983, more than 66 percent of the underground workings had been flooded. More than 85 percent of the underground mine workings have been inundated with water through 2013. The upper 12 percent of the underground workings will never be flooded as they are at elevations above the specified CWL; therefore, less than 3 percent of the underground workings remain to be flooded.

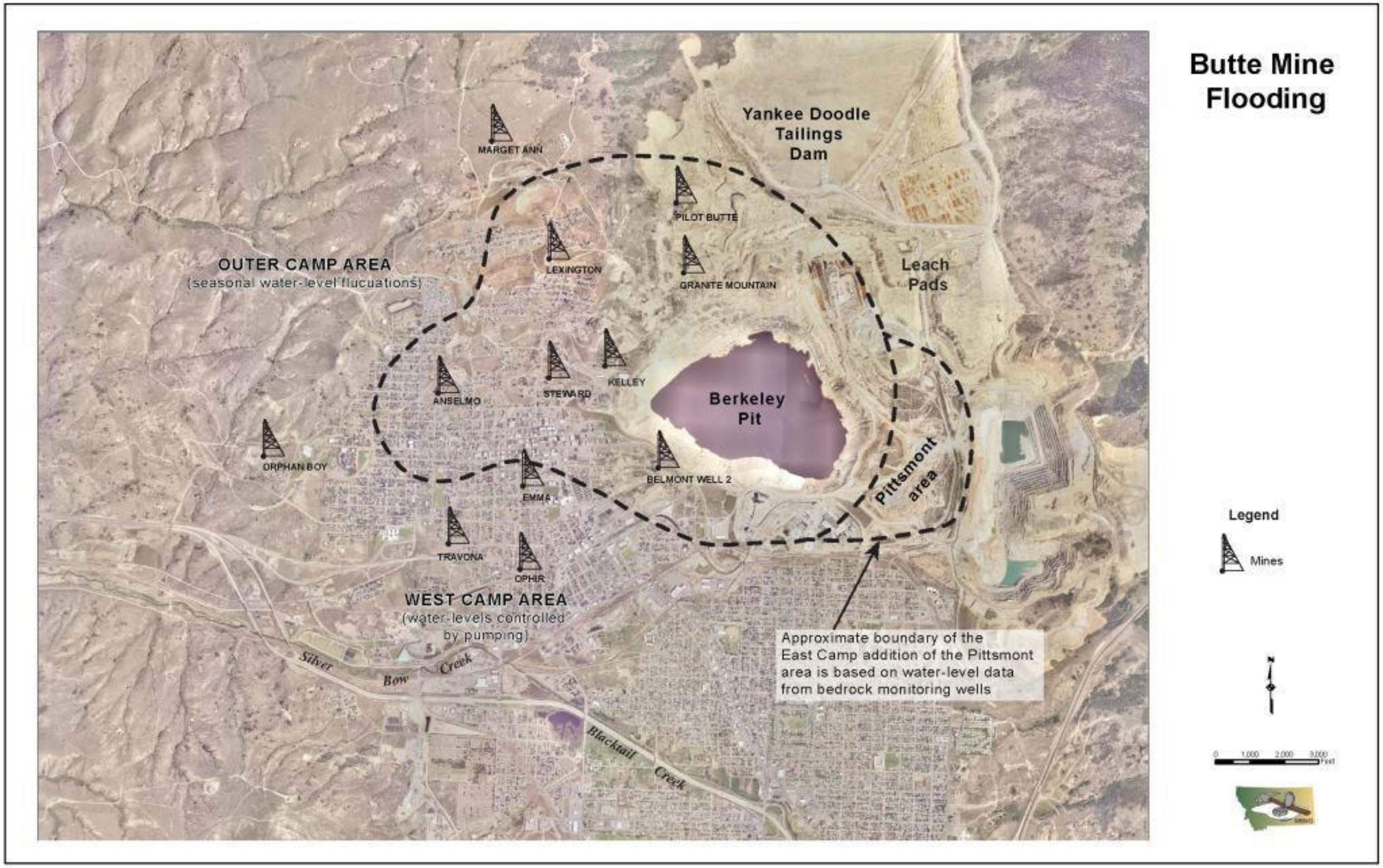


Figure 1-7. The mines of the Butte Hill are currently considered in three groups: the East Camp, which includes the Berkeley Pit and the area east; the West Camp, in the southwest part of the hill; and the Outer Camp, which includes the outlying mines.

Section 1.2 Notable 2013 Activities and Water-Level and Water-Quality Observations

Three events occurred in 2013 that influenced water levels and monitoring activities. A rotational slump occurred in the southeast corner of the Berkeley Pit, resulting in a water-level increase within the pit and several nearby bedrock wells of 0.60 ft; a constriction was found in monitoring well LP-17 that prevented its sampling; and pumping was temporary suspended in the West Camp System to allow a study of the system's critical water level. The main activities and observations for 2013 are listed below:

(1) Montana Resources (MR) continued mining and milling operations throughout 2013 following their November 2003 resumption of mining.

(2) A rotational slump occurred in the southeast corner of the Berkeley Pit on February 8, 2013, resulting in a water-level rise of about 0.60 ft. The slump occurred while MR was attempting to stabilize the area where two slumps occurred in 2012 by pushing waste rock from the Pittsmont Dump into the pit; the slump increased the volume of material that entered the pit. The area adjacent to the slump continued to be a concern for further slumps and a personnel safety concern for workers entering the pit. All monitoring and sampling activities within the pit were suspended.

(3) MR suspended Berkeley Pit copper recovery activities due to damage to the pipeline during the February slump and employee safety concerns.

(4) MR continued to use water from the HSB drainage to recharge leach pads. Flows from 1,200 to 2,500 gpm were diverted to the leach pads. Water levels increased in several LP wells downgradient of the reactivated leach pads, and water-quality changes were observed in several of the constituents analyzed as part of monthly monitoring of the HSB water.

(5) East Camp alluvial well LP-16 continued to have a modest increase in sulfate, copper, and zinc from that in years prior to 2012.

(6) East Camp alluvial well LP-17 was plugged and abandoned due to a constriction in the casing. A replacement well (LP-17R) was installed adjacent to the abandoned well.

(7) MR continued to operate three pumping wells to lower alluvial groundwater levels adjacent to the August and November 2012 and February 2013 Berkeley Pit landslides/slumps. Monitoring well LP-15 was used for dewatering purposes also.

(8) Berkeley Pit sampling was cancelled due to safety concerns following February 2013 rotational slump in the southeast corner of the Berkeley Pit.

(9) MR backfilled the Ecology Pond, installing a clay liner to limit infiltration. The area was re-contoured and will act as a surge pond for extreme concentrator system upsets and storm water runoff.

(10) West Camp pumping activities were suspended from July 8, 2013 to September 17, 2013 during a study and review of the system's Critical Water Level (CWL) and underground void area. Water levels were allowed to rise 10 ft above the 5435 system CWL.

Section 1.3 Precipitation Trends

Total precipitation for 2013 was 11.33 inches, compared to 9.05 inches in 2012. The 2013 amount is 1.35 inches below the long-term (1895–2013) average. Precipitation totals have been below average for 6 of the past 10 years and 19 of the last 32 years. The 2013 precipitation total was a decrease of 10 percent below the long-term average of 12.68 inches. Table 1.3.1 contains monthly precipitation statistics from 1982 through 2013, while figure 1-8 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 (12.47 inches vs. 12.69 inches). Figure 1-9 shows departure from normal precipitation from 1895 through 2013.

Table 1.3.1 Butte Precipitation Statistics, 1982–2013.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Mean	0.44	0.41	0.74	1.07	1.97	2.27	1.36	1.32	1.02	0.76	0.58	0.49	12.44
Std. Dev.	0.32	0.28	0.40	0.68	0.78	1.19	1.03	0.88	0.77	0.54	0.38	0.37	2.88
Maximum	1.40	1.26	1.84	3.20	3.88	4.62	4.18	3.10	2.99	2.21	1.50	1.99	19.96
Minimum	0.09	0.11	0.11	0.00	0.81	0.50	0.00	0.09	0.03	0.00	0.07	0.01	8.32
Number of years precipitation greater than mean													13
Number of years precipitation less than mean													19

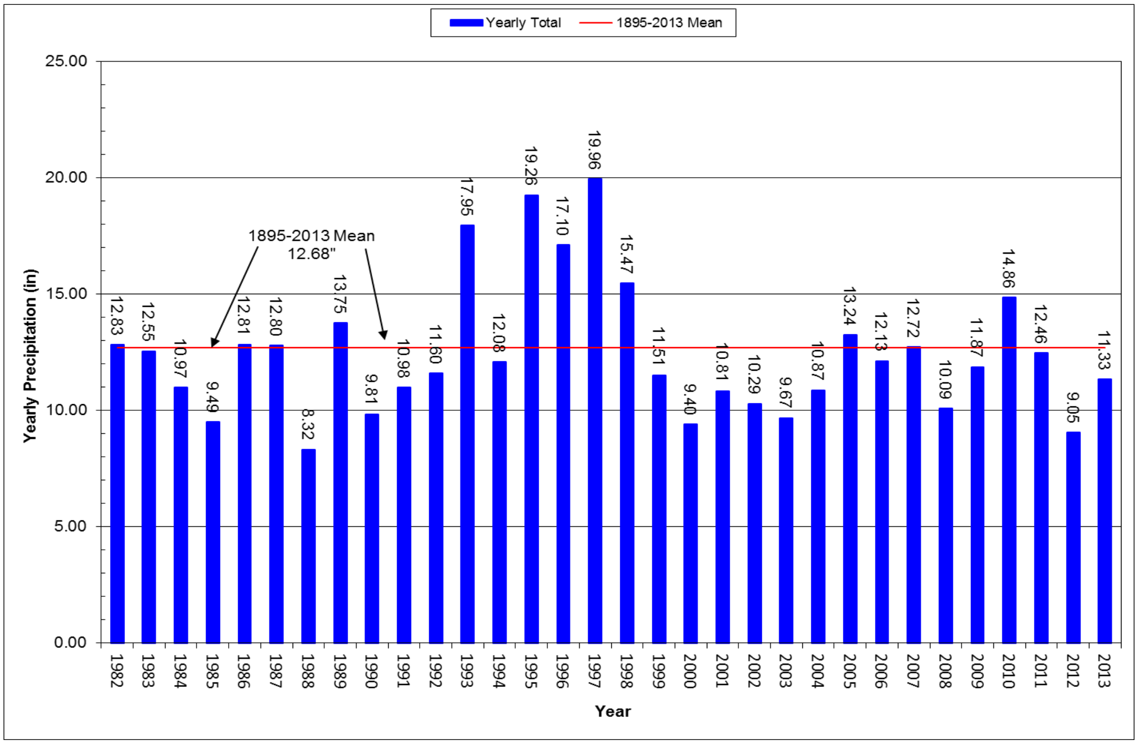


Figure 1-8. Yearly precipitation totals 1982–2013, showing 1895–2013 mean.

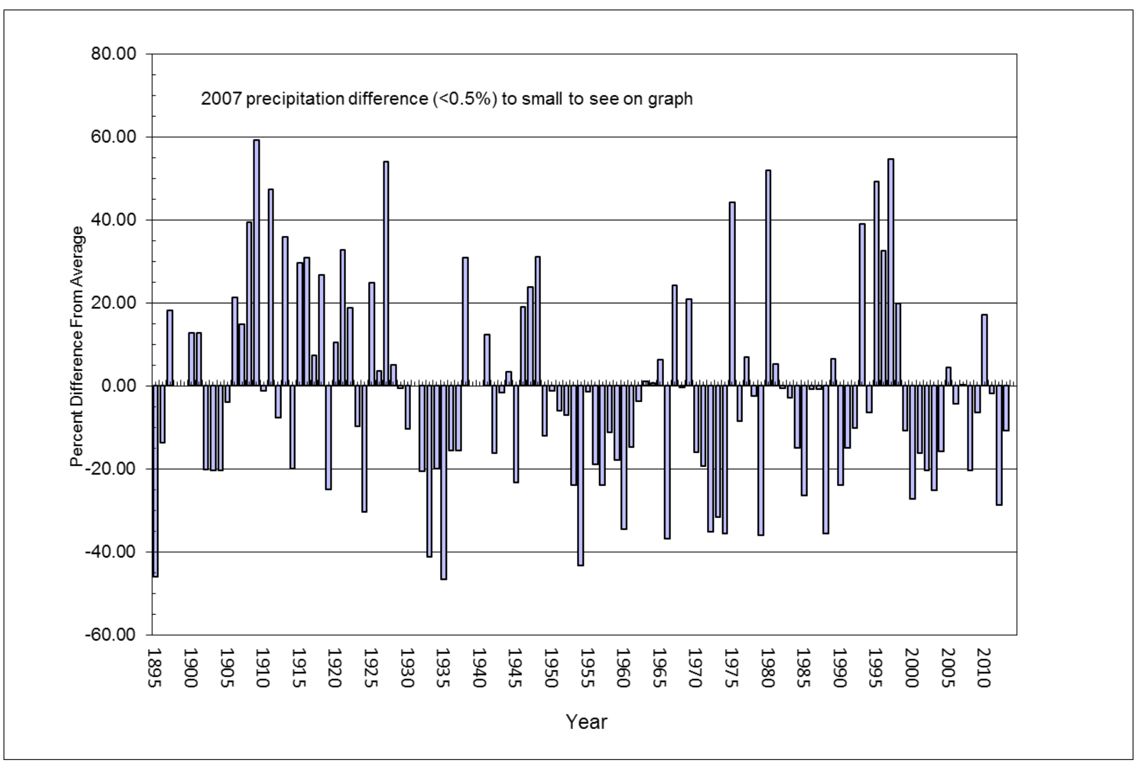


Figure 1-9. Percent precipitation variation from normal, 1895–2013.

SECTION 2.0 EAST CAMP SYSTEM

The East Camp is composed of that portion of the bedrock aquifer affected by underground mine dewatering in 1982 and the overlying shallow alluvial aquifer. The East Camp alluvial system includes the alluvial aquifer within the active mine area and a portion of the alluvial aquifer outside the active mine area, primarily to the south (fig. 2-1). The East Camp Bedrock Monitoring System consists of the Anselmo, Belmont, Granite Mountain, Kelley, Steward, Lexington, and Pilot Butte mines, and the Berkeley Pit (fig. 2-2). It also includes the bedrock system adjacent to the East Camp mines. 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 groundwater monitoring system consists of the LP- and MR97-series wells that are located within the active mine area, plus selected AMC, GS, AMW, and BMF05 series wells. All of the wells associated with the latter four groups are located south of the active mine area, with the exception of wells AMC-5 and AMC-15, which are located within the mine area. Each group of wells represents sites installed or monitored during different studies that have been incorporated in the BMFOU-CD monitoring program. Water-level elevations and monthly precipitation amounts are shown on hydrographs for selected wells. Water-quality results are shown and discussed for the sampled wells. Unlike the water-level monitoring program, water-quality sampling did not occur at every East Camp monitoring well and takes place only once or twice per year. Four new alluvial monitoring wells were installed within the East Camp system during late 2005 and early 2006 as stipulated in the 2002 Consent Decree. These wells replaced domestic wells that were monitored from 1997 through 2002. The wells were situated in areas where data gaps existed and were equipped with transducers for increased water-level data collection. The new wells were identified as BMF05 and are discussed with the GS-series wells. Water-quality samples were collected thrice per year throughout 2007 (to help establish baseline conditions) and semi-annually thereafter.

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, i.e., elevated metal concentrations. Sites outside historic mining areas reflect conditions more typical of the regional hydrogeology.

Figure 2-1. East Camp alluvial monitoring wells.

Figure 2-2. East Camp bedrock monitoring wells.

Section 2.1.1 AMC-Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown in figure 2-3; table 2.1.1.1 lists the annual water-level changes for these sites. Water levels decreased in six of seven AMC series wells for 2013, while one well (AMC-10) remains dry. Well AMC-10 has been dry since its installation in 1983. The decrease in water levels for the AMC wells for 2013 is similar to that of 2012. Water levels had a net decline during the first 20 years of monitoring, followed by a net increase the next 10 years; however, a majority of the wells had a net decrease past 2 years. The overall water-level change is a net decline in six wells, with one well dry. Net declines vary from 3.4 ft to more than 27.5 ft.

Well AMC-5 is located within the active mine area, while wells AMC-6 and AMC-8 are located south of the active mine area and the Butte Concentrator facility (fig. 2-3). Well AMC-12 is located southwest of these wells. Hydrographs for wells AMC-5 and AMC-12 (fig. 2-4), and AMC-6 and AMC-8 (fig. 2-5) show the long-term trends in the shallow alluvial groundwater system south of the pit. Monthly precipitation amounts are shown as bars and are plotted on the right-hand y-axis.

Well AMC-5 exhibited the greatest water-level increase following MR's resumption of mining in 2003, followed by 2 years of water-level decline. This well is located just north of the Emergency (Dredge) and Ecology ponds, located in the southwest corner of the concentrator yard (fig. 2-3). The Emergency (Dredge) Pond received considerable inputs of fresh water prior to MR's start-up in the fall of 2003. The water-level trend for 2003–2005 for this well, shown in figure 2-4, is similar to the trend seen in 1986–1987, which coincides with the start-up of mining following ARCO's 1983 suspension of mining. It is apparent that filling the Emergency (Dredge) Pond with make-up water for milling operations has a considerable influence on alluvial water levels in the immediate area. The water level in well AMC-5 began to rise in the summer of 2006 following increased precipitation in April and June. The water level continued to rise throughout the remainder of the summer before leveling off in the fall; water levels rose again in early 2007 before stabilizing the remainder of the year. While the initial water-level increases coincide somewhat with early spring precipitation, the overall water-level trends for 2006 through 2013 do not appear to consistently respond to seasonal precipitation changes; it is more likely a response to operational changes within MR's water-handling system.

Well AMC-12 water-level variations during 2006–2007 differed from those between 2001 and 2005, with a net water-level rise of more than 3.5 ft (fig. 2-4). These changes in water levels may be related to the completion of construction activities in the Metro Storm Drain (MSD) portion of the nearby Silver Bow Creek (SBC) channel and the periodic discharge of clean water to this channel. Annual water-level changes have been a tenth of a foot or less during 2008–2010; 2011 changes were the largest (1.13 ft) since 2006, which may be related to MR's cleaning of the Ecology Pond. The 2013 water-level decline may be in response once again to the draining and discontinued use of the Ecology Pond. Seasonal trends are noticeable on the well hydrograph.

Table 2.1.1.1 AMC-Series Wells.

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	-3.60	-4.05	-2.55	DRY	-2.75	-2.15	-2.90
1986	6.10	2.40	-0.40	DRY	0.10	-0.20	-1.60
1987	0.10	0.60	1.30	DRY	0.70	0.20	0.30
1988	0.20	-0.60	-0.20	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
Change Yrs. 1–10	**-27.15**	**-7.30**	**-9.80**	**0.00**	**-3.65**	**-3.445**	**-13.00**
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	0.40	DRY	0.18	0.09	0.58
1999	-1.56	-2.03	-1.70	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
Change Yrs. 11–20	**-4.89**	**-3.01**	**-3.38**	**0.00**	**-0.60**	**-0.24**	**-1.71**
2003	6.97	3.50	0.97	DRY	0.53	0.03	0.37
2004	-1.13	0.44	1.42	DRY	-0.37	-0.42	0.38
2005	-1.68	-1.06	-0.45	DRY	-0.51	-0.22	-0.76
2006	0.73	0.97	2.72	DRY	1.24	0.72	1.72
2007	1.07	0.63	1.14	DRY	0.32	0.55	1.12
2008	-0.23	-0.50	-0.26	DRY	-0.06	-0.42	0.70
2009	0.05	0.57	2.53	DRY	0.04	1.02	0.35
2010	0.49	-0.03	-0.37	DRY	-0.10	-0.63	1.25
2011	0.41	1.90	1.87	DRY	1.13	0.59	0.86
2012	-0.77	-2.16	-2.10	DRY	-1.08	-0.49	-1.77
Change Yrs. 21–30	**5.91**	4.26	7.47	**0.00**	1.14	0.73	4.22
2013	**-1.43**	**-1.34**	**-1.87**	**DRY**	**-0.83**	**-0.52**	**-2.18**
Change Yrs. 31–40	**-1.43**	**-1.34**	**-1.87**	**0.00**	**-0.83**	**-0.52**	**-2.18**
Net Change	**-27.56**	**-7.39**	**-7.58**	**0.00**	**-3.94**	**-3.48**	**-12.67**

(Minus sign (-) indicates a decline (drop) in water level.)

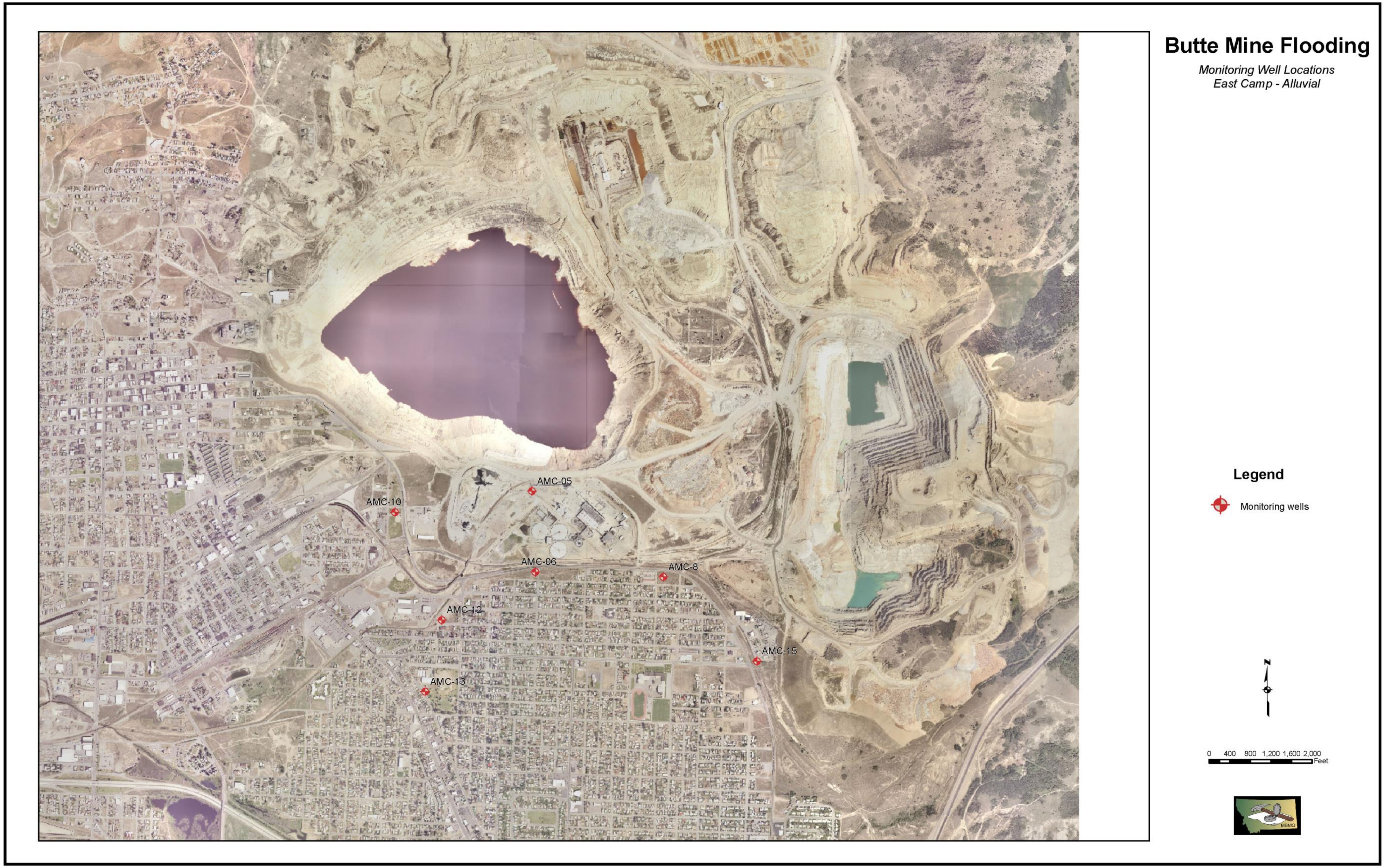


Figure 2-3. AMC well location map.

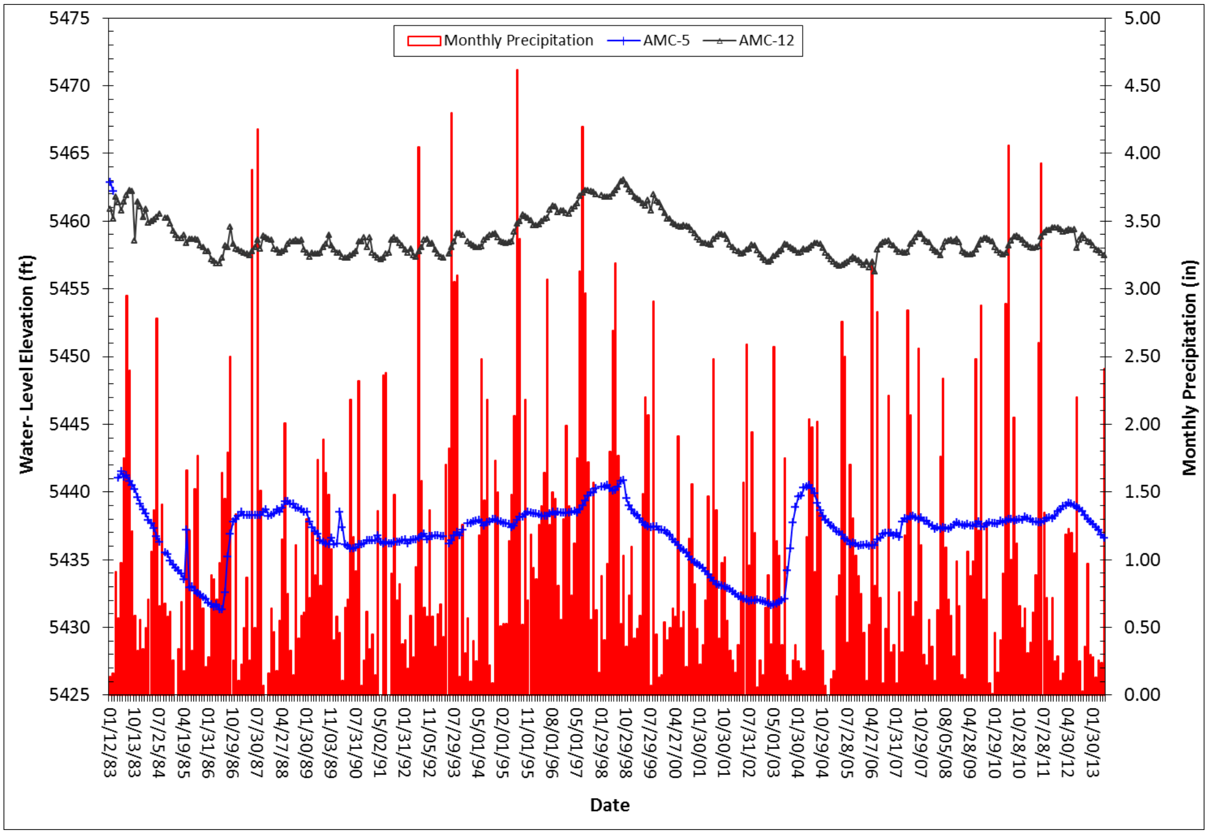


Figure 2-4. Water-level hydrographs for wells AMC-5 and AMC-12.

Well AMC-6 is directly south of the concentrator facility and the Emergency (Dredge) and Ecology ponds. Water-level trends during 2003–2004 were similar to those seen in 1986–1987 following the resumption of mining. However, water levels in 2005 appear to be less influenced by water levels in the Emergency (Dredge) and Ecology ponds. Water levels in this well continued their strong downward trend that began the fall of 2004 through the spring of 2005. Beginning late spring 2005, minor water-level increases (1 ft or less) occurred that might be in response to precipitation events (fig. 2-5). Water levels have risen each spring since 2006 following precipitation events, while falling in the autumn through 2010. In 2011 water levels continued to rise throughout the entire year (May–December). The continued rise was most likely associated with operational/maintenance activities associated with mining/milling operations. MR emptied the Ecology Pond and removed sediment that had accumulated in it for decades during the summer of 2011; following excavation of sediment, MR refilled the pond, resulting in an increased water-level rise in October that continued throughout the remainder of the year (fig. 2-5). It appears the removal of sediment from the pond increased leakage and recharge to the alluvial aquifer in the vicinity. This change masked the seasonal water-level decline seen in past years. MR drained the

Ecology Pond in early 2012, resulting in a water-level decrease; it is possible the water-level decline in 2013 is the result of the capping and re-contouring of the Ecology Pond area. Previous water-level responses in this well had been strongly influenced by seasonal precipitation conditions; water-level responses during 2011–2013 were most likely influenced by MR operational changes (filling and draining of pond).

The water-level trend from 2003 through 2005 in well AMC-8 (fig. 2-5) was very similar to that in the 1986–1988 time period, with water levels declining following a period of water-level increases associated with the resumption of mining. While water levels had a net decline for 2005, there was a slight increase during the late fall–early winter that originally appeared to have been in response to precipitation events; water levels continued to rise throughout almost all of 2006 and 2007, independent of climatic trends. Water levels continued their upward trend through 2008; however, there was more of a seasonal trend in 2009–2010 than in the past several years. Water levels followed a similar downward trend, as seen in AMC-6, throughout 2013 with no seasonal variation.

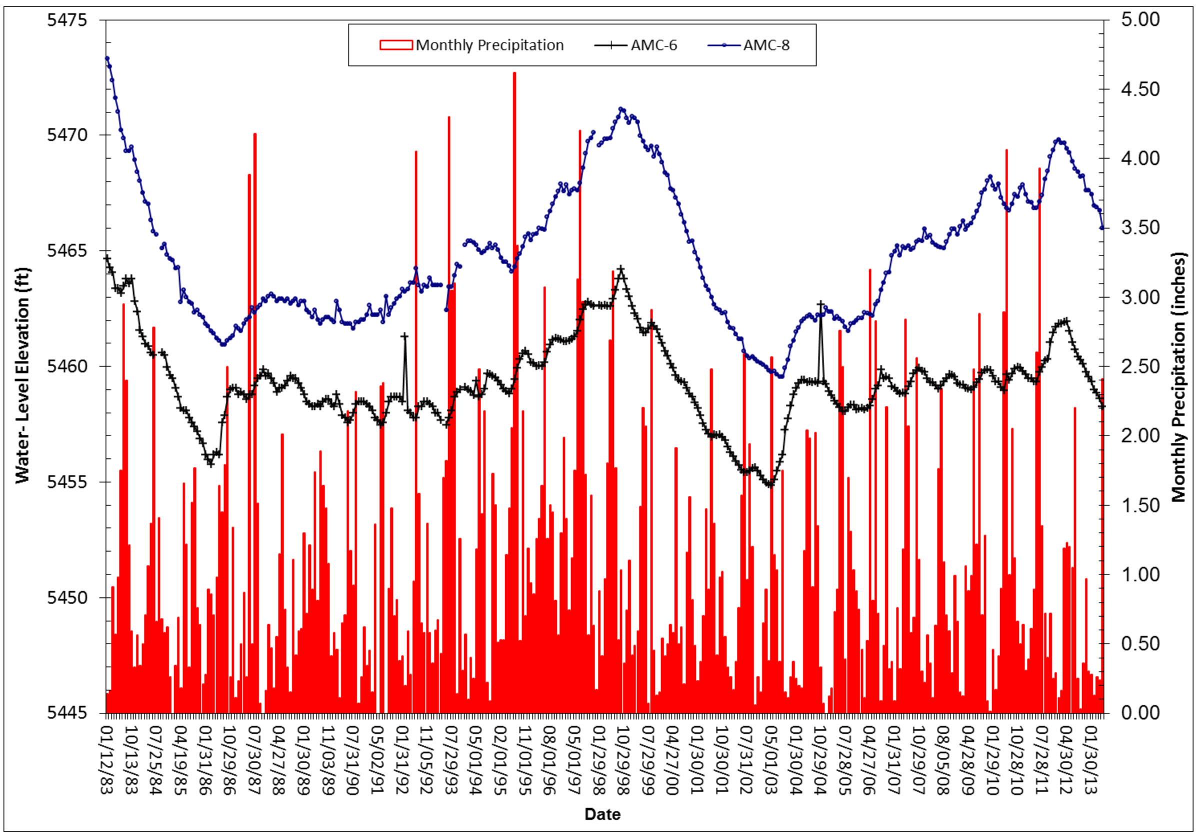


Figure 2-5. Water-level hydrographs for wells AMC-6 and AMC-8.

Well AMC-13 is located on the west side of Clark Park, south of wells GS-44S and GS-44D. This well's hydrograph shows both a response to precipitation events and possibly lawn watering (fig. 2-6a). Water levels begin to rise in late spring and continued throughout the summer, before starting to decline in the fall.

Well AMC-15 is located on the west side of the Hillcrest waste dump (fig. 2-3) in an area where reclamation has taken place. Water in this well is much deeper (90 ft) than in the other AMC wells, and the hydrograph reflects this. There were minor seasonal changes in water levels for a number of years. The influence of below-normal precipitation is shown by the steep decline in water levels beginning in late 1999 (fig. 2-6b), when this well did not show any significant response to precipitation. The water-level decline began leveling off in mid-2003, when the water level rose almost half of 1 foot from September through December 2003. These time frames correspond to the 1998 Berkeley Pit landslide and the fall 2003 resumption of mining by MR. Water levels have shown a continual increase through 2011, with apparent seasonal variations. However, peak water levels occur later in the year (November–December) than in other alluvial well sites. No seasonal variation occurred during 2013, as water levels continued their downward trend from the late summer of 2012.The water level has net rise during 7 of the past 10 years.

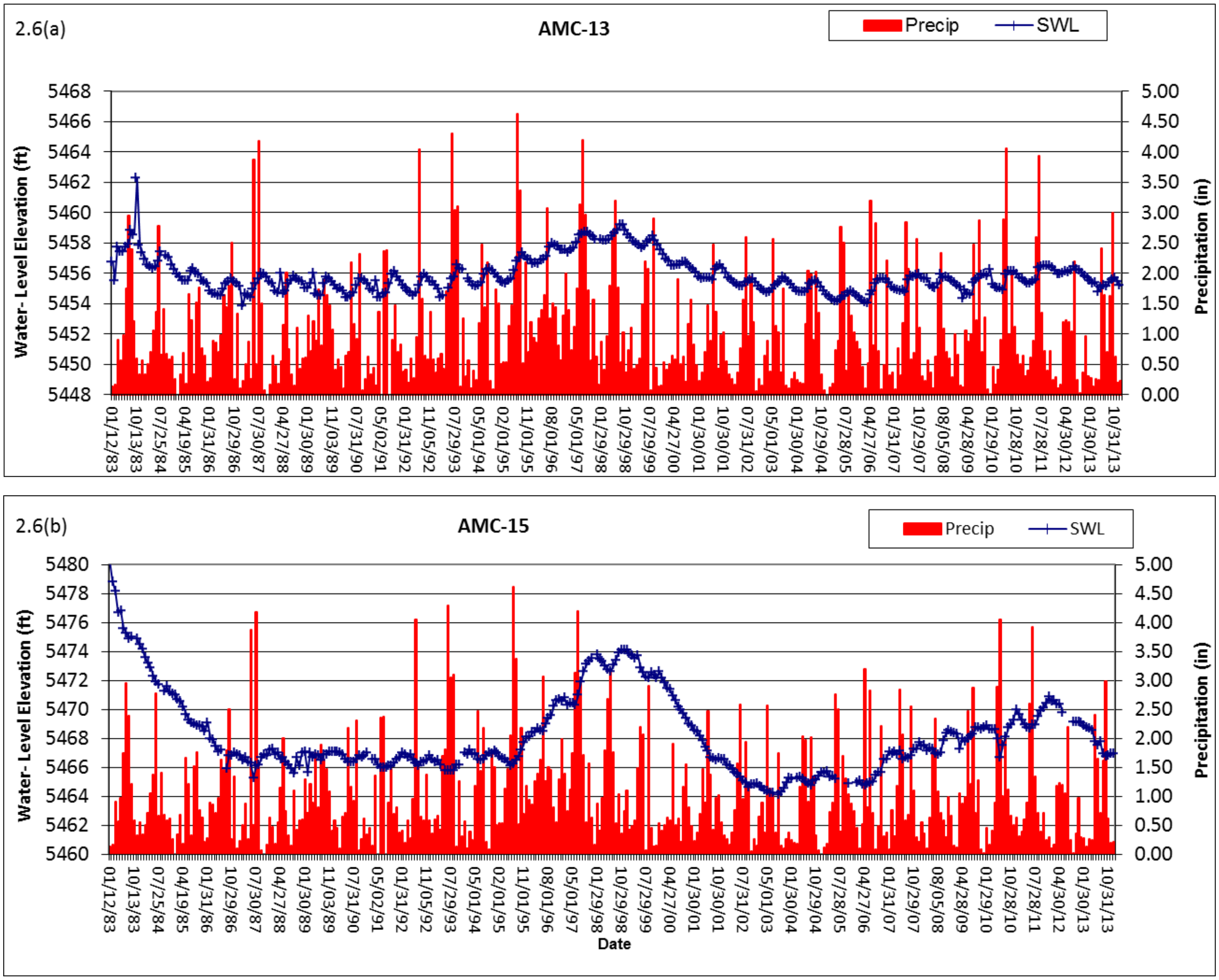


Figure 2-6. Water-level hydrographs for wells AMC-13 (a) and AMC-15 (b).

Section 2.1.1.1 AMC-Series Water Quality

Trends of concentrations for chemical constituents in the 2013 data collected from the AMC-series wells are summarized in table 2.1.1.2. Well AMC-5, just south of the Berkeley Pit, has exceeded maximum contaminant levels (MCLs) and secondary maximum contaminant levels (SMCLs) throughout the period of record. The concentrations of most of the dissolved metals have shown a slight downward trend or remained stable in recent years.

AMC-6 shows a continued, consistent trend of decreasing concentrations of nearly all dissolved constituents. Cadmium and zinc are the only constituents whose concentrations exceed drinking water standards. The concentration of sulfate increased slightly from 175 mg/L in 2004 to 250 mg/L in 2008 (fig. 2-7). Current concentrations have decreased and are well below historic 1980s levels.

The concentrations of dissolved constituents in the 2013 samples in well AMC-8 are consistent with previous results. As in the past, the concentrations of sulfate continue to increase (fig. 2-7). Sulfate concentrations have doubled since the fall of 2006, increasing from 400 mg/L to more than 800 mg/L in April 2013. Cadmium concentrations have increased in the past several years and are currently above the MCL.

Table 2.1.1.2 Exceedances and trends for AMC-series wells, 2013.

Well Name	Exceedances	Concentration	Remarks
AMC-5	Y	Variable	High iron, manganese, cadmium, copper, and zinc
AMC-6	Y	Downward	Downward trend continues; cadmium and zinc exceed MCL
AMC-8	Y	Variable	Increasing sulfate; cadmium exceeds MCL
AMC-12	Y	Stable	Very high iron, manganese, cadmium, copper, and zinc
AMC-15	N	Variable	Unchanged in recent years, currently only sampled every 2 years; Mn exceeds MCL

Access was restored to wells AMC-12 and AMC-15, allowing the wells to be sampled in 2006 and subsequent years. Well AMC-12 has high-to-very high concentrations of iron, manganese, cadmium, copper, and zinc; this well is located just south of the historic Silver Bow Creek drainage (MSD), which received untreated mine and process water for decades.

As in the recent past, no strong trends are apparent in most of the AMC-series wells; however, several show a slight downward trend over the period of record. Overall, metal concentrations in 2013 showed very little change from previous years, with the exception being sulfate and cadmium concentrations in well AMC-8, which continued to increase. Wells closest to historic and current mining operations have the highest levels of contamination; well AMC-5 and AMC-12 have very high levels of iron, manganese, cadmium, copper, and zinc.

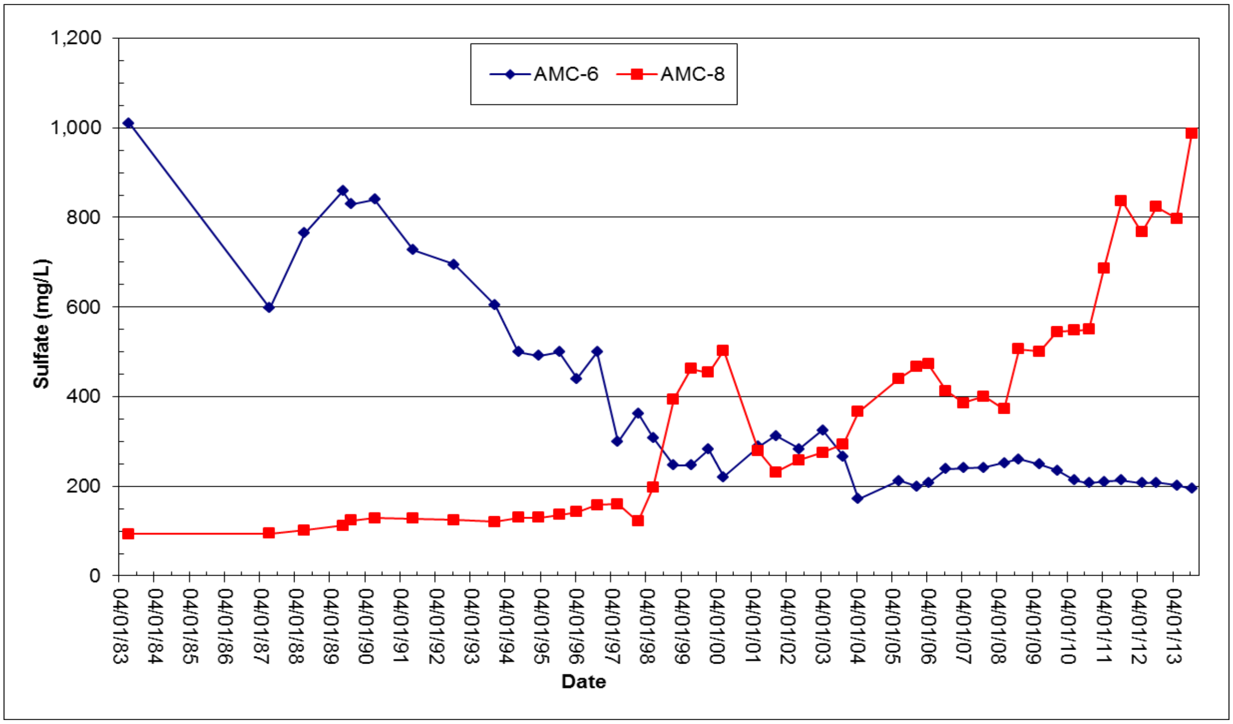


Figure 2-7. Sulfate concentration changes over time for wells AMC-6 and AMC-8.

Section 2.1.2 LP-Series Wells

The locations of the LP-series monitoring wells are shown in figure 2-8; table 2.1.2.1 presents a summary of annual water-level changes for these sites. As discussed in Duaime and others (1998), these wells were installed in 1991 and 1992 as part of the BMFOU RI/FS study. Water-level monitoring and sampling of the LP-series wells continued throughout 2013, with water levels declining in 8 of the remaining 12 wells, not already plugged or dry, during 2013. Wells near MR dewatering activities had the largest water-level decline, varying from 2.09 ft to 15.35 ft. Since monitoring began, water levels have experienced a net decline in 16 of the LP wells, ranging from 4.54 ft in LP-10 to 80.33 ft in well LP-15. Well LP-14 has a net water-level increase of 2.56 ft.

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. Well LP-6 was plugged and abandoned in 2010 to allow for mine expansion. Well LP-7 had been dry from 2001 through 2004 before having a water-level rise during 2005; however, it had a corresponding decline in 2006 and had been dry until 2013, when it rose slightly. Well LP-8 has been dry since May 2010. Well LP-17 was plugged and abandoned and LP-17R was drilled as a replacement the fall of 2013.

Table 2.1.2.1 Annual water-level change in LP-Series wells (ft).

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
Change Years 1–10	**-14.73**	**-17.70**	**-19.93**	**-15.16**	**-18.00**	**-3.79**	**-16.64**	**-26.75**	**-26.88**
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
2004	-0.65	0.46	P&A*	13.06	3.85	3.24	Dry	18.13	2.96
2005	0.81	-0.43	P&A*	4.12	3.40	-3.62	-0.79	2.85	2.08
2006	-1.43	-0.96	P&A*	-2.77	-2.06	Dry	Dry	-2.35	-0.44
2007	-0.09	0.14	P&A*	-3.39	-2.36	Dry	Dry	-5.59	-2.37
2008	-0.02	0.13	P&A*	-3.80	-1.61	Dry	Dry	-7.83	-1.39
2009	0.48	0.13	P&A*	-3.87	-1.59	Dry	Dry	-5.23	-0.07
2010	0.96	0.89	P&A*	-2.13	-1.42	P&A*	Dry	0.01	0.06
Change Years 11–20	**-12.57**	**-6.68**	**-11.52**	**-15.44**	**-14.12**	**-0.38**	**-0.79**	**-16.26**	**-6.82**
2011	0.22	0.05	P&A*	-0.34	0.03	P&A*	Dry	Dry	0.61
2012	1.15	-0.08	P&A*	0.26	0.07	P&A*	Dry	Dry	3.95
2013	3.17	0.43	P&A*	3.16	1.61	P&A*	0.06	Dry	3.72
Change Years 21–30	**4.54**	**0.40**	P&A*	**3.08**	**1.71**	**Dry**	**0.06**	**Dry**	**8.28**
Net Change	**-22.76**	**-23.98**	**-31.45**	**-27.52**	**-30.41**	**-4.17**	**-17.37**	**-43.01**	**-25.42**

(Minus sign (-) indicates a decline (drop) in water level.)

Table 2.1.2.1 Annual water-level change in LP-Series wells (ft). (cont.)

Year	LP-10	LP-11	LP-12	LP-13	LP-14	LP-15	LP-16	LP-17	LP-17R
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	
Change Years 1–10	**-5.11**	**-5.38**	**-1.09**	**-0.93**	**0.70**	**-5.93**	**-7.80**	**-2.14**	
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	
2004	-1.41	P&A*	0.20	0.26	0.95	-0.06	0.52	0.71	
2005	4.19	P&A*	1.53	0.78	-0.27	0.27	-0.27	0.26	
2006	3.19	P&A*	4.48	2.78	2.95	1.43	1.33	2.68	
2007	0.73	P&A*	0.87	0.73	1.22	1.51	1.66	2.54	
2008	1.23	P&A*	1.92	1.27	0.29	1.05	0.28	0.94	
2009	-0.83	P&A*	3.23	1.97	3.32	1.70	1.47	2.20	
2010	-0.77	P&A*	0.09	-0.19	0.53	-0.18	0.27	0.32	
Change Years 11–20	**3.94**	**0.00**	**7.59**	**4.83**	**5.49**	**5.40**	**4.11**	**7.57**	
2011	-1.03	P&A*	0.78	0.94	1.61	0.87	0.53	0.16	
2012	-3.12	P&A*	-5.59	-4.46	-3.19	-65.32	-3.53	-4.15	
2013	0.78	P&A*	-2.09	-3.12	-2.05	-15.35	-4.36	-3.37	-0.31
Change Years 21–30	**-3.37**	**P&A***	**-6.90**	**-6.64**	**-3.63**	**-79.80**	**-7.36**	**-7.26**	**-0.31**
Net Change	**-4.54**	**-5.38**	**-0.40**	**-2.74**	**2.56**	**-80.33**	**-11.05**	**1.83**	**-0.31**

(*) Plugged and abandoned
(Minus sign (-) indicates a decline (drop) in water level.)

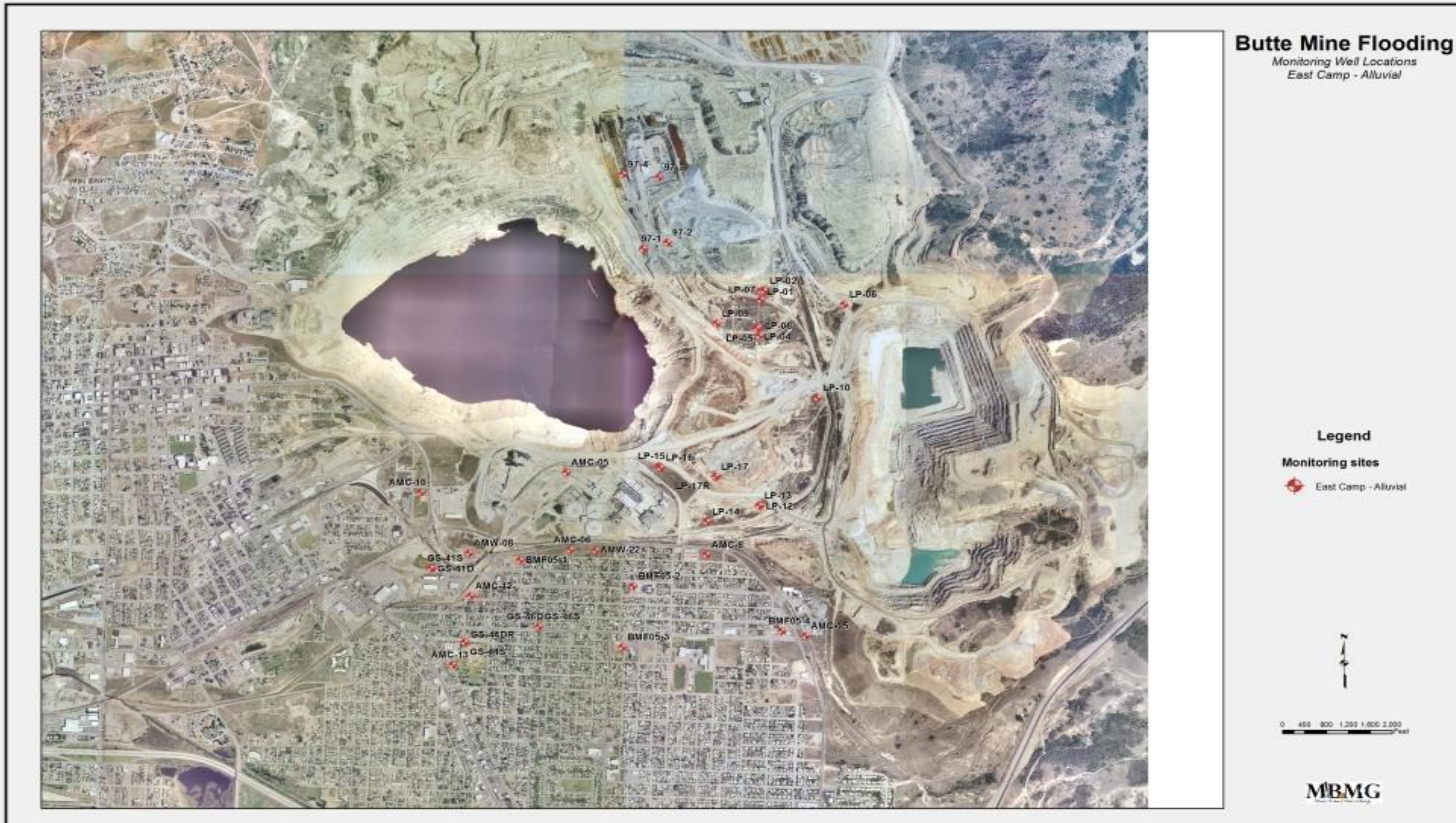


Figure 2-8. LP-series and MR97 wells location map.

The increases in water levels to the south of the leach pads and north of the Pittsmont Waste Dump is a substantial change from trends seen in water levels (decline) between 1992 and 2003. Water-level declines had been especially true since the deactivation of the leach pads in 1999. However, as part of its resumption of mining, MR began leaching operations on a limited scale in 2004, continuing periodically throughout 2005. The wells with the greatest water-level rise in 2004 and 2005 (LP-04 and LP-10) are located south and downgradient of the leach pads. Limited leaching operations have continued during 2010–2013 by MR as part of their active mining operations. Operation of the leaching system may be reflected in the continued water-level increases in several wells. Figures 2-9 and 2-10 show water levels over time for five of the LP-series wells, which are located south of the leach pads and north of the Pittsmont Waste Dump.

Wells LP-01 and LP-02 are located near the base of several leach pads and are screened in two different intervals. The wells are screened at depths of 129–159 ft and 177–197 ft, respectively, and are completed in the deeper portion of the alluvial aquifer. Well LP-01 is completed at a deeper depth and, as shown in figure 2-9, water levels steadily declined for the most part since its installation through 2004. Between 2005 and 2008 water levels have varied slightly, with periodic increases followed by declines; water levels have steadily increased since 2009. The water-level changes in this well have been less erratic in recent years than those seen in the shallow well, LP-02, possibly the result of the increased lag time associated with recharge events. Water levels in wells LP-01 and LP-02 show a greater response to operational practices associated with the leach pads than to climatic changes. This is consistent with interpretations of water-level responses made following MR's 1999 deactivation of the leach pads. Recent water-level increases may be due to reactivation of leach pads.

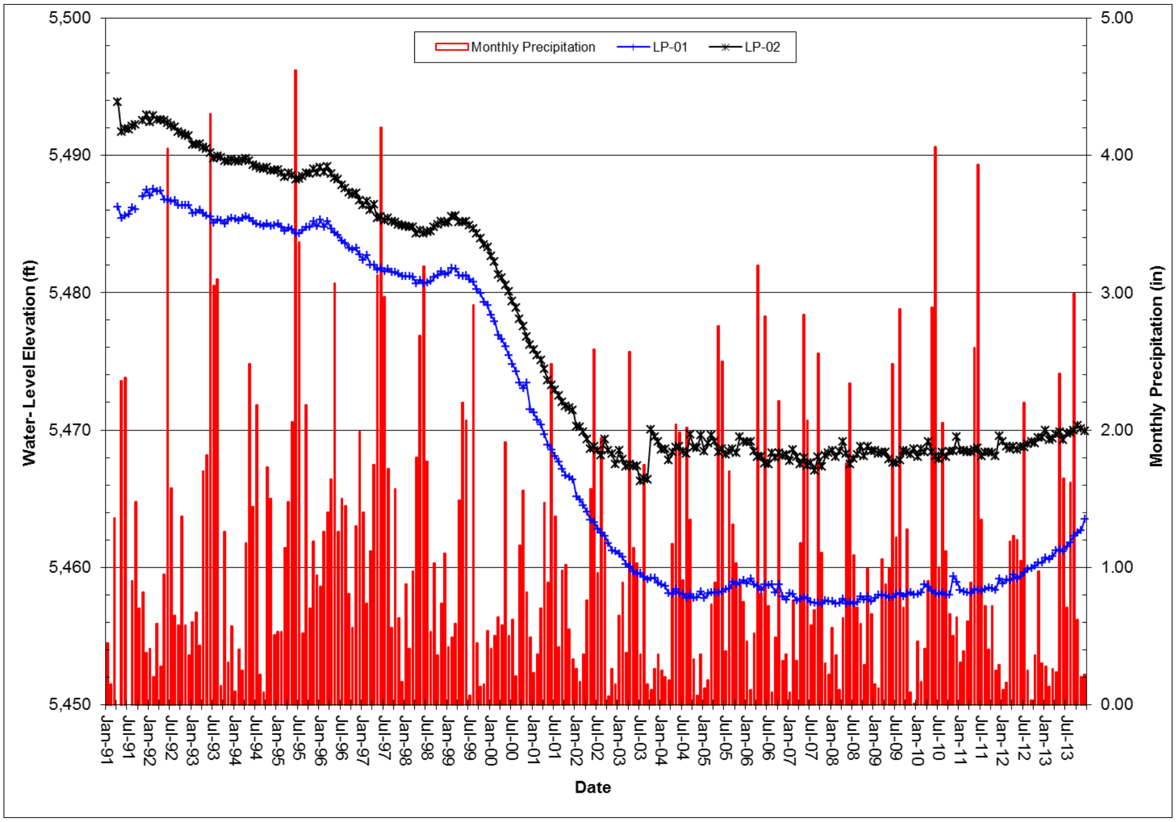


Figure 2-9. Water-level hydrographs for wells LP-01 and LP-02.

Figure 2-10 shows water levels over time for wells LP-04, LP-07, and LP-08, which are located south of wells LP-01 and LP-02 and north of the Pittsmont Waste Dump (fig. 2-8). These wells are completed at different depths also. Well LP-04 is screened from 125 ft to 145 ft below ground surface, while well LP-07 is screened from 90 ft to 95 ft below ground surface, and well LP-08 is screened 81 ft to 96 ft below ground surface. Based upon these well-completion depths, wells LP-07 and LP-08 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. The water-level trends were similar for wells LP-04, LP-07, and LP-08 for many years; however, well LP-07 was dry from 2006 through 2012, while LP-08 has been dry since mid-2010. It is interesting to note that while well LP-08 was dry for a period from mid-2003 through mid-2004, the subsequent water-level trend did not vary from that shown for well LP-04 once the water level rose back above the screen interval. It is apparent that the control on water levels is the same on all of these wells and the operation, or lack of operation, of the leach pads, whichever the case may be, has a much greater influence on water levels than climatic changes, as there is very little seasonal variation noticeable in figure 2-10.

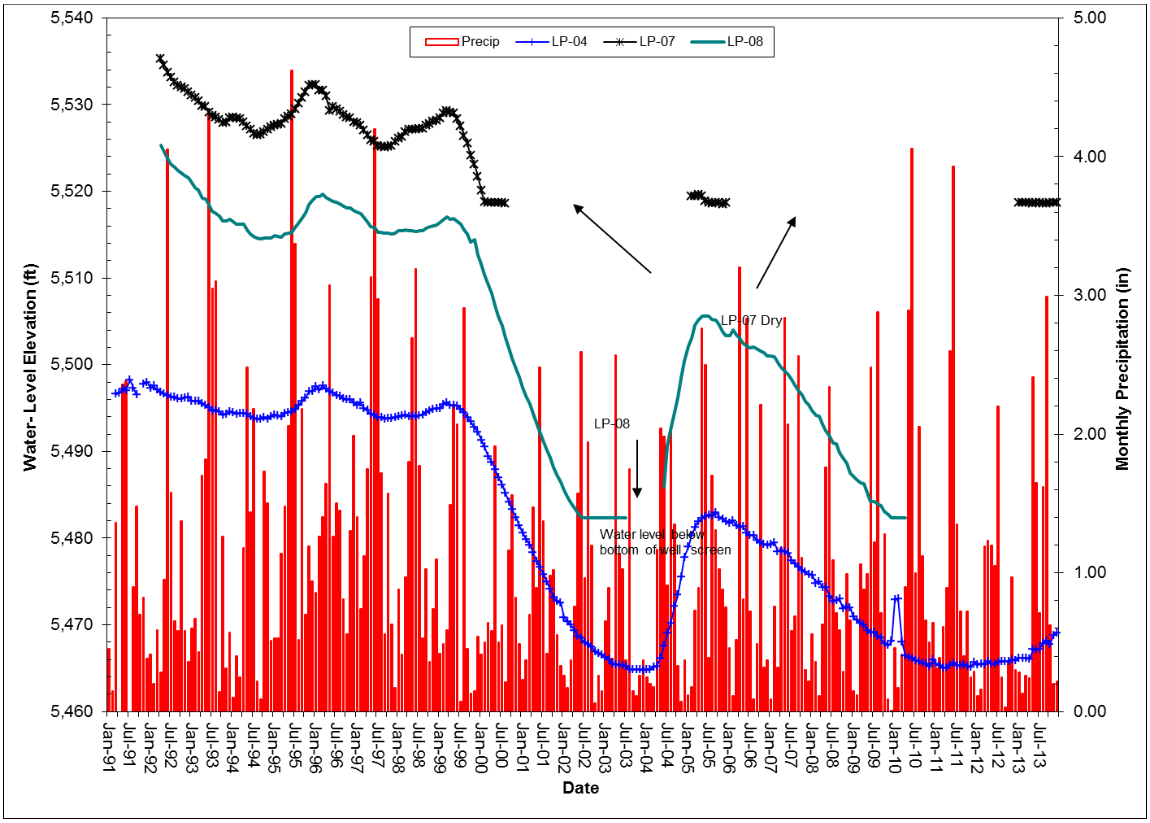


Figure 2-10. Water-level hydrographs for wells LP-04, LP-07, and LP-08.

Wells LP-14, LP-15, and LP-16 are located southwest of the Pittsmont Dump (fig. 2-8). A consistent increase in water levels occurred in these wells following their installation in 1992, until the Berkeley Pit landslide of 1998 (fig. 2-11). After that landslide, water levels declined in a similar manner in all three wells until beginning to rise in September 2003 and continuing through May 2004. Since then water-level changes had been minor until May 2006, when water levels increased at a greater rate. At the end of 2011, the water level in LP-14 was within 0.5 ft of its water level just prior to the landslide; however, water-levels in LP-15 and LP-16 were 10 ft or more below their 1998 pre-landslide levels. Water levels decreased during most of 2012, with no noticeable change following the August or November 2012 landslides or the February 2013 slump. This is in contrast to observations made following the 1998 landslide when water levels decreased dramatically. Transducers were installed in monitoring wells LP-12, LP-13, and LP-16 to better track water-level changes, following the November 2012 landslide.

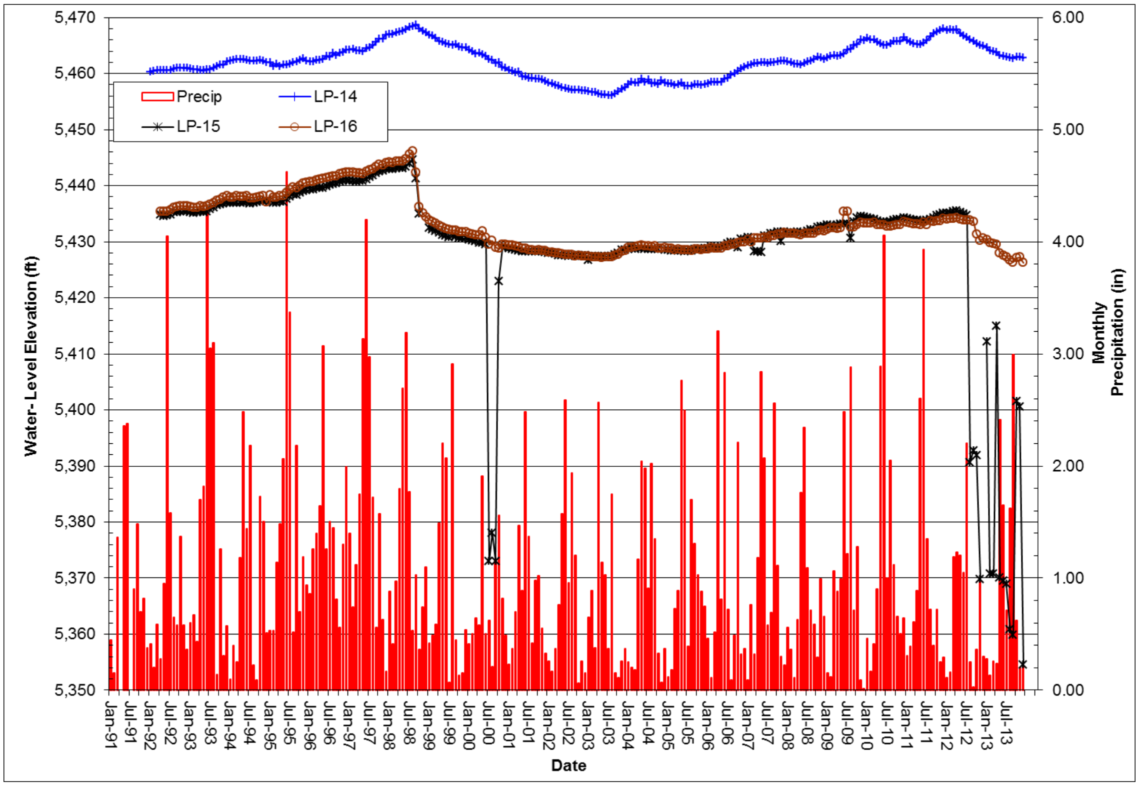


Figure 2-11. Water-level changes for wells LP-14, LP-15, and LP-16 before and after the 1998 Berkeley Pit landslide.

Wells LP-15 and LP-16 are located near one another and were completed as a nested pair, with well LP-15 screened from a depth of 215 ft to 235 ft below ground surface and well LP-16 screened from 100 ft to 120 ft below ground surface. Water-level trends are generally similar in these wells regardless of completion depth. None of these wells shows any response to climatic conditions, i.e., precipitation events. MR began operation of the pump installed in well LP-15 shortly after the August 2012 landslide and continued its operation through 2013. Pumping has resulted in significant drawdown of water levels in this well and well LP-16 (fig. 2-12). MR also installed three additional dewatering wells in the area, which have operated almost continuously since their installation. The net result of these pumping activities was a decrease in water levels in the alluvial aquifer in the general area of dewatering.

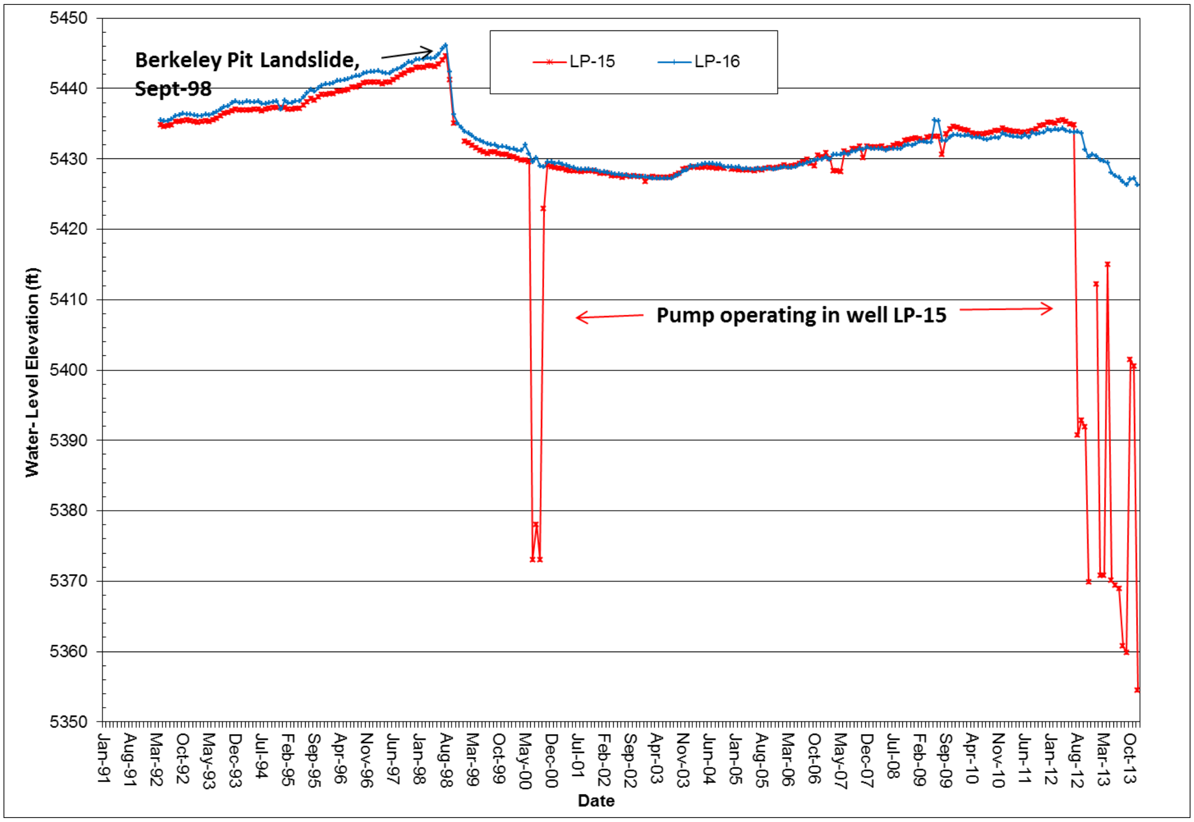


Figure 2-12. Water-level hydrographs showing influence of dewatering on water-levels in wells LP-15 and LP-16.

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. Water levels in these LP-series wells are controlled by the operation, dewatering, and subsequent reactivation of the leach pads, by operation of the Yankee Doodle Tailings Dam, by depressed water levels in the Berkeley Pit, or by a combination of all three. The water-level response seen in wells adjacent and downgradient of limited leaching operations during 2004–2005 and 2009–2013 clearly demonstrates the relationship of water-level changes and the leach pad operations. The influence of climatic conditions is minimal, at best, on these wells.

An alluvial aquifer potentiometric map (fig. 2-13), constructed using December 2013 water levels (BMF monitoring well network sites only) shows how alluvial waters 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.

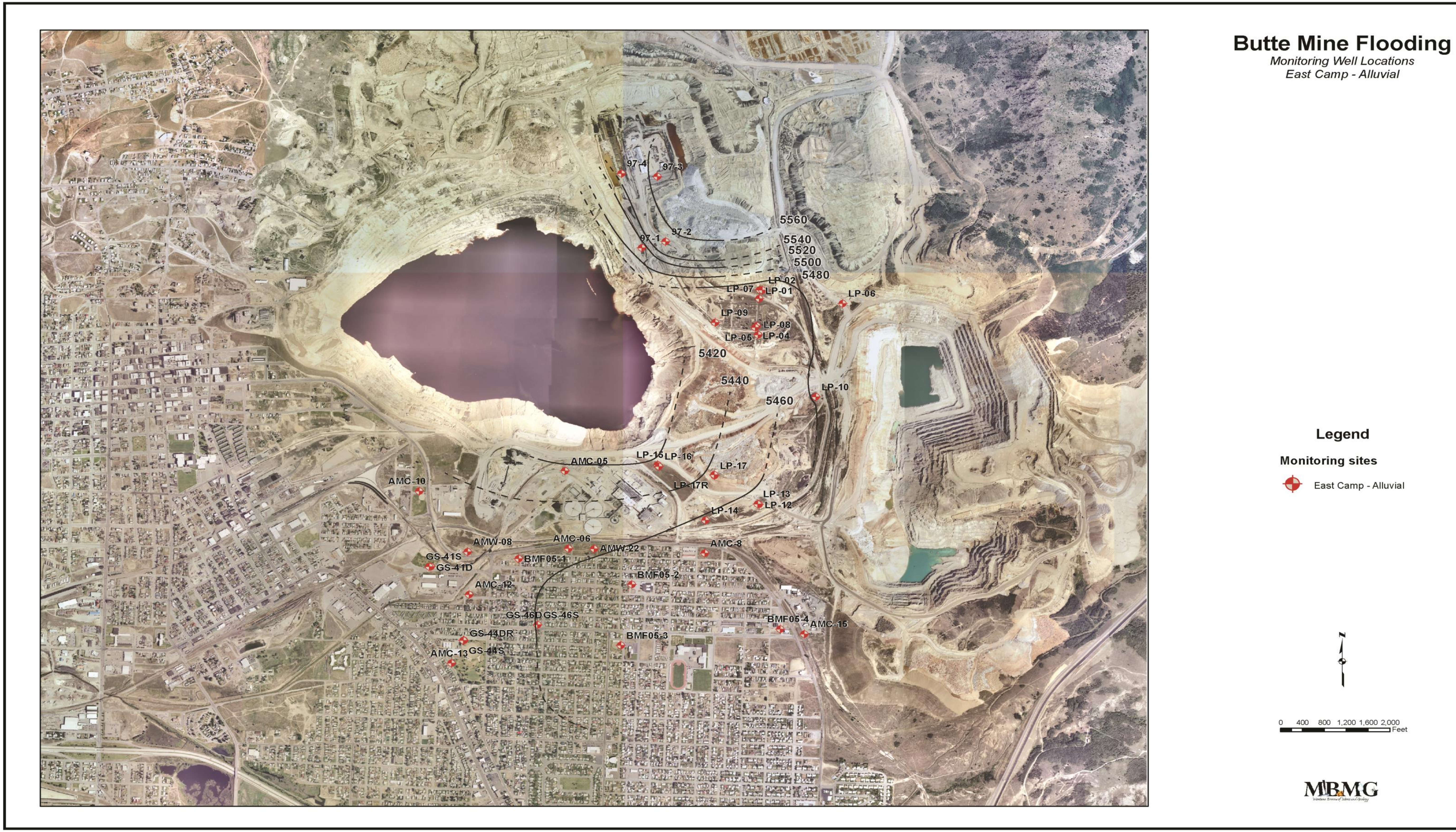


Figure 2-13. Alluvial aquifer potentiometric map for December 2013 (contour interval is 20 ft).

Section 2.1.2.1 LP-Series Wells Water Quality

Current water-quality monitoring of the LP-series wells is restricted primarily to those wells west and south of the Pittsmont Dump (fig. 2-8), with the exception of three wells: LP-08 (when it is not dry), LP-09, and LP-10, which are south of the leach pad area and north of the Pittsmont dump. Water-quality trends in 2013 showed limited changes in several wells; the changes are summarized in Table 2.1.2.2.

Well LP-9 was sampled a half dozen times following its installation in 1992 through 1996 and then not sampled again until April 2003; it has been sampled yearly since then. A comparison of the data indicates large increases in the concentration of most dissolved constituents starting in 1994. Data collected from 2003–2013 show that the increase in sulfate and zinc was sustained (fig. 2-14). The concentration of cadmium increased from 600 μg/L in 1992 to levels greater than 10,000 μg/L from 2003 to 2013; zinc increased from 172,000 μg/L in 1992 to levels greater than 1,500,000 μg/L from 2003 to 2013. (Zinc concentrations have declined since 2009; however, they are still an order of magnitude above historic levels.) In general, the concentrations of dissolved metals increased by nearly an order of magnitude over the past 6 to 10 years and approach those values seen in the pregnant solution of the upgradient leach pads.

Well LP-16 exhibited moderate increases for sulfate, copper, and zinc in 2010–2013 samples (figure 2-15). This is a change from historic trends. No other analytes showed an increasing trend.

Well LP-17 had the most significant change in trend during 2006–2012, with concentrations of cadmium, copper, and zinc decreasing by 50 percent from 2003–2005 concentrations. Nitrate concentrations were extremely high in the 2006–2009 samples, decreasing in 2010–2012 samples. However, those concentrations were still three times the MCL. A water-quality sample was collected from LP-17's replacement well the fall of 2013; concentrations were similar to those seen previously in LP-17.

The water-quality trend in other LP-series wells generally remained the same in 2013 as in recent years. A summary of exceedances and trends is presented in table 2.1.2.2.

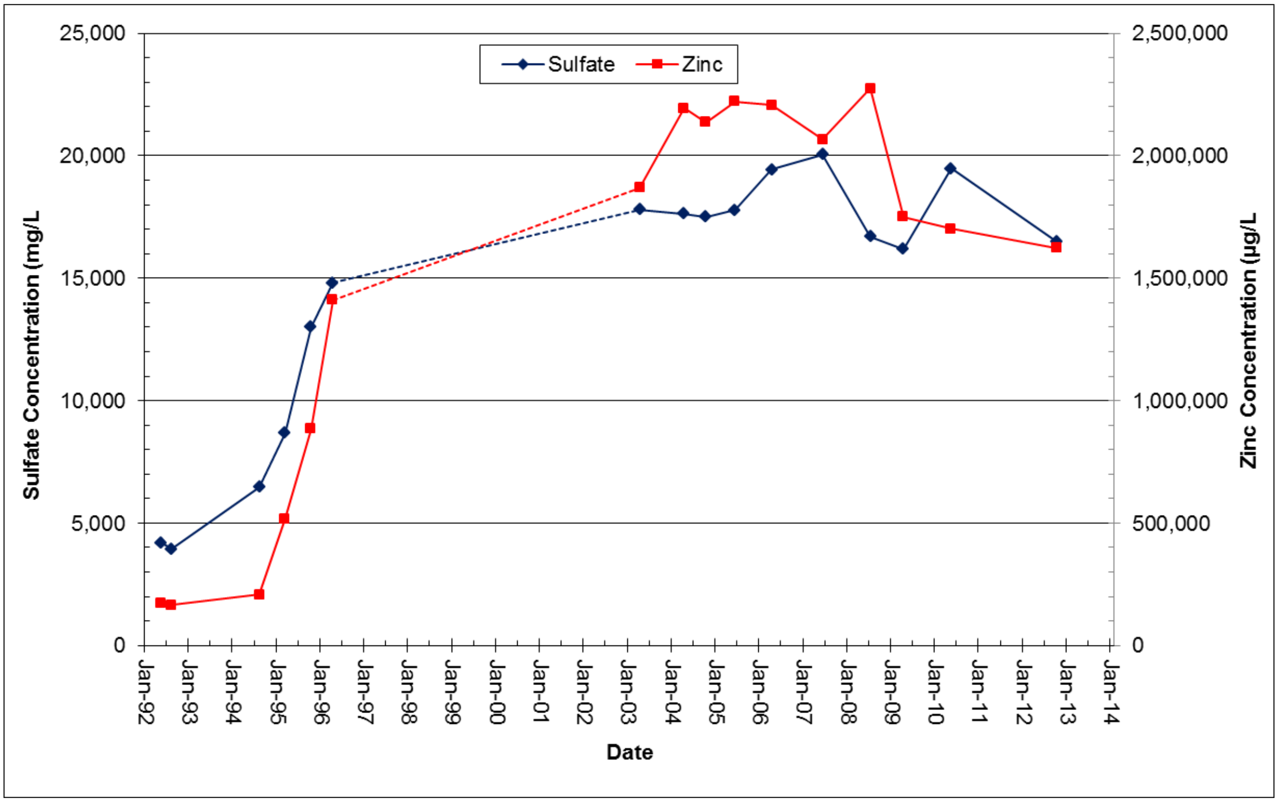


Figure 2-14. Sulfate and zinc concentrations in well LP-09.

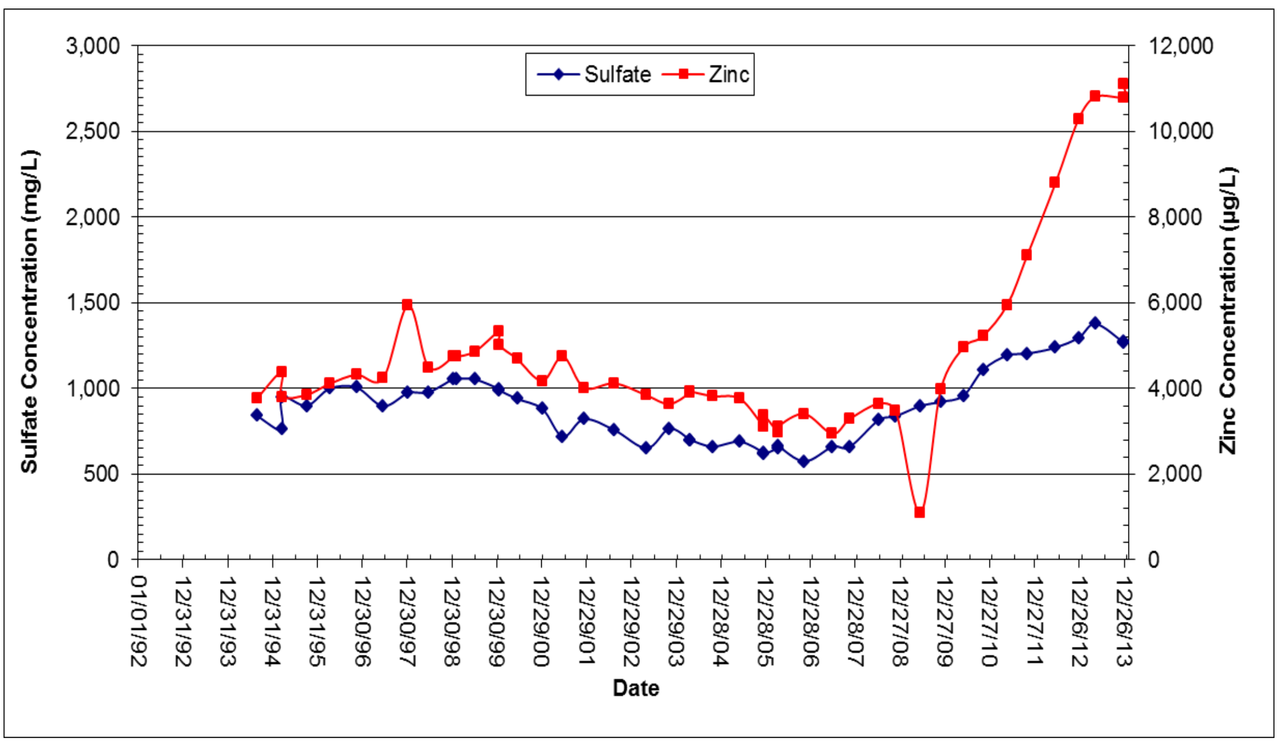


Figure 2-15. Sulfate and zinc concentrations in well LP-16.

Table 2.1.2.2 Exceedances and trends for LP series wells, 2013.

Well Name	Exceedances (1 or more)	Concentration Trend	Remarks
LP-08	Y	Downward	Very elevated concentrations. No 2010–2013 sample.
LP-09	Y	Upward	Large increases since 1992. No 2011 sample.
LP-10	N	None	No significant changes in 2013, not sampled in 2006–2007, 2010 due to access problems.
LP-12	Y	None	No significant changes in 2013.
LP-13	Y	Variable	No significant changes in 2013. Zinc dropped below MCL in 2013.
LP-14	Y	Variable	Cadmium exceeds MCL.
LP-15	Y	None	Net change is small for most analytes. No 2009–2010 samples due to access issues.
LP-16	Y	Upward	Sulfate trend continues increase seen in 2008, copper and zinc increased 2009–2013.
LP-17/LP-17R	Y	Downward	Nitrate declining; however, still 2.5 times MCL.

Section 2.1.3 Precipitation Plant Area Wells

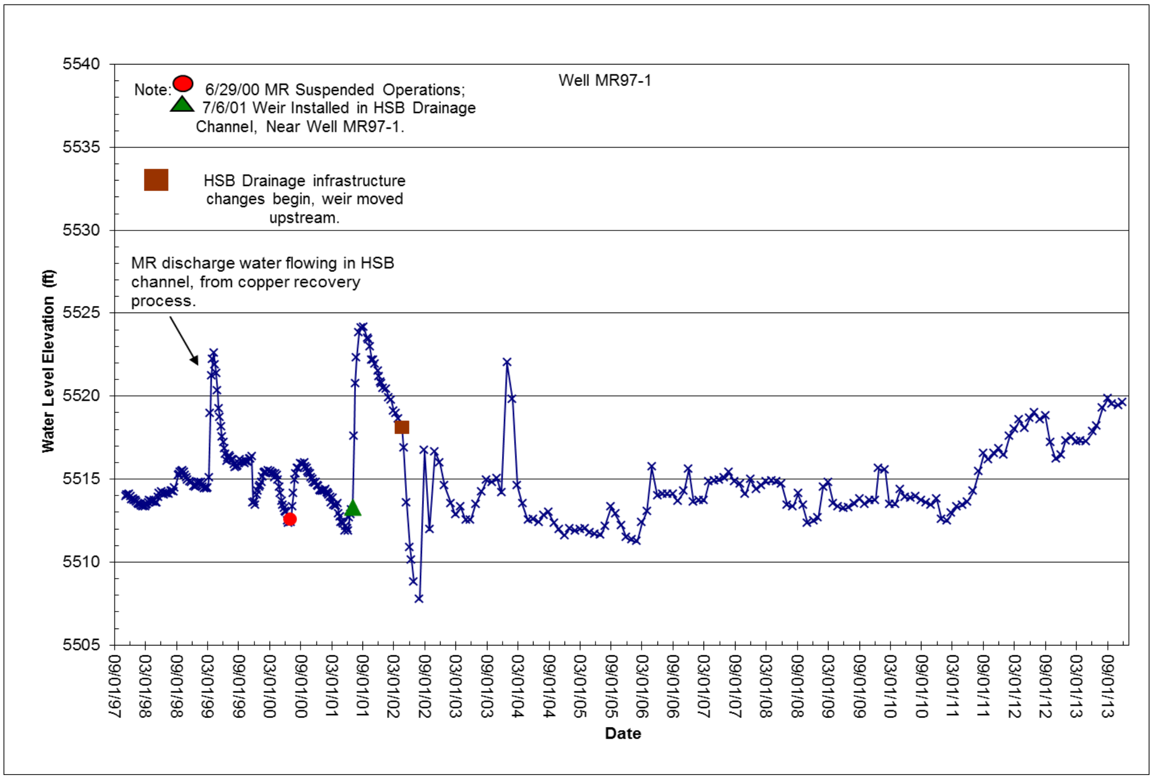
Wells MR97-1, MR97-2, MR97-3, and MR97-4 (fig. 2-8) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Table 2.1.3.1 lists annual and net water-level changes for these wells. Water-level changes appear to correspond to flow in these ditches and water levels in ponds.

Table 2.1.3.1 Annual water-level changes in MR97-series wells (ft).

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
2004	-10.01	-0.08	-4.28	1.86
2005	-0.67	-0.06	0.60	-1.84
2006	2.27	2.20	1.82	0.41
Change Years 1–10	**-0.34**	**-8.15**	**-11.77**	**2.90**
2007	0.78	0.18	3.88	0.81
2008	-1.73	0.39	-0.10	0.13
2009	2.97	2.46	1.08	-3.71
2010	-3.07	0.05	1.25	-1.97
2011	3.88	5.51	0.24	1.93
2012	0.87	1.29	0.38	-0.21
2013	1.86	2.03	1.95	-0.18
Change Years 11–20	**5.56**	**11.13**	**8.68**	**-3.20**
Net Change	**5.22**	**2.98**	**-3.09**	**-0.30**

(Minus sign (-) indicates a decline (drop) in water level.)

Water levels in well MR97-1 have shown the greatest degree of variation (fig. 2-16) due to the various changes in mining operations and infrastructure. Water levels increased when MR began to discharge water from their Berkeley Pit copper recovery project into the pit (Spring 1999). These variations were characterized by an initial increase in water levels followed by a gradual decrease before leveling off. The channel that carries water back to the pit after the removal of copper is adjacent to well MR97-1. This channel had been unused since April 1996, when HSB drainage water was captured and prevented from flowing into the pit. 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 shutdown. The HSB discharge water used the same drainage channel as the discharge water from the copper recovery project, and the flow of water was only about one-third the previous flow. If anything, with the decrease of flow in the channel, less water would be available for groundwater recharge and water levels would either stabilize or drop. Surprisingly, they rose before gradually declining over the next year.



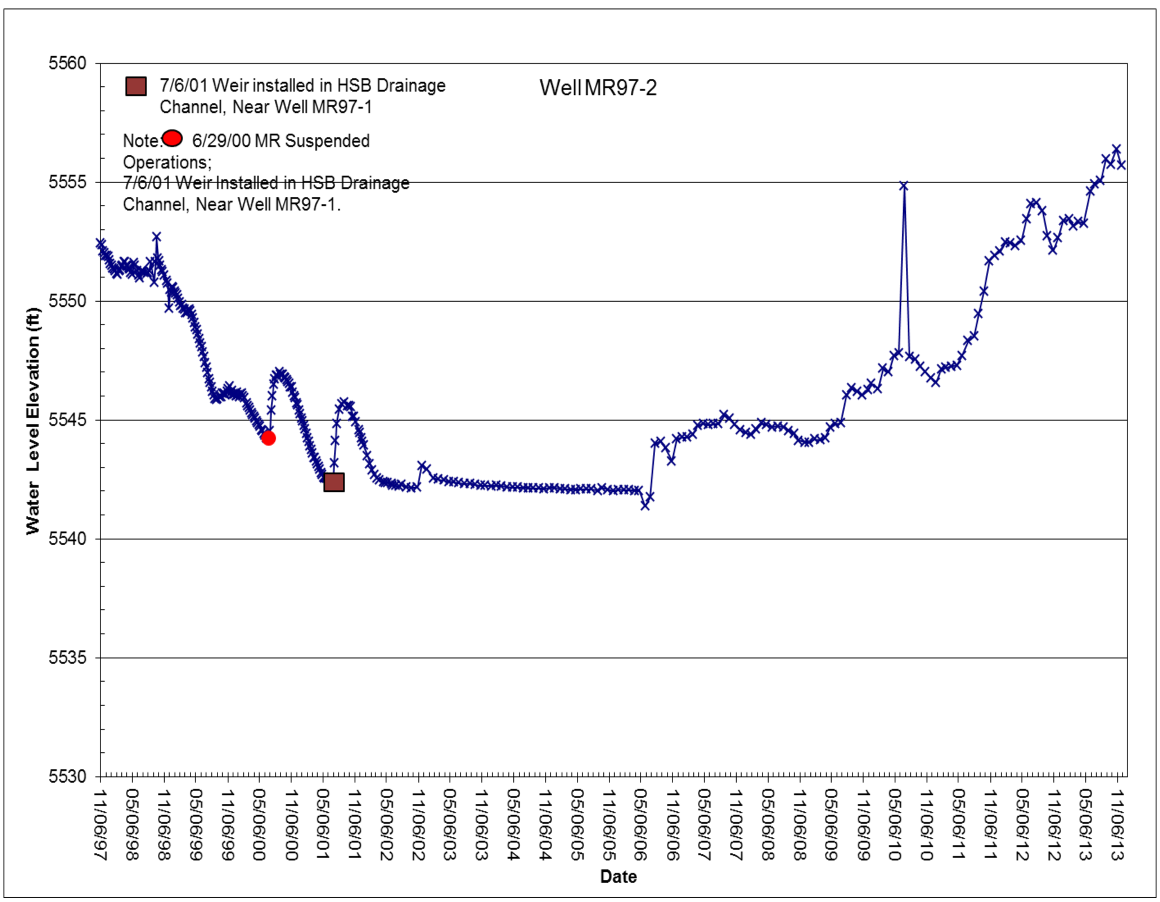


Figure 2-16. Water-level hydrograph for well MR97-1 (top) and MR-97-2 (bottom).

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 as part of infrastructure changes relating to the HSB water treatment plant construction. 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 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 during December 2003. The December rise coincides with the resumption of MR's copper recovery project and the corresponding flow of discharge water in the drainage ditch near well MR97-1. Water levels subsequently declined the first part of 2004 before leveling off for most of the remainder of 2004 and early 2005. Water levels have shown minor periodic variations between 2005 and 2013, with a slight upward trend.

Wells MR97-2 and MR97-3 are adjacent to historic collection ditches associated with the leach pads. Water-level changes were apparent in these two wells during 1999–2000 when MR made operational changes in leaching operations. As a result, the amount and level of water in collection ditches lessened and were reflected as a drop in water levels in wells MR97-2 and MR97-3 (figs. 2-16 and 2-17). Increases in water levels were noticed in 2009–2013 when limited leaching operations resumed.

Water-level increases were also seen in wells MR97-2, MR97-3, and MR97-4 following MR's suspension of mining (figs. 2-16, 2-17, and 2-18). The response in water levels in well MR97-2 (fig. 2-16) 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 2003–2005 through mid-2006 and did not show the same fluctuations as noted in well MR97-1. However, water levels increased during June, July, and November 2006, leveled off before rising during early spring 2007, before leveling off then decreasing slightly the later part of 2007. Water levels increased from 2009 to 2013.

The water level in well MR97-3 showed only minor responses during the 2001 and 2002 construction activities (fig. 2-17). With the exception of a brief period early in 2004, water levels continued to drop in this well until spring 2005, when they rose for several months before leveling off. Water levels continued to rise throughout most of 2006 and 2007, resulting in a net water-level increase of almost 1.8 ft and 3.88 ft in 2006 and 2007, respectively. Water levels have varied through the year from 2008 to 2013. This MR-series well is the farthest away from the HSB drainage channel and appears to be the least responsive to operational changes and flows in the discharge channel.

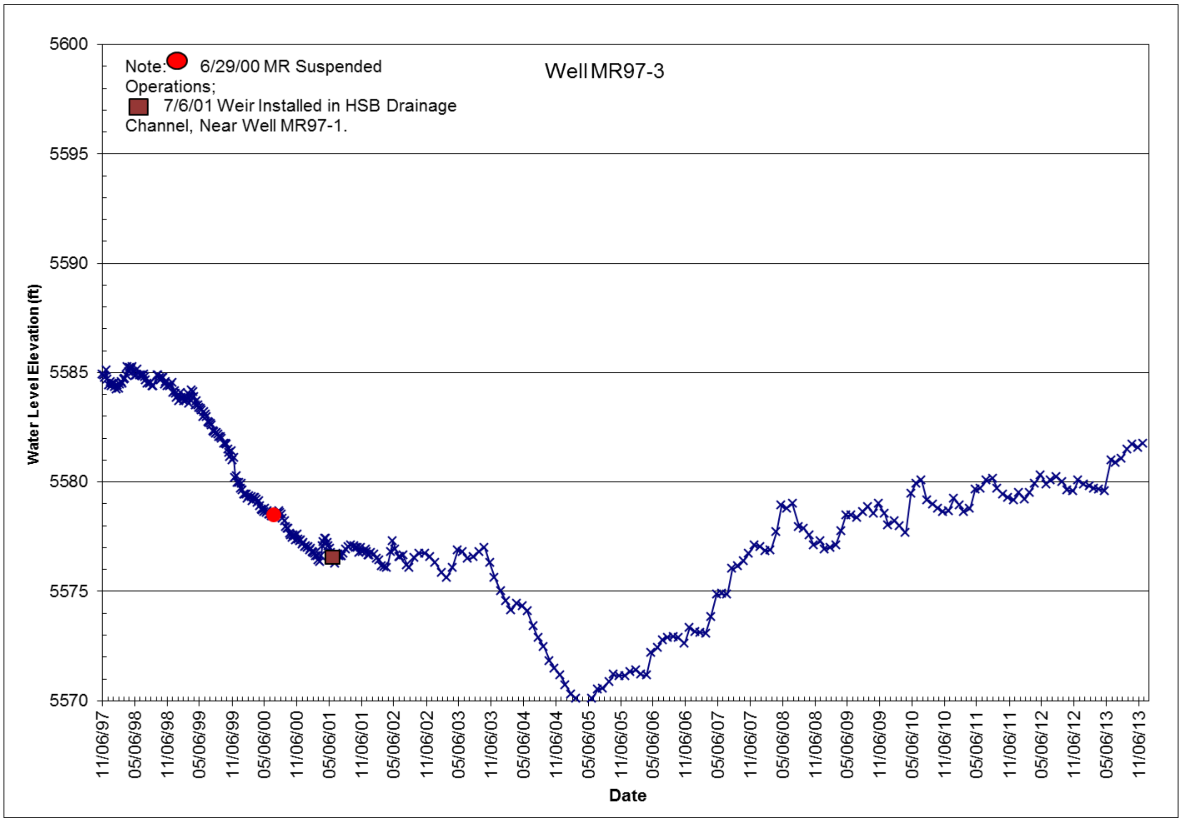


Figure 2-17. Water-level hydrograph for well MR97-3.

Water-level changes in well MR97-4 (fig. 2-18) have shown the least amount of variability over time. Water levels declined during most of 2011, with a net decline of almost 2 ft. The net water-level change in this well is less than 0.50 ft over time.

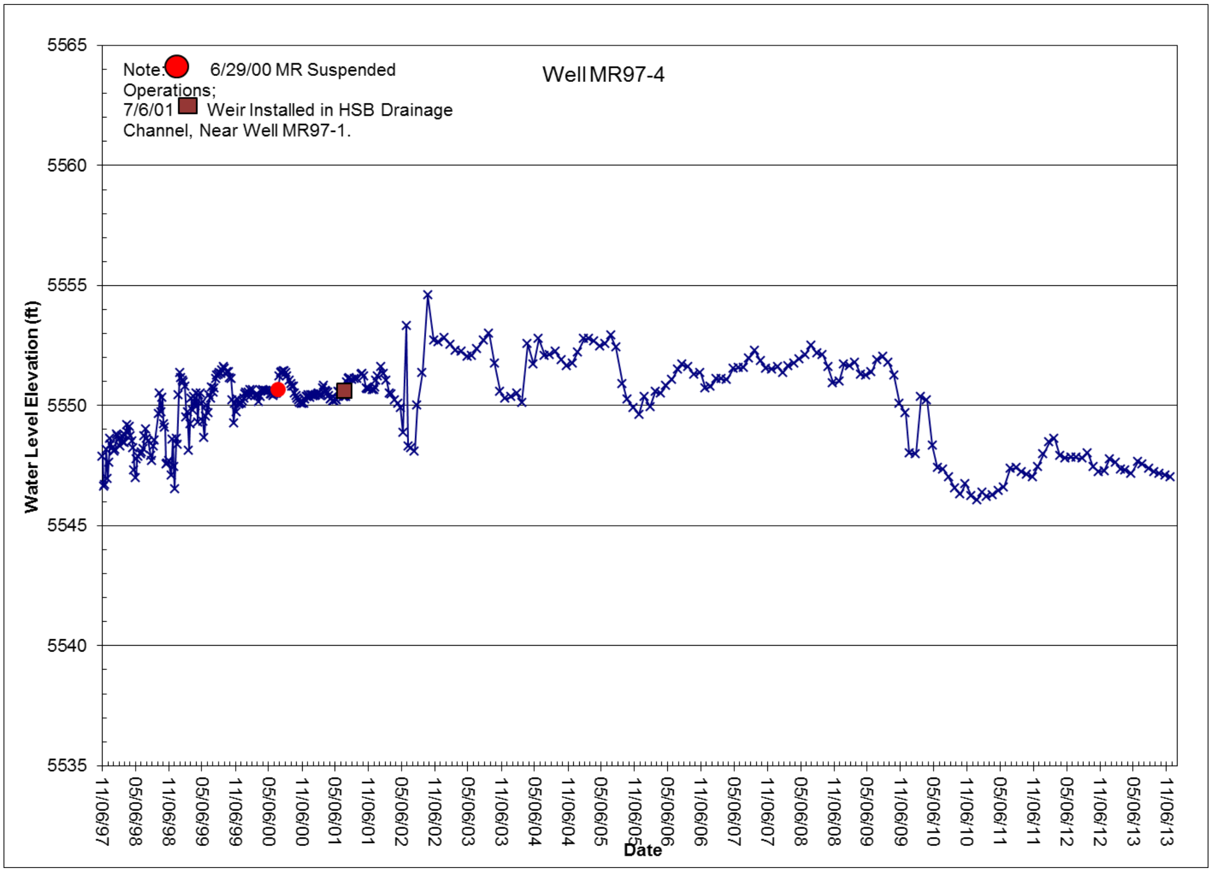


Figure 2-18. Water-level hydrograph for well MR97-4.

Water levels have declined 3 ft in the well (MR97-3) nearest the leach pads and ancillary facilities since its installation in 1997 (table 2.1.3.1), while rising between 5.22 and 2.98 ft in wells MR97-1 and MR97-2, respectively. It appears there is a direct influence on the shallow alluvial aquifer in this area with mine operations. Changes in mine operations (i.e., precipitation plant and leach pad) affect groundwater recharge in this area. Other changes, such as the weir installation and relocation, have affected groundwater levels in the area in the past.

No water-quality samples have been collected from this group of wells between 2001 and 2013. Previous sampling documented the presence of very elevated metal concentrations in the area. This contamination is most likely the result of leach pad and precipitation plant operations.

Section 2.1.4 GS and BMF05-Series Wells

Continuous and monthly water-level monitoring of the six GS wells and four BMF05 wells continued throughout 2013. The locations of these wells are shown in figure 2-19; table 2.1.4.1 contains annual water-level changes for these wells. Wells GS-41, GS-44, and GS-46 are nested pairs. That is, the wells were drilled adjacent to each other, but were drilled and completed at different depths. The S and D identify the shallow and deep well in each nested pair. During most years water-level changes are similar in these six wells. Water levels have a net increase over the period of monitoring in four of the six GS-series wells, with net increases ranging from 0.2 ft to 1.3 ft.

Figures 2-20 through 2-22 are water-level hydrographs with monthly precipitation totals shown for the three 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 and then decline throughout the fall.

Water-level changes in wells GS-41S and GS-41D were similar once again during 2013 (fig. 2-20), and the influence of precipitation was very noticeable. Water levels decreased about 0.75 ft in these two wells during 2013.

Net water-level changes in the GS-44 series wells during 2013 were similar to those seen in the past and to those seen in 2013 in the GS-41 wells. Seasonal trends of water levels rising in the summer and early fall, then declining, were similar to those seen in the past and in wells GS-41S and GS-41D throughout 2013 (fig. 2-21). The water levels in wells GS-44S and GS-44D decreased 0.65 ft during 2013.

Overall, water-level trends were similar during 2013 in wells GS-46S and GS-46D (fig. 2-22), and followed similar seasonal trends discussed previously for wells GS-41 and GS-44. Water levels decreased about 1 ft during 2013, while having a net water-level rise since monitoring began.

In both the GS-41 and GS-44 wells, the water levels in the shallow wells are higher than those in 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. However, as noted in the following section, the water quality in well GS-46D is of good quality, and as such this would not be a concern.

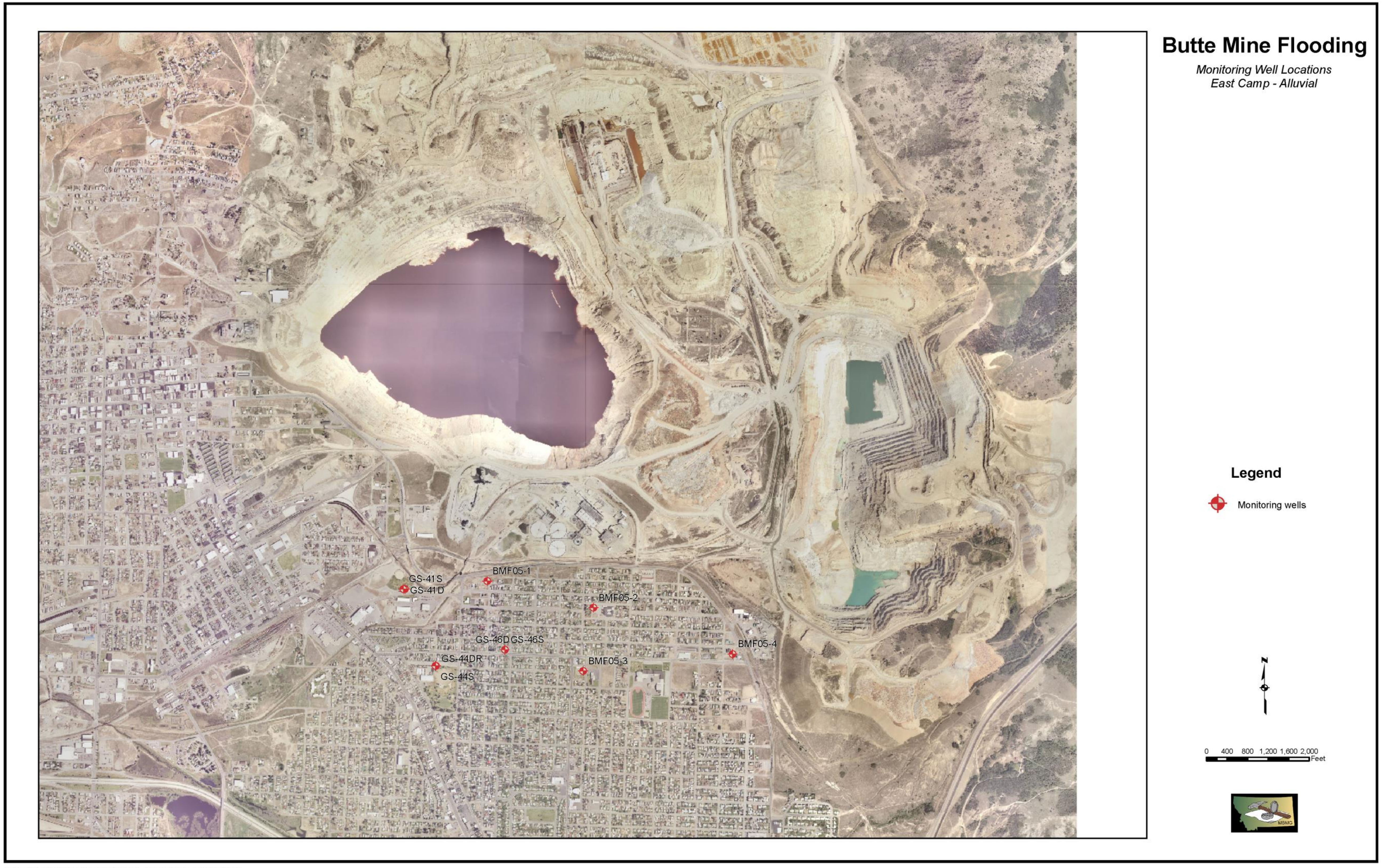


Figure 2-19. Location map for GS and BMF series wells.

Table 2.1.4.1 Annual water-level changes in GS and BMF05-series wells (ft).

Year	GS-41S	GS-41D	GS-44S	GS-44D	GS-46S	GS-46D	BMF05-1	BMF 05-2	BMF 05-3	BMF 05-4
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	1.26	1.32	1.26	1.38	1.30				
1996	0.59	1.65	1.12	0.89	0.98	1.20				
1997	1.32	0.20	0.58	0.79	1.09	1.18				
1998	-0.18	-0.06	0.09	0.07	1.17	0.24				
1999	-1.41	-1.49	-1.28	-1.25	-2.41	-1.65				
2000	-1.91	-1.78	-1.51	-1.39	-1.21	-2.07				
2001	-0.28	-0.41	-0.22	-0.38	-1.64	-0.92				
2002	-0.82	-0.81	-0.94	-0.82	-1.18	-1.18				
Change Years 1–10	**-0.38**	**-0.43**	**-0.22**	**-0.17**	**-0.84**	**-0.88**				
2003	0.19	0.26	0.27	0.17	-0.81	0.77				
2004	-0.31	-0.41	-0.76	-0.52	-0.08	-0.02				
2005	-0.60	-0.53	-0.40	-0.33	-0.59	-0.52				
2006	1.36	1.28	1.01	1.06	1.45	1.28	1.86	1.21	1.71	1.97
2007	0.24	0.22	0.34	0.33	0.20	0.41	-0.25	0.67	0.31	0.63
2008	-0.42	-0.39	0.24	-0.08	0.84	0.20	-0.18	-0.49	-0.09	0.10
2009	0.22	0.26	0.41	0.36	0.46	0.50	0.47	0.56	0.97	0.65
2010	0.11	0.14	-0.04	-0.02	-0.20	-0.10	0.03	0.00	0.05	0.16
2011	0.81	0.93	0.68	0.68	0.99	0.98	1.28	2.44	1.04	0.63
2012	-1.02	-1.03	-0.56	-0.60	-0.74	-0.75	-1.43	-2.76	-1.01	-0.75
Change Years 11–20	**0.58**	**0.73**	**1.19**	**1.05**	**3.14**	**2.75**	**1.78**	**1.63**	**2.98**	**3.39**
2013	**-0.72**	**-0.75**	**-0.65**	**-0.65**	**-1.01**	**-1.10**	**-1.41**	**-1.11**	**-1.63**	**-1.20**
Change Years 21–30	**-0.72**	**-0.75**	**-0.65**	**-0.65**	**-1.01**	**-1.10**	**-1.41**	**-1.11**	**-1.63**	**-1.20**
Net Change	**-0.52**	**-0.45**	**0.32**	**0.23**	**1.29**	**0.77**	**0.37**	**0.52**	**1.35**	**2.19**

(Minus sign (-) indicates a decline (drop) in water level.)

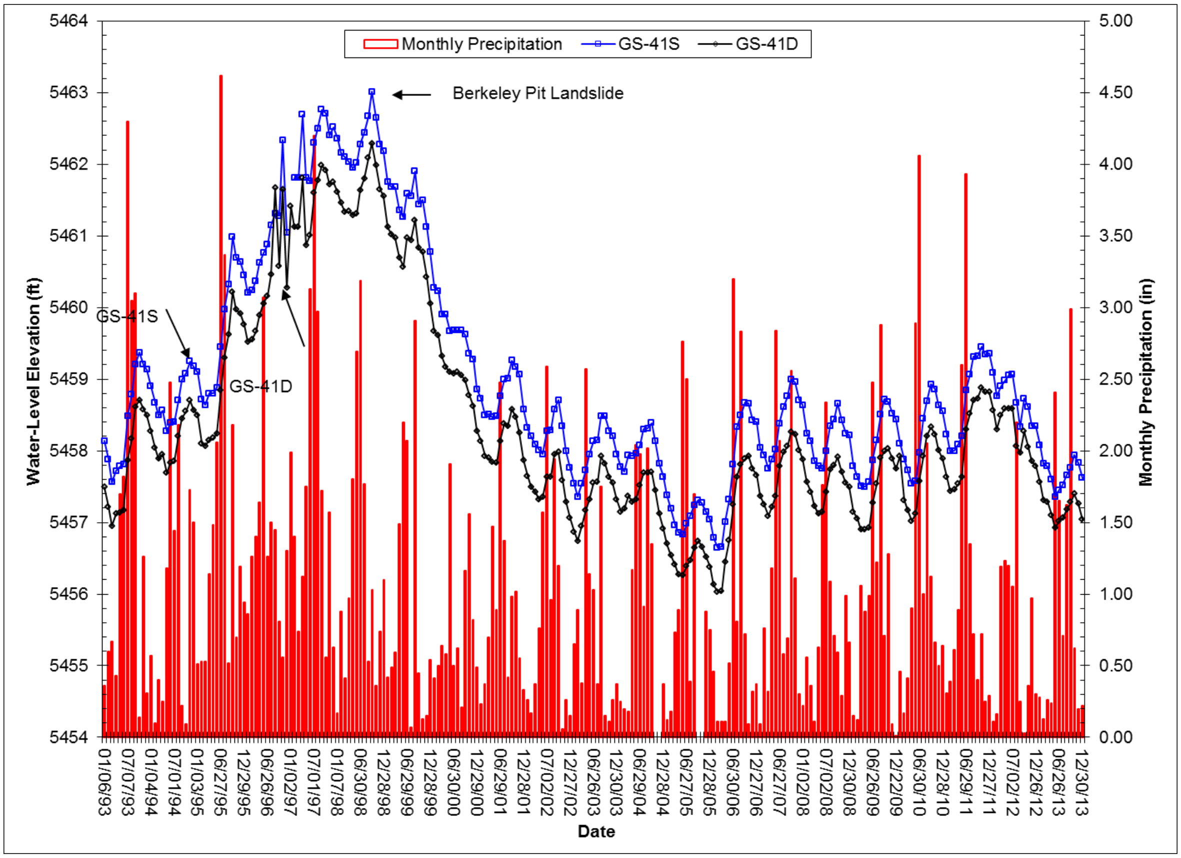


Figure 2-20. Water-level hydrographs for wells GS-41S and GS-41D.

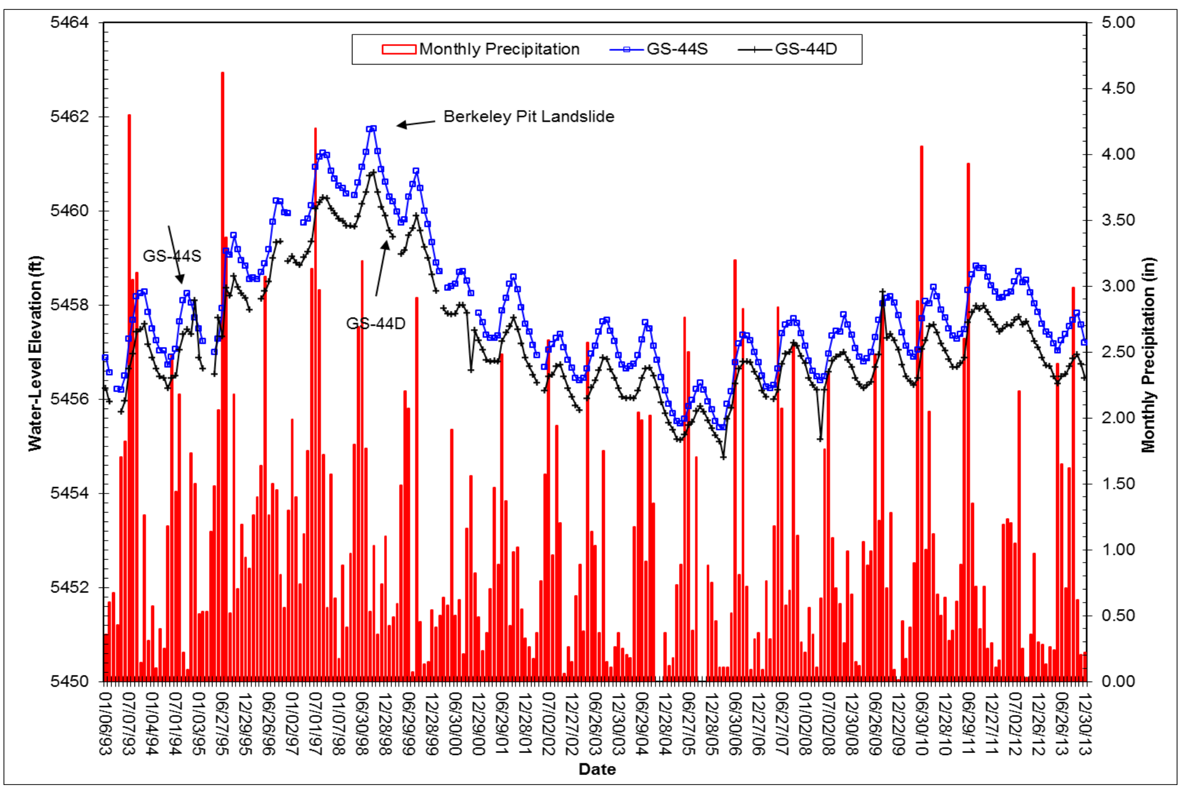


Figure 2-21. Water-level hydrographs for wells GS-44S and GS-44D.

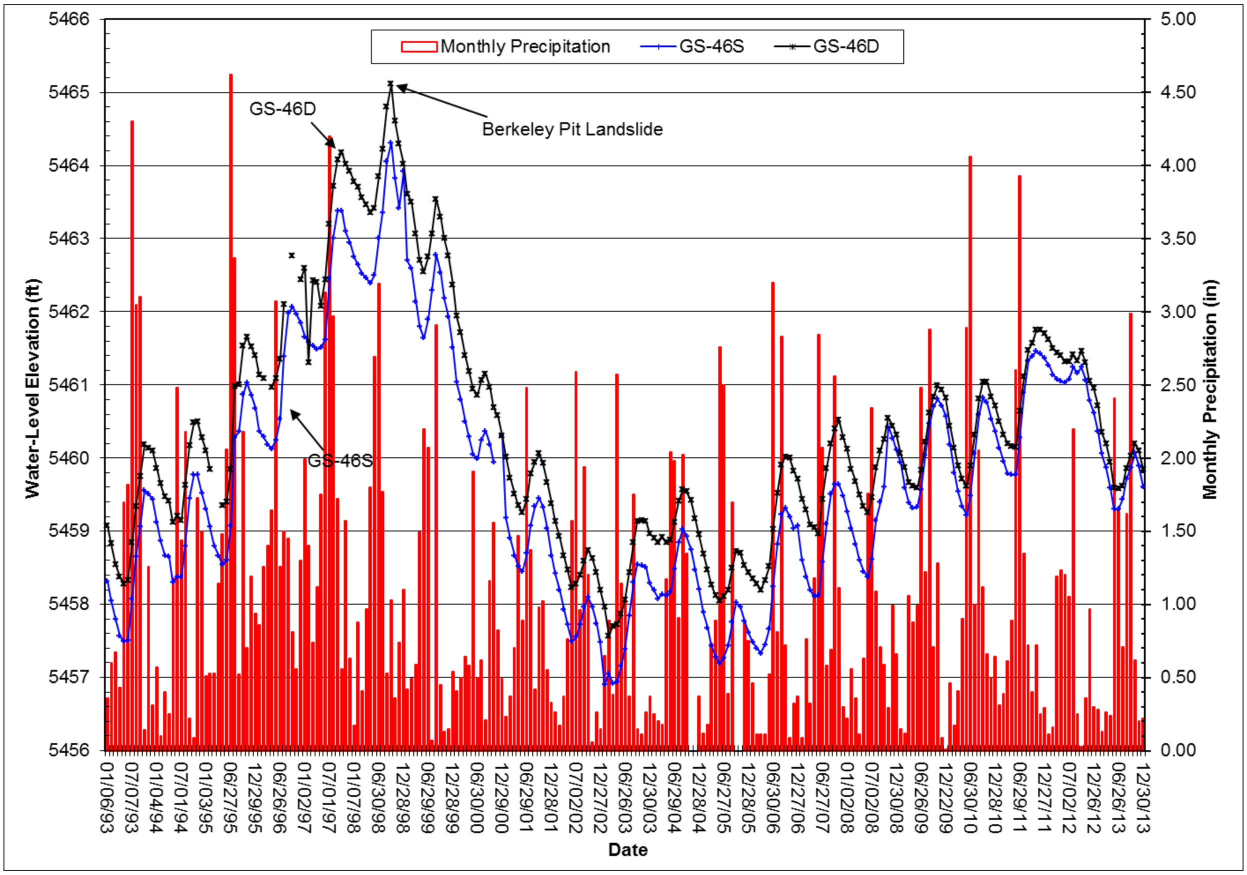


Figure 2-22. Water-level hydrographs for wells GS-46S and GS-46D.

The BMF05-series wells were installed in late 2005 and early 2006. These wells were installed to replace the domestic wells that were part of the post RI/FS monitoring program. The domestic wells were monitored from 1997 through 2002; however, it was determined that dedicated monitoring wells would be more reliable for the long-term monitoring program and would not be influenced by household usage. The locations of these wells are shown in figure 2-19. The wells were located to provide coverage throughout the same area covered by the domestic wells and to provide information for areas south of the Berkeley Pit active mine area. This area is important to better define the groundwater divide between the Butte Mine Flooding alluvial aquifer and Butte Priority Soils. Pressure transducers were installed in the spring of 2006 in each well for continuous water-level monitoring. Water levels have a net rise in all four wells since their installation (table 2.1.4.1).

Figure 2-23 shows daily average water levels for the BMF05-series wells based upon data collected from the pressure transducers. The transducers record water-level changes every hour; the data are then converted to daily averages to reduce the size of the dataset. The data from the continuous monitoring shows a slight overall upward trend in these wells. Well BMF05-1 saw a larger than normal water-level increase in the last quarter of 2011; this increase corresponds to the refilling of MR's

Ecology Pond following maintenance activities during the summer of 2011. A water-level decline occurred in this well, corresponding to the timing of MR's 2012 draining of the pond. Water-level trends were similar to those noted in well AMC-6, located nearby. The 2013 water-level trend follows a more seasonal trend.

Figure 2-24 is a hydrograph based upon monthly water levels and monthly precipitation totals. Each well's response time to precipitation events varies, most likely as a result of the different depths to water; the deeper the water level, the longer it takes for recharge from snowmelt and precipitation to reach the water table. The seasonal trends are not as pronounced in this group of alluvial wells as those seen in the GS-series wells.

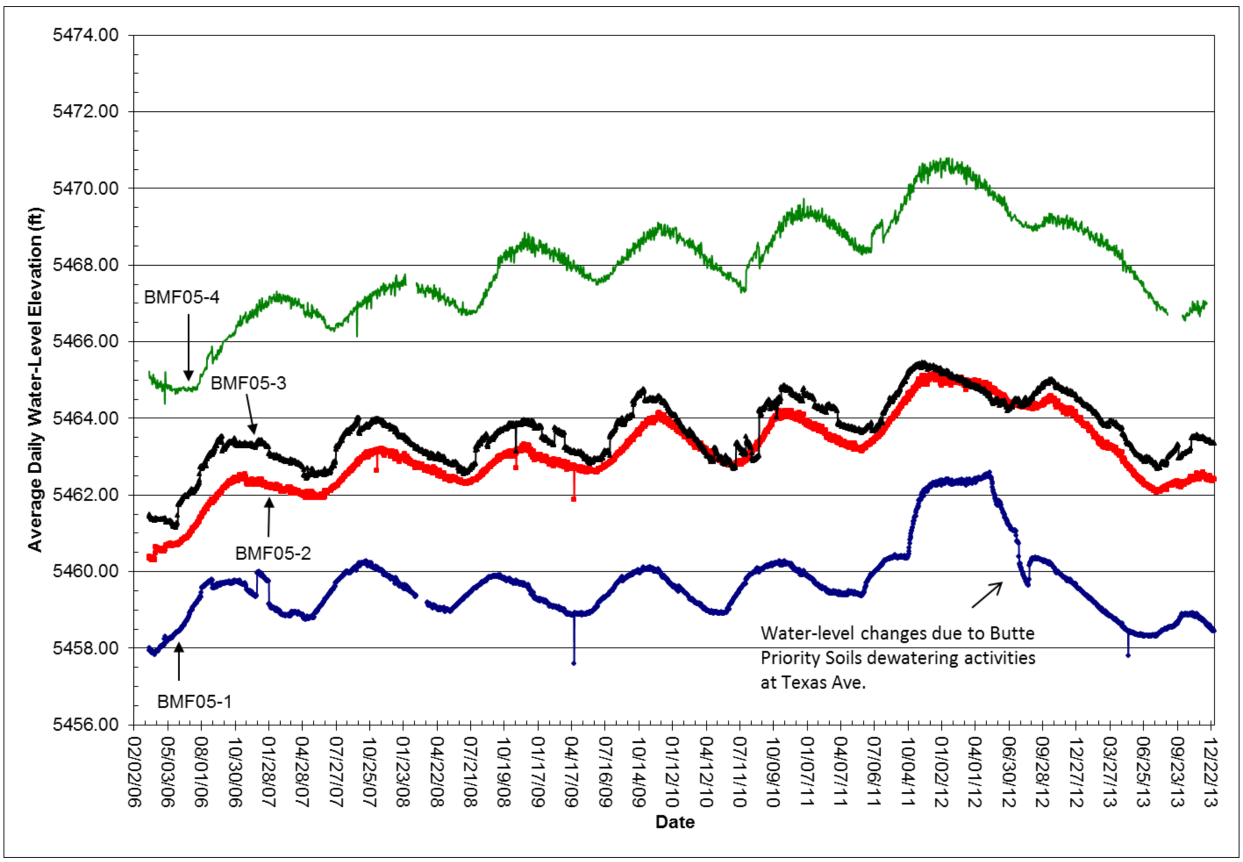


Figure 2-23. Average daily water levels for BMF05-series wells.

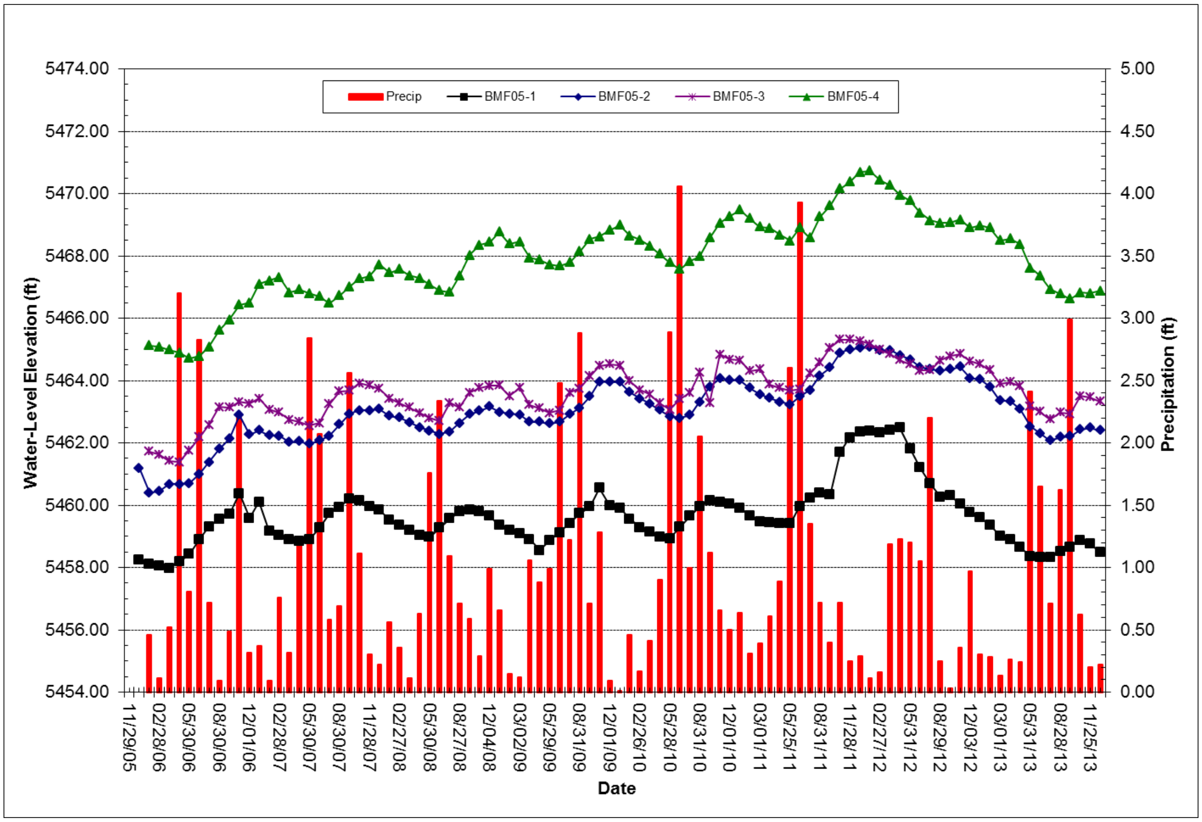


Figure 2-24. Monthly water levels versus precipitation, BMF05-series wells.

Section 2.1.4.1 GS and BMF05-Series Wells Water Quality

Water-quality samples were collected during the spring (April–May) sample event from GS-series wells as part of the 2013 BMFOU monitoring. The poor water quality in GS-41S and GS-41D reflects their proximity to the Parrot Tailings area; concentrations of dissolved constituents are extremely high. Data collected in 2013 confirms the large increases noted in many of the dissolved constituents since 2004; concentrations were similar to those seen in 2010–2012 data.

The concentration of several dissolved constituents continues to exceed MCLs in wells GS-44S and GS-44D at the north end of Clark Park. Cadmium concentrations continue to increase in well GS-44S and are at levels above the MCL in 2005–2013 samples, after being below the MCL for the 2003–2004 periods. While well GS-44D continues to exhibit concentrations greater than the MCL for cadmium, overall concentrations have decreased by as much as 50 percent, or more, over the period of record. Wells GS-46S and GS-46D, northeast of Clark Park, continued to exhibit good water quality in 2013 and showed little or no change in trend, with the exception of uranium (GS-46S), which exceeds the MCL in the 2005–2009 and 2011 sample results.

Water-quality samples were collected from the BMF05 wells three times a year during 2006–2007 to establish baseline conditions for these sites. Semi-annual samples were collected beginning in 2008. Well BMF05-1 is extremely contaminated, with pH less than 5.50 and elevated concentrations of iron, manganese, cadmium, copper, and zinc. Table 2.1.4.2 shows the mean values for the elevated constituents and the appropriate MCL or SMCL standard.

Table 2.1.4.2 Mean concentrations of analytes that exceed water-quality standards, well BMF05-1.

Analyte	Mean Concentration (mg/L)	MCL (mg/L)	SMCL (mg/L)
pH	5.13		6.5-8.5
Iron	8.47		0.30
Manganese	118.		0.05
Aluminum	0.564		0.05-0.2
Cadmium	0.196	0.005	
Copper	3.38		1.0
Zinc	45.7		2.0
Sulfate	1,536		250

Based upon the location of this well (fig. 2-19), adjacent to the historic Silver Bow Creek channel and downgradient from MR's concentrator, it is not surprising that the groundwater in the area is contaminated with mining-related type wastes. Contaminant concentrations are similar to those in well AMC-5 located to the north. Mean concentrations are above standards for pH in wells BFM05-2 and BMF05-4.

Section 2.2 East Camp Underground Mines

Monitoring of water levels in the seven East Camp underground mines continued. Their locations are shown in figure 2-25. During 2013, water levels rose between 6.62 and 6.87 ft in the mines, which were similar to last year's totals. The Berkeley Pit water level rose 8.12 ft, which is 1.38 ft more than last year (table 2.2.1). Waste material and unconsolidated alluvium that fell into the pit from the rotational slump that occurred on the southeast corner of the Berkeley Pit on February 8, 2013 resulted in an additional water-level rise of 0.60 ft in the pit and several nearby bedrock wells. No additional water-level increase was noted in the underground mine workings from this slump. Figure 2-26 shows the annual water-level changes graphically for these sites. The rate of water-level rise has slowed by 50 to 60 percent since 2003 when the Horseshoe Bend drainage water was diverted away from the pit.

Table 2.2.1 Annual water-level changes in East Camp mines (ft).

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		
Change Years 1–10	***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
Change Years 11–20	**201.74**	**184.45**	**188.69**	**170.64**	**190.62**	**199.12**	**68.30**	**74.76**
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
2004	7.68	7.31	7.86	7.54	7.48	7.67		7.53
2005	7.03	7.10	7.37	7.17	7.00	6.98		6.97
2006	7.69	7.70	8.29	7.74	7.99	7.92		8.61
2007	6.90	6.91	7.55	6.38	7.25	7.28		7.39
2008	6.63	5.42	6.28	7.01	5.58	5.68		6.13
2009	7.17	6.69	6.79	7.33	7.13	6.92	52.79	6.38
2010	7.32	7.30	7.83	7.45	7.80	6.48	7.03	7.07
2011	7.20	7.31	8.22	8.46	7.11	8.99	7.91	9.11
Change Years 21–30	**86.26**	**80.39**	**87.28**	**85.84**	**83.38**	**84.97**	**82.56**	**84.57**
2012	**6.74**	**6.54**	**6.42**	**6.67**	**6.43**	**6.42**	**7.08**	**5.96**
2013	**8.12**	**6.87**	**6.98**	**6.84**	**6.62**	**6.72**	**6.85**	**6.77**
Change Years 31–40	**14.86**	**13.41**	**13.40**	**13.51**	**13.05**	**13.14**	**13.93**	**12.73**
Net Change*	***314.86***	***552.85***	***3,186.79***	***2,157.49***	***2,162.60***	***517.33***	***172.89***	***172.06***

(Minus sign (-) indicates a decline (drop) in water level.)

(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 from February 2003 to April 2009, 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.

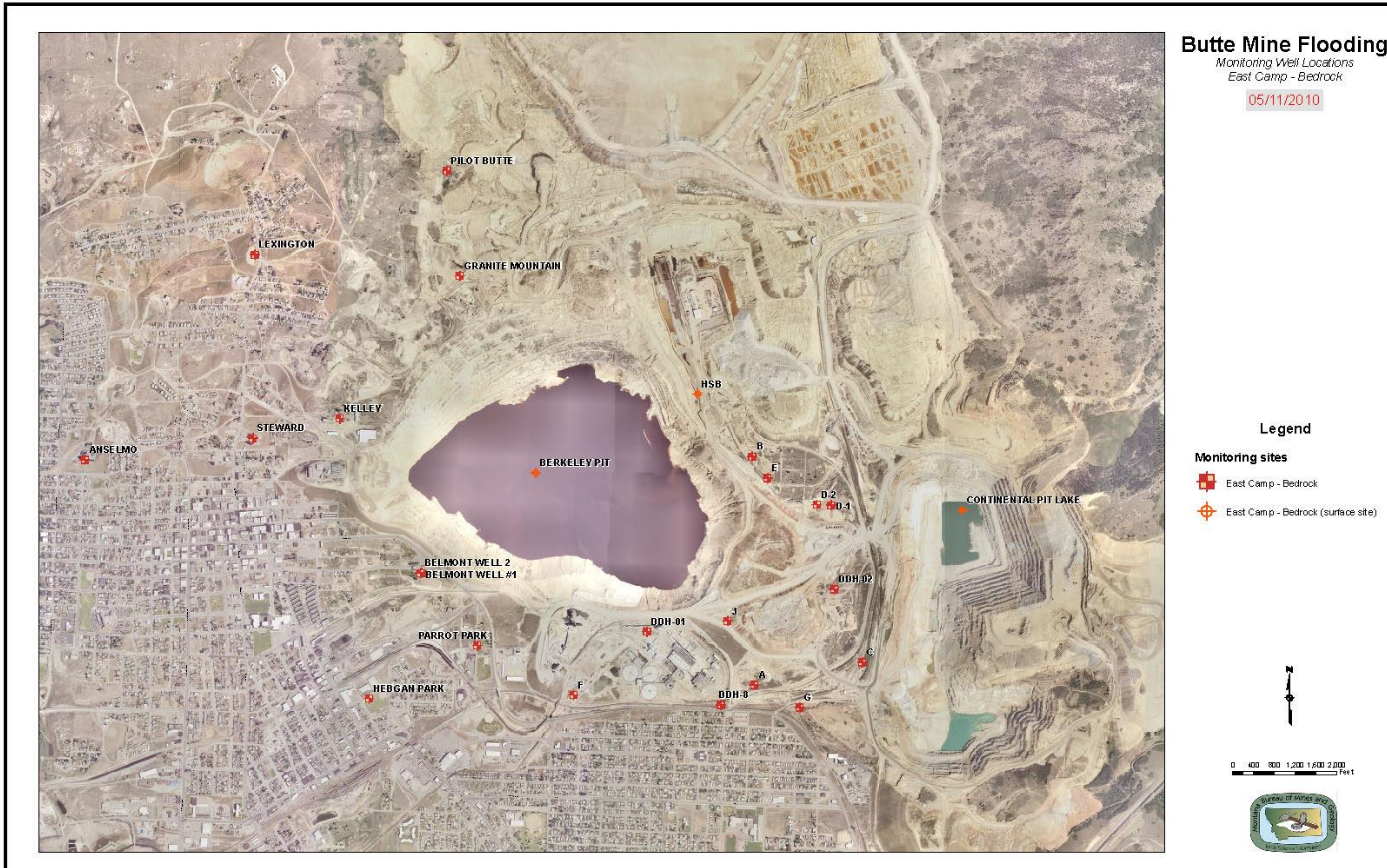


Figure 2-25. East Camp mines and bedrock wells location map.

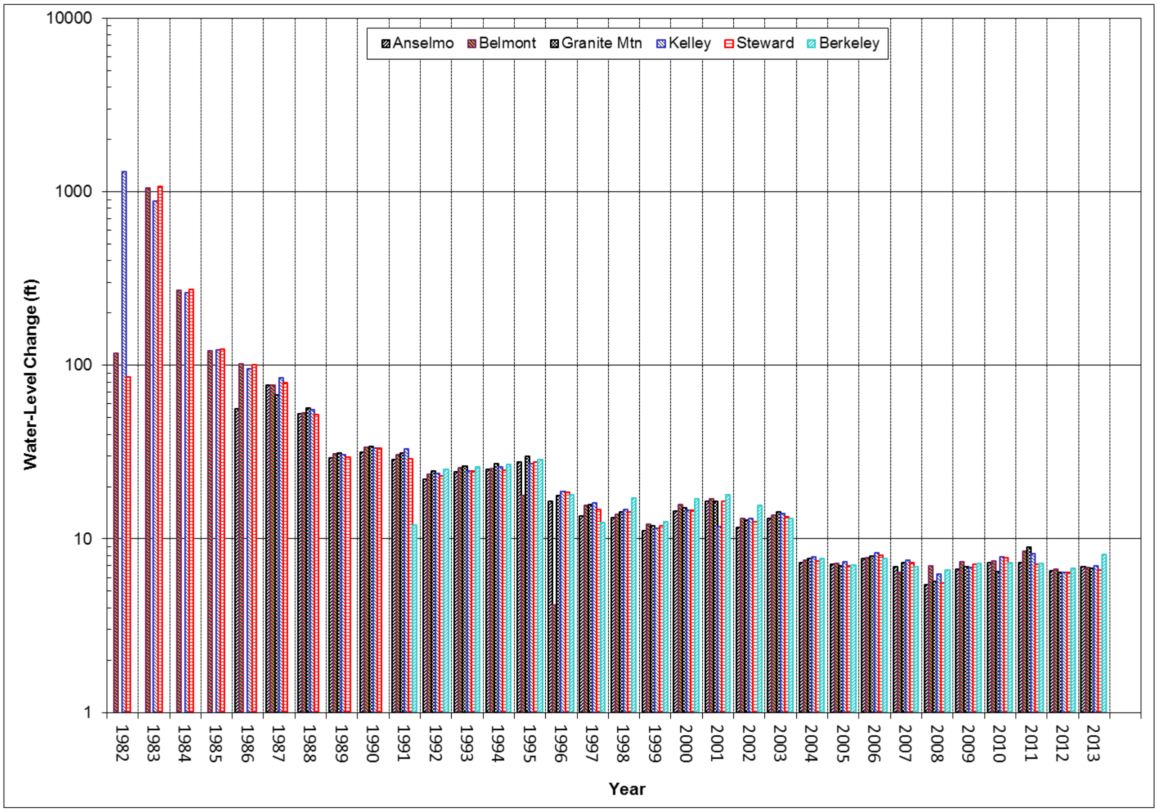


Figure 2-26. East Camp mines annual water-level changes.

The hydrograph (fig. 2-27) is based upon water levels for the Anselmo Mine and Kelley Mine for the period of record. Except for the steadily increasing water levels, there are no obvious variations on this figure; however, when more detailed water levels are plotted from 1995 through 2013, several changes are noticeable (fig. 2-28). The removal of HSB drainage water discharging into the pit in April 1996 resulted in a flattening of the line, while the July 2000 addition of the HSB drainage water, following MR's suspension of mining, resulted in an increased slope of the line. The slope of the line, or rate of rise, shown in fig. 2-29 remained the same throughout 2013, corresponding to the continued removal of the HSB drainage water and its subsequent treatment; the HSB treatment plant came on-line during late November 2003. A similar trend was seen in all the East Camp underground mines.

There is no apparent influence on water levels in the underground mines from monthly precipitation (figure 2-27). It is obvious that the rise in water levels is a function of historic mine-dewatering activities and the void areas in the underground mine workings and Berkeley Pit and is not a function of precipitation. Based upon volume estimates of the underground mines and December 2013 water-level elevations, 85 percent of the underground workings are flooded. Since approximately 12 percent of the underground workings are above the CWL elevation of 5,410 ft, only 3 percent of the underground workings remain to be flooded.

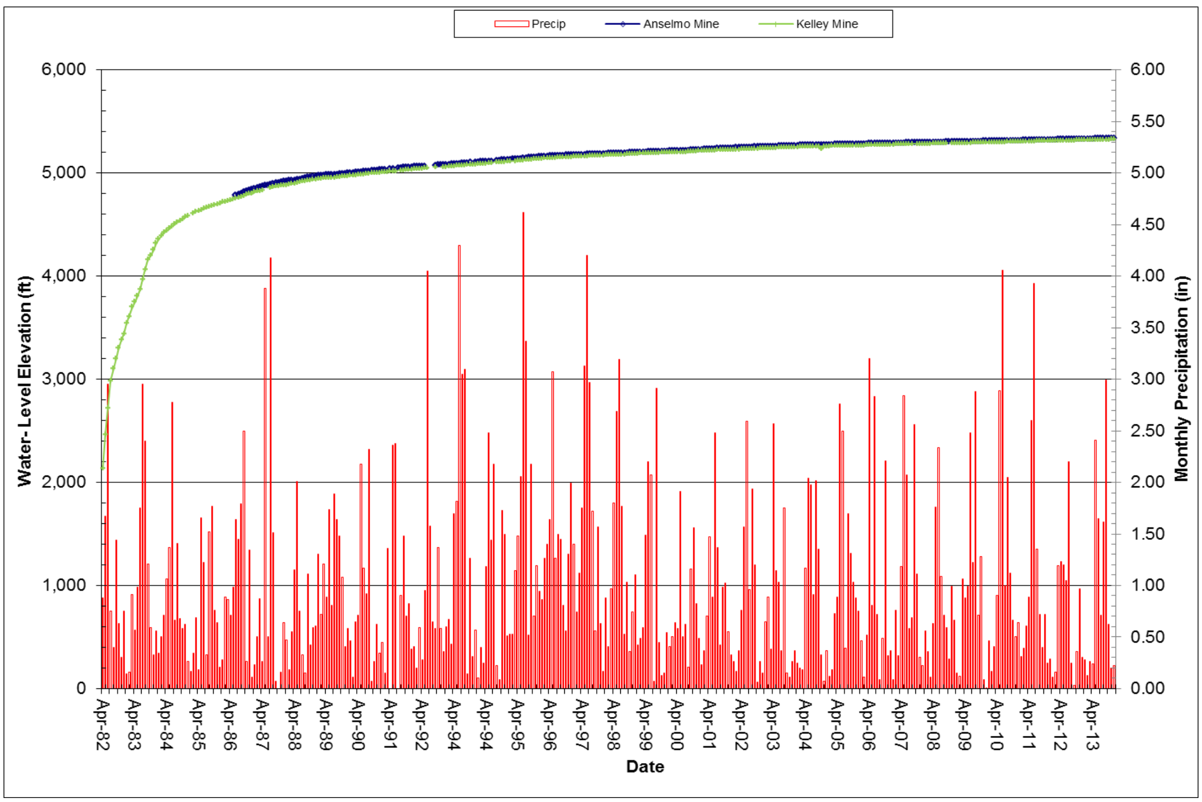


Figure 2-27. Anselmo Mine & Kelley Mine hydrograph versus precipitation, 1983–2013.

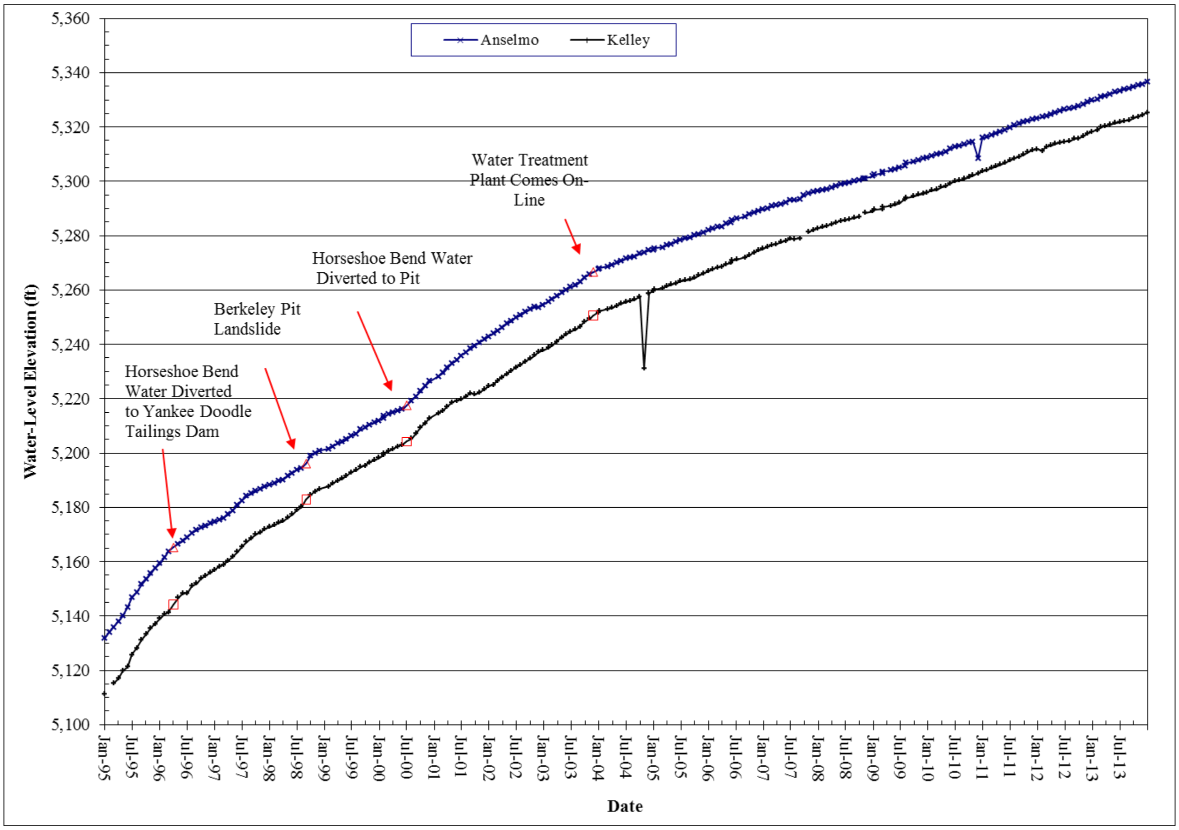


Figure 2-28. Anselmo Mine and Kelley Mine hydrograph, 1995–2013.

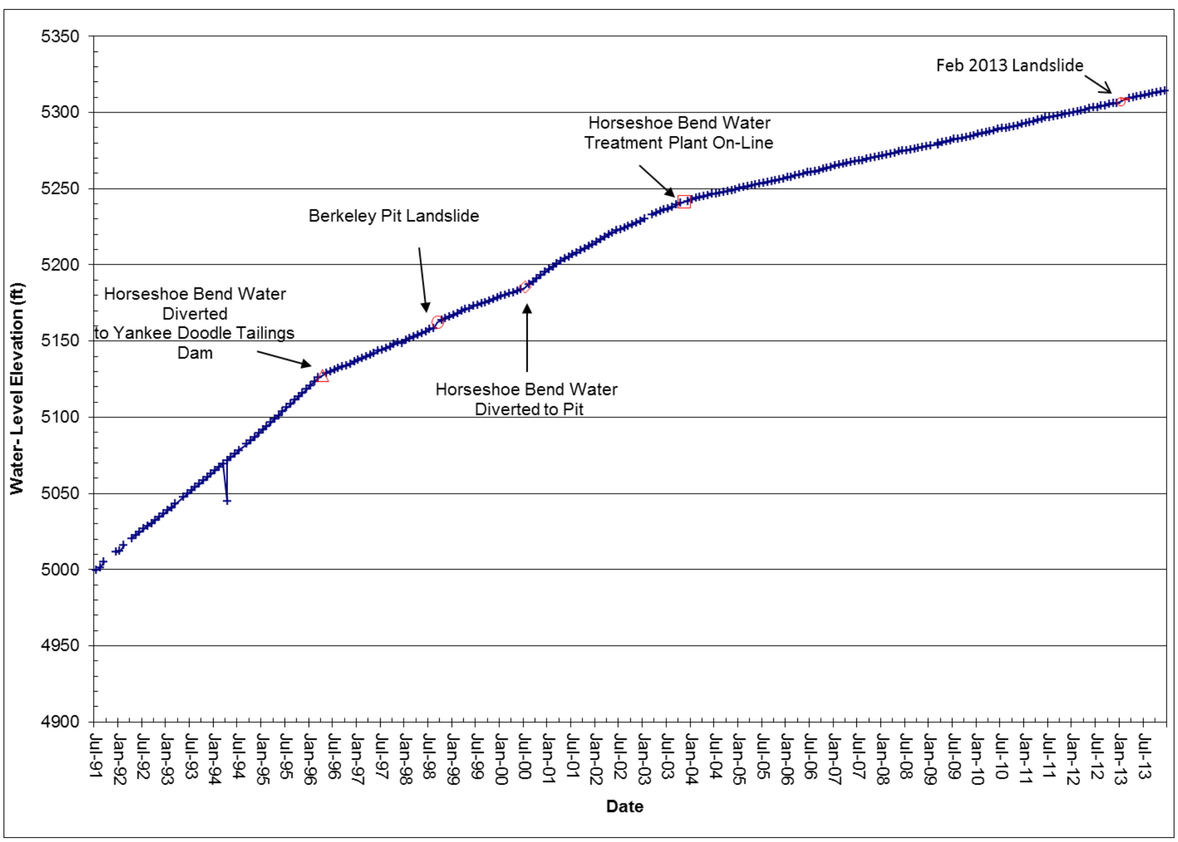


Figure 2-29. Water-level hydrograph for the Berkeley Pit, 1991–2013.

Figure 2-29 shows monthly water-level changes in the Berkeley Pit from 1991 through 2013. Water-level changes (increases) seen over the past 6 months of 2000, following the addition of HSB drainage water, continued through 2003. However, water-level increases were much less from 2004 to 2013 as a result of the decreased inflow of water into the pit.

The 1994 ROD and 2002 CD established eight points of compliance (POC) in the East Camp system, five of which are within the mine system. These points of compliance were selected to ensure contaminated water was contained within the underground mine system and Berkeley Pit. The POC elevation was established at 5,410 ft above sea level. Under the terms specified in the ROD and CD, the water level cannot exceed the 5,410 ft elevation at any POC without monetary penalties being applied to the settling parties. Water levels remain highest in the sites farthest from the Berkeley Pit. The East Camp mine compliance point with the highest water level at the end of 2013 was the Pilot Butte Mine, which was at an elevation of 5,339 ft, or 71 ft below the action level. This continues to confirm that water is flowing towards the pit, thus keeping the pit the low point in this system.

Section 2.2.1 Water Quality

Earlier reports discussed the lack of appreciable change in water quality within the East Camp mines until 2002 when several of the shafts exhibited significant departure from previous trends. Data from the 2013 sampling indicate that the changes in concentration are sustained for yet another year. Again, most notable is the elevated concentration of arsenic, iron, manganese, zinc and sulfate in the Kelley shaft The Anselmo, Kelley and Steward mines were sampled during the spring 2013 sample event at a depth of 100 ft below the water surface. No depth samples were collected from any of the mines due to obstructions at depth in the mine shaft Concentrations varied very little with sample depth in previous years. (Data shown in figures are from samples collected 100 ft below the water surface.)

<u>Kelley</u>: iron, sulfate, arsenic, and aluminum increased to near historic concentrations in 2003–2004, decreasing gradually from 2005–2013 (fig. 2-30). Copper concentrations increased in the 2010–2013 samples; however, they remain very low.

<u>Anselmo</u>: the trend for iron concentrations remains elevated but less than 2004 concentrations; arsenic concentrations were similar to those seen in 2004; zinc concentrations remain similar to those seen in 2007 (fig. 2-31). Copper concentrations remain very low (<20 μg/L).

<u>Steward</u>: the iron and arsenic concentrations in the Steward shaft remain high, following the upward trend of recent years. The trend has been downward for zinc and copper (fig. 2-32); however, zinc concentrations remain well above standards.

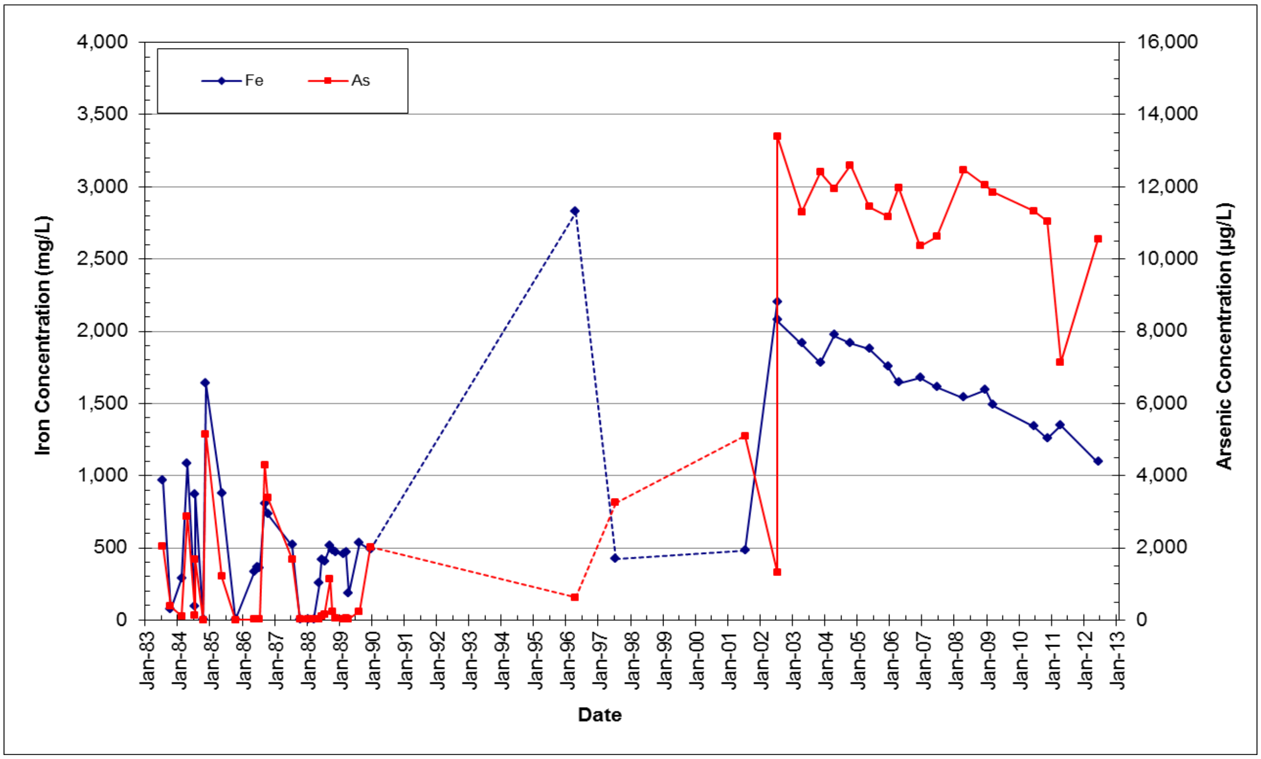


Figure 2-30. Kelley Mine Iron and arsenic concentrations over time.

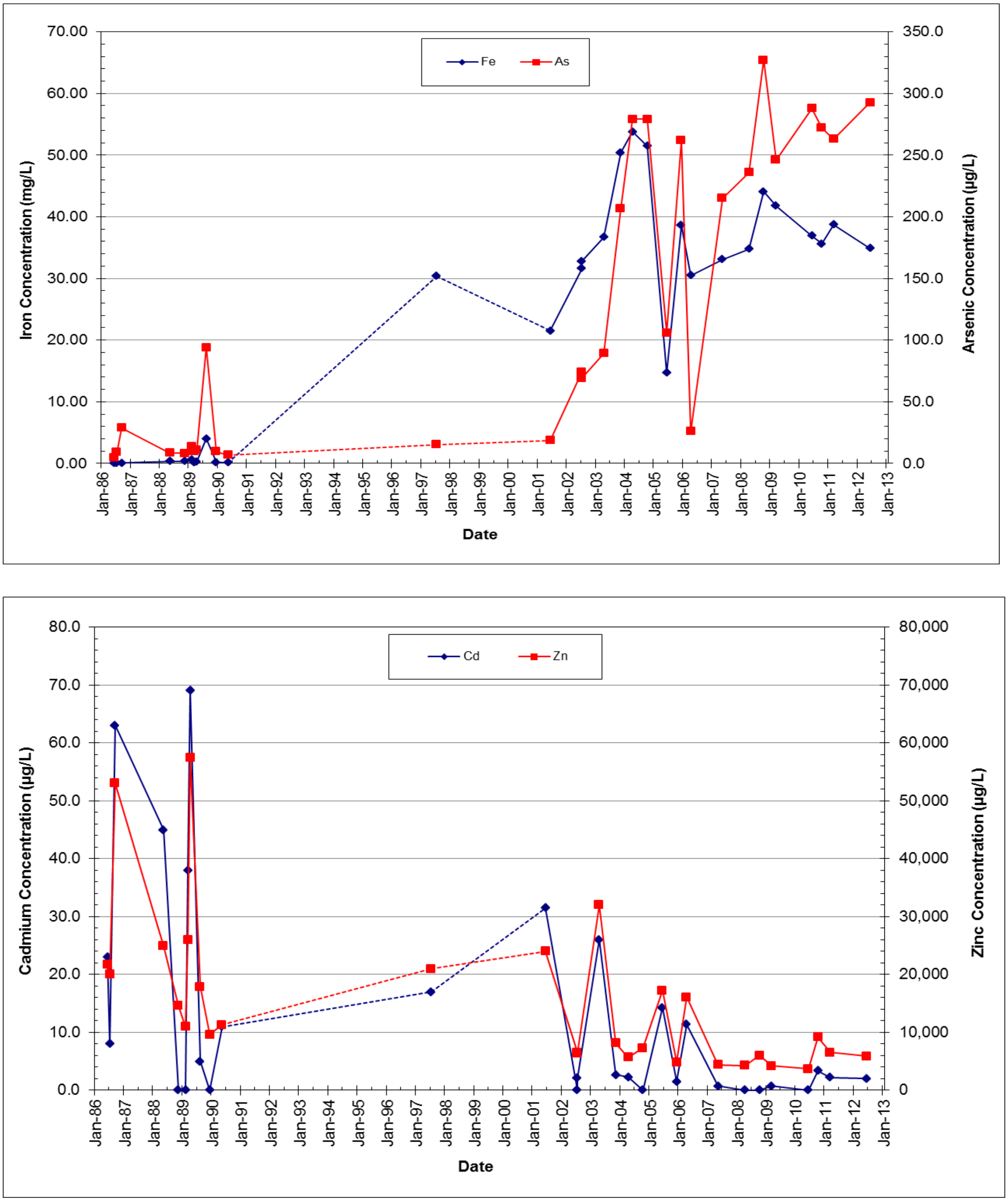


Figure 2-31. Anselmo Mine Iron and arsenic concentrations (top) and cadmium and zinc concentrations (bottom) over time.

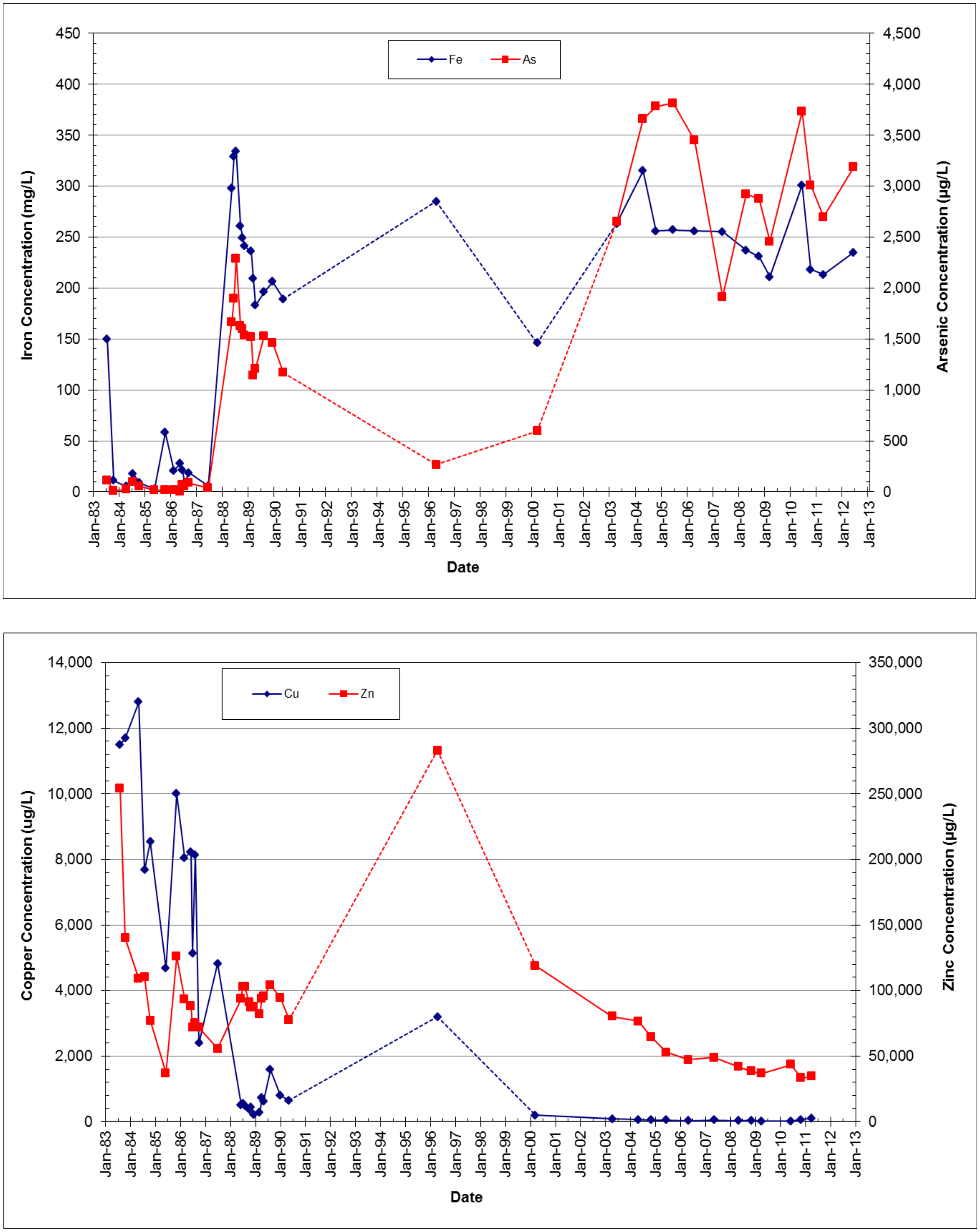


Figure 2-32. Steward Mine Iron and arsenic concentrations (top) and cadmium and zinc concentrations (bottom) over time.

Section 2.2.2 RI/FS Bedrock Monitoring Wells

Monitoring of the nine RI/FS and ROD-installed bedrock wells continued. Monitoring well locations are shown in figure 2-25. Water levels rose in wells A, B, C, D-1, D-2, G, and J at rates similar to those in the East Camp Mine system; while water levels in wells E and F increased at lesser rates. Table 2.2.1.1 contains yearly water-level changes and figure 2-33 shows these changes graphically.

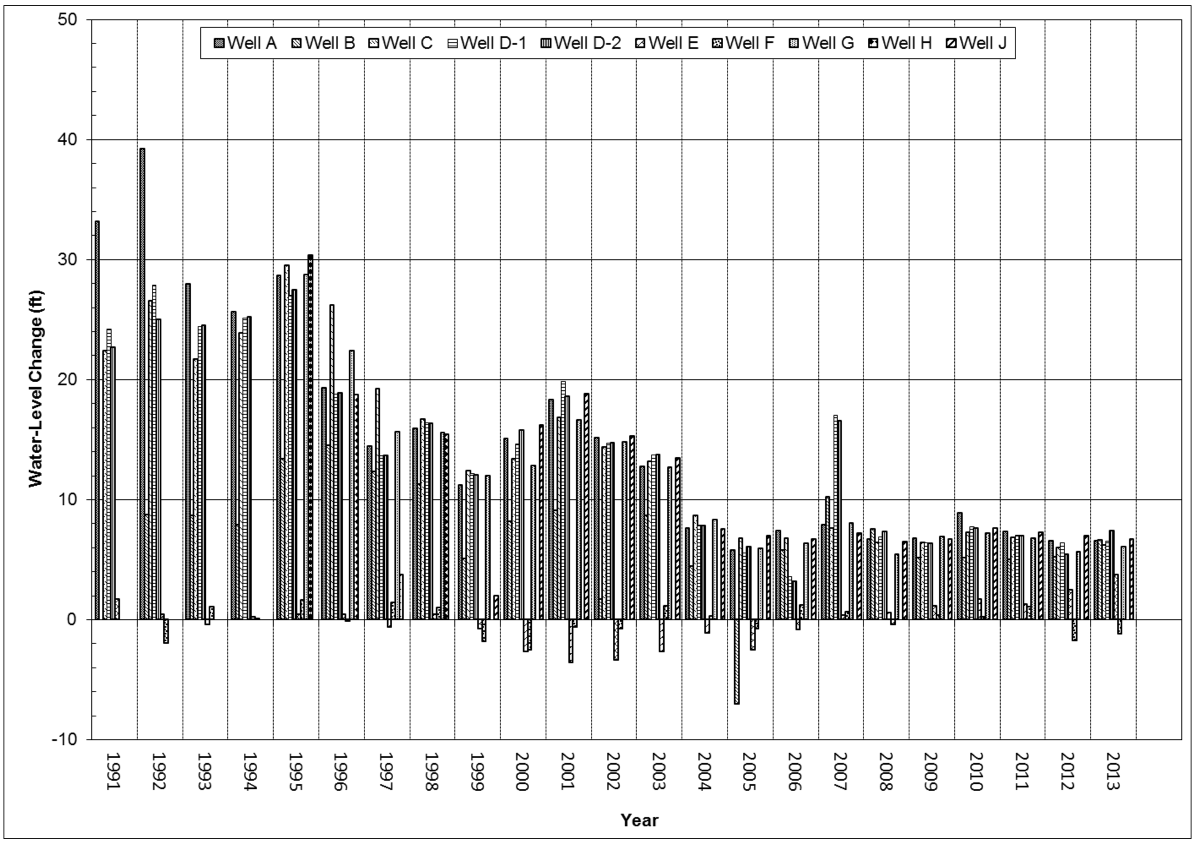


Figure 2-33. RI/FS bedrock wells annual water-level change.

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 or seasonal changes through 2013. 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 the major influences on water-level increases. Figure 2-34 is a hydrograph for well A showing monthly water levels and monthly precipitation totals with 1996, 2000, and 2003 HSB operational changes identified. The void areas in the mines and Berkeley Pit control the annual rate of rise in this system.

Table 2.2.1.1 RI/FS bedrock well annual water-level change (ft).

	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H(1)	Well J(2)
1982										
1983										
1984										
1985										
1986										
1987										
1988										
1989										
1990										
1991	33.18		22..38	24.20	22.68	1.73				
Change Years 1–10	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	2.40	8.72	
1997	4.44	2.35	9.25	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	
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
Change Years 11–20	215.88	99.37	206.52	199.86	197.68	-5.95	-1.64	123.86	68.29	36.99

(Minus sign (-) indicates a decline (drop) in water level.)

Table 2.2.1.1 RI/FS bedrock well annual water-level change (ft) (cont.)

Year	Well A	Well B	Well C	Well D-1	Well D-2	Well E	Well F	Well G	Well H(1)	Well J(2)
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
2004	7.60	4.46	8.71	7.90	7.83	-1.12	0.32	8.31	P&A	7.58
2005	5.82	-7.00	6.76	5.56	6.08	-2.51	-0.73	5.95	P&A	7.03
2006	7.44	5.82	6.81	3.56	3.20	-0.83	1.22	6.39	P&A	6.72
2007	7.93	10.23	7.64	17.01	16.56	0.38	0.67	8.06	P&A	7.23
2008	6.70	7.59	6.40	6.89	7.36	0.59	-0.41	5.47	P&A	6.49
2009	6.79	5.18	6.41	6.37	6.34	1.14	0.39	6.90	P&A	6.70
2010	8.87	5.19	7.29	7.77	7.62	1.69	0.24	7.22	P&A	7.64
2011	7.32	5.04	6.82	7.01	7.00	1.27	1.06	6.77	P&A	7.29
Change Years 21–30	86.38	46.94	84.45	90.46	90.47	-5.42	3.19	82.62	0.00	85.45
2012	**6.55**	**5.24**	**6.02**	**6.37**	**5.44**	**2.46**	**-1.72**	**5.67**	P&A	**7.03**
2013	**6.54**	**6.66**	**6.24**	**6.51**	**7.41**	**3.74**	**-1.20**	**6.07**	P&A	**6.70**
Change Years 31–40	**13.09**	**11.90**	**12.26**	**12.88**	**12.85**	**6.20**	**-2.92**	**11.74**	**0.00**	**13.73**
Net Change	**348.53**	**158.21**	**325.61**	**327.40**	**323.68**	**-3.44**	**-1.37**	**218.22**	**68.29**	**136.17**

(Minus sign (-) indicates a decline (drop) in water level.)

(1) Well plugged and abandoned (P&A) due to integrity problems. (2) Well J was drilled as a replacement for well H.

Table 2.2.1.1 RI/FS bedrock well annual water-level change (ft) (cont.)

Year	DDH-1[3]	DDH-2	DDH-4	DDH-5	DDH-8
1982					
1983					
1984					
1985					
1986					
1988					
1989	29.53			34.83	30.48
1990	36.24	30.99	5.44	217.61	35.96
1991	27.03	28.20	39.81	27.01	28.96
Change Years 1–10	**92.80**	**59.19**	**45.25**	**89.45**	**95.40**
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	2.24	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
1999	11.66	12.00	11.88	4.85	15.50
2000	14.64	16.11	14.77	P&A	10.42
2001	18.14	18.78	18.52	P&A	18.93
Change Years 11–20	**196.47**	**200.79**	**217.66**	**150.97**	**197.00**

Table 2.2.1.1 RI/FS bedrock well annual water-level change (ft) (cont.)

Year	DDH-1(3)	DDH-2	DDH-4	DDH-5	DDH-8
2002	14.63	14.80	13.14	P&A	13.64
2003	13.05	13.90	NA	P&A	14.49
2004	7.08	7.89	NA	P&A	7.90
2005	4.87	5.89	NA	P&A	57.52
2006	6.30	6.75	NA	P&A	6.03
2007	3.08	8.75	NA	P&A	5.90
2008	P&A	6.58	NA	P&A	4.62
2009	P&A	6.97	NA	P&A	5.15
2010	P&A	7.50	NA	P&A	4.60
2011	P&A	7.44	NA	P&A	4.93
Change Years 21-30	**49.01**	**86.47**	**13.14**	**0.00**	**124.78**
2012	P&A	**7.10**	NA	P&A	**2.51**
2013	P&A	**6.76**	NA	P&A	**3.08**
Change Years 31-40	**0.00**	**13.86**	**0.00**	**0.00**	**5.59**
Net Change	**338.38**	**360.31**	**276.05**	**240.42**	**422.77**

(Minus sign (-) indicates a decline (drop) in water level.)

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

(3) Well DDH-1 plugged, no data after July 2007

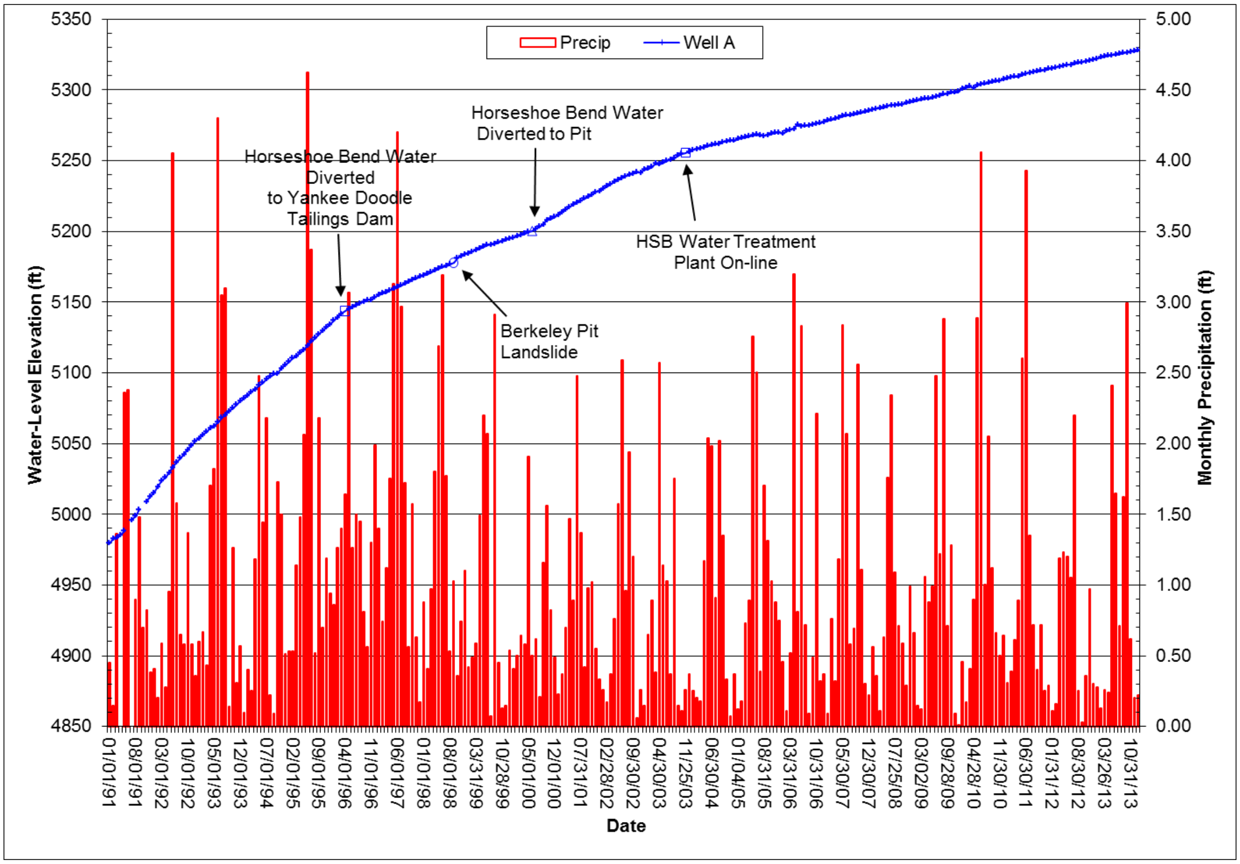


Figure 2-34. Water-level hydrograph for bedrock well A.

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 and 2004 water-level increases were closer to 60 percent that of the other bedrock wells; however, as a result of the influence of the July 2005 earthquake and water-quality sampling on this well, the water level had a net 7 ft decline for 2005. The 2006 water-level increase was about 75 percent that of the Berkeley Pit, indicating there were no long-term effects in water levels from the 2005 earthquake. The 2007 water-level increase in well B was almost 130 percent that of well A and 150 percent of the Berkeley Pit, which is the first time the annual water-level rate of rise for this well exceeded either of these other sites. The 2008 water-level increase in well B was only slightly higher than that seen in any of the wells or mines in the East Camp system; the 2009–2012 increases were 1–2 ft less than those of the other bedrock wells and mine shafts. The 2013 water-level increase was similar to that of a majority of the other bedrock wells. Attention will be paid to this site's water-level changes to see if this trend continues. Hydrographs for wells A and B, showing monthly water-level elevations, are in figure 2-35.

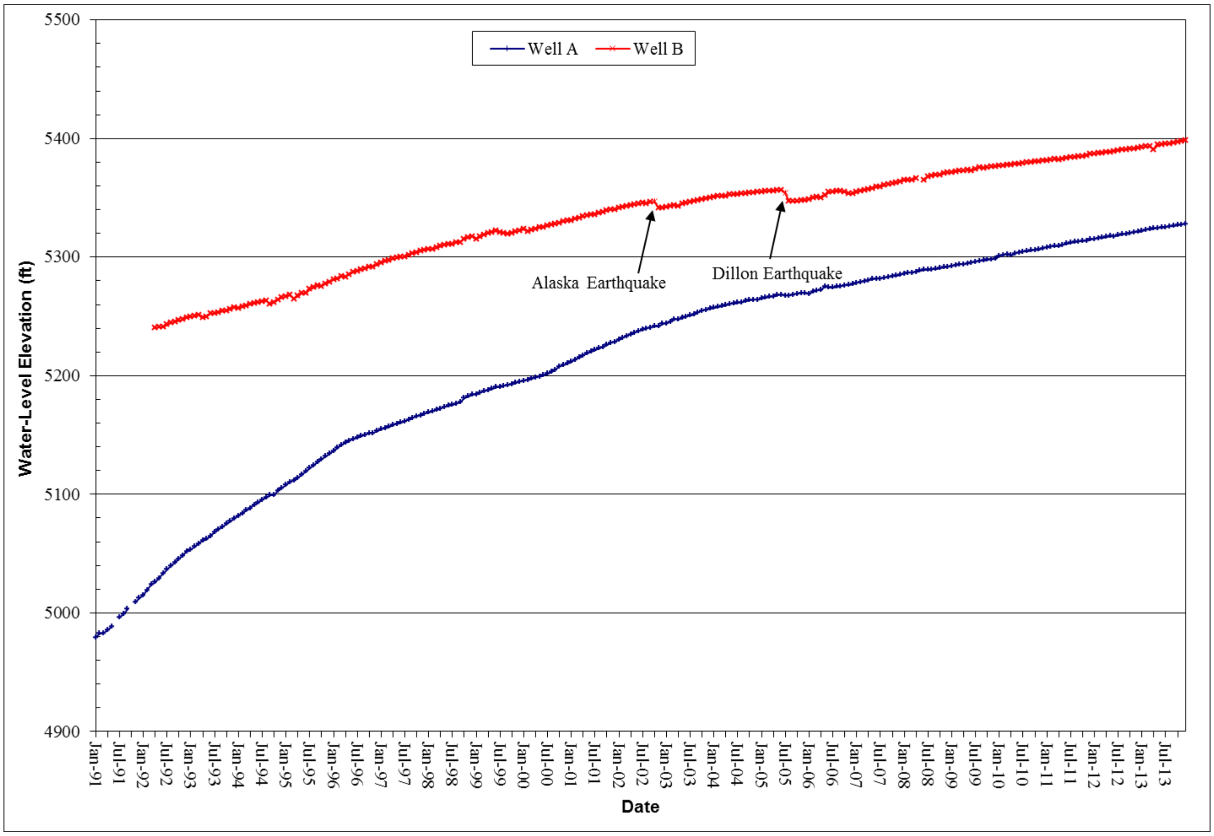


Figure 2-35. Water-level hydrographs for East Camp bedrock wells A and B.

Water levels in wells E and F do not follow the trends seen in a majority of 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 and interconnection to historic mining activities. The water level in well E has a net decline of about 3 ft over time, while well F has a net decline of 1.3 ft. It is very apparent that these wells were not influenced by dewatering based upon current water levels and their lack of response to rising water levels in the surrounding bedrock system.

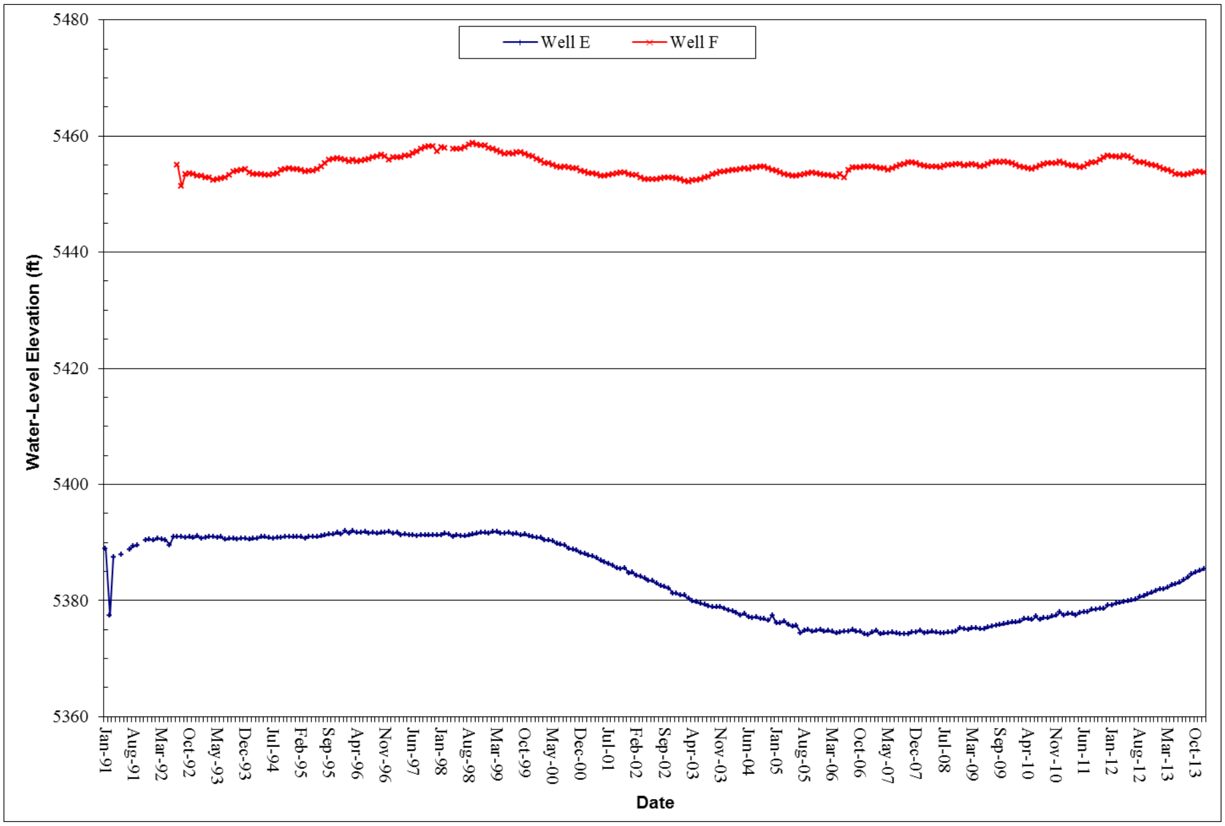


Figure 2-36. Water-level hydrographs for East Camp bedrock wells E and F.

Well H was plugged and abandoned due to casing integrity problems, and well J was drilled as a replacement for it in 1999. 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 in figure 2-37. Historic water levels for well H are shown in this figure, with a linear projection of water levels included. Water levels for well J initially plotted very closely to those projected for well H, verifying that well J was completed in the same bedrock zone as well H. However, beginning in April 2004, the water level for well J plotted below the projected water level for well H. This is a result of the filling rate slowing from the diversion and treatment of water from the HSB drainage. The projected water level for well H does not take into account the removal of HSB water from the pit. If water levels had continued to rise as shown by the projection line for well H, water levels may have been up to 90 ft higher than they currently are. The diversion of HSB drainage water has had a significant impact on the slowing of the pit filling rate.

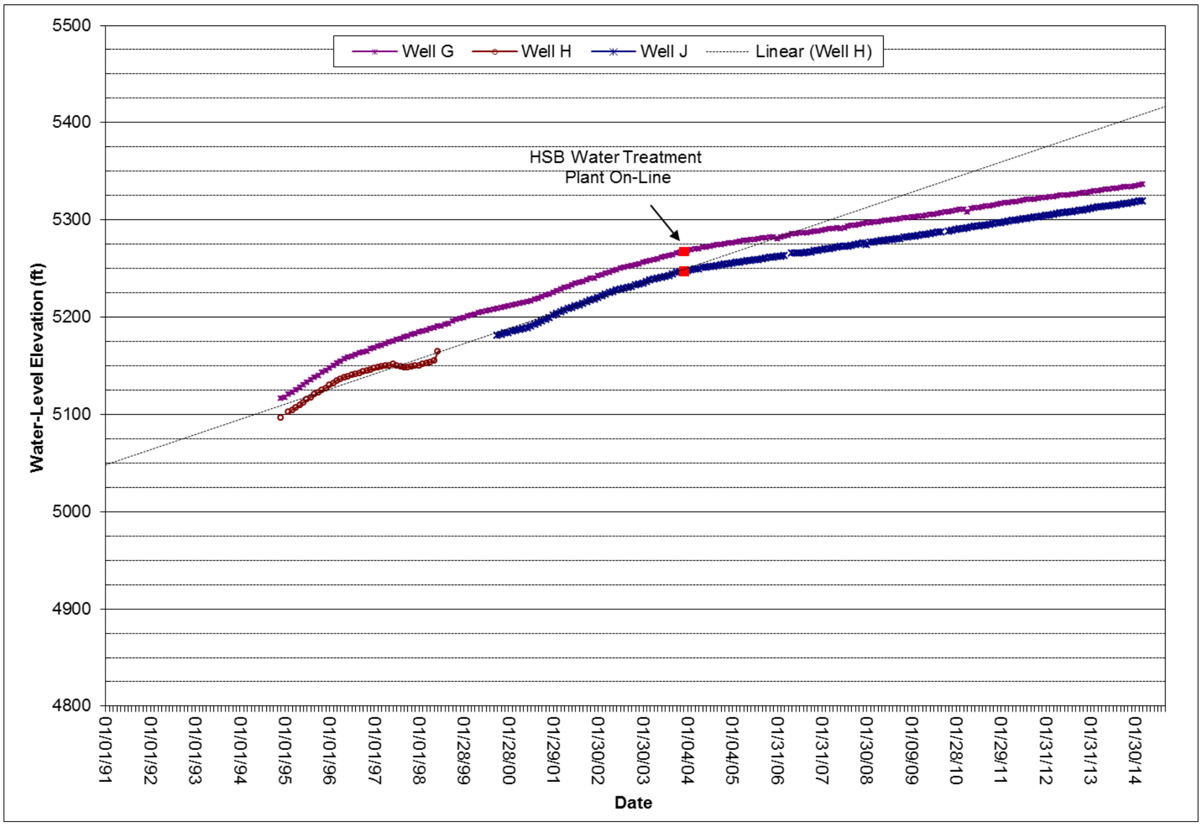
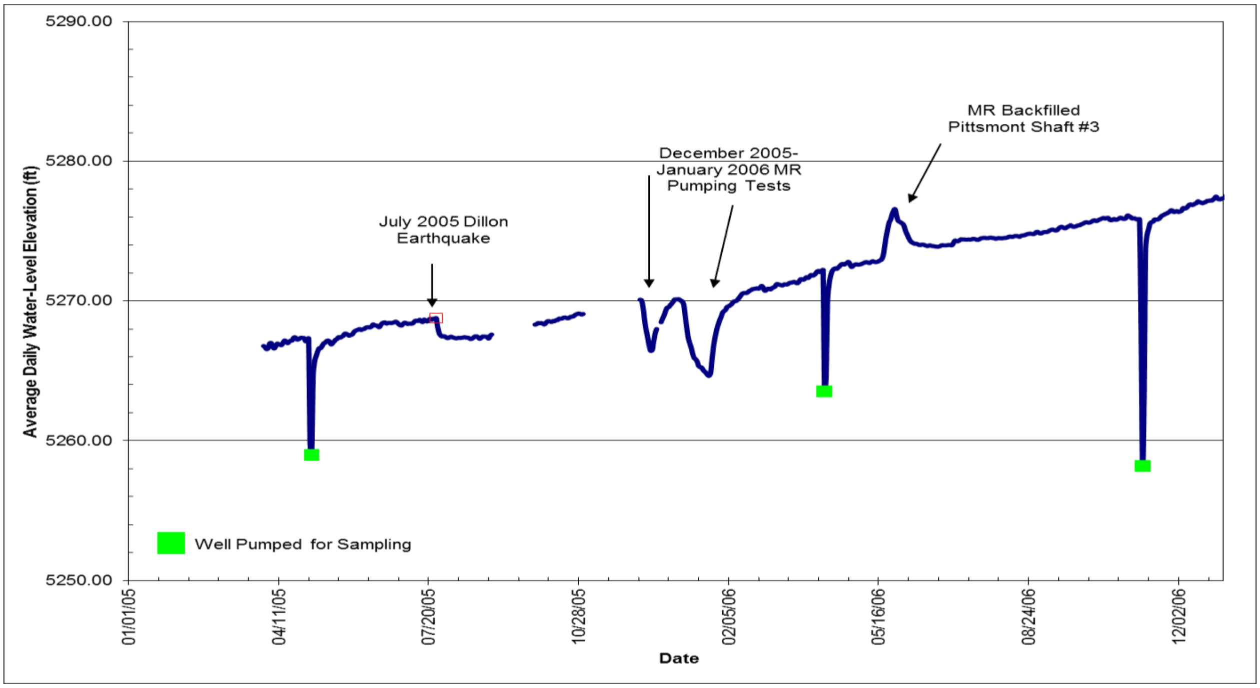


Figure 2-37. Water-level hydrographs for bedrock wells G, H, and J.

The 2002 CD monitoring program specified that water levels be monitored on a semi-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. Figure 2-38 is a hydrograph for a selected time period where a number of different events occurred that influenced water levels in bedrock well A. The top graph shows water-level data collected by a transducer and the level of detail when each different event occurred, while the bottom graph shows the level of detail from monthly water-level measurements. It is very apparent that the level of detail is much greater with the transducer data; the date and time a change occurs can be detected within a 1-hour time interval, and the magnitude of the change can be better determined. The increased level of monitoring allows more accurate interpretation of water-level changes whether they are natural (i.e., earthquakes or slumps) or man-induced (i.e., pumping). Water-level transducers have been installed in additional bedrock wells, beyond those specified in the 2002 CD, to better track water-level changes in the East Camp bedrock system in response to various activities, i.e., grouting and backfilling of underground mine workings, and the MERDI/MSE pumping test at the Belmont Mine site. The sites with increased level of monitoring are: well D-2, well DDH-2, well F, well J, Belmont well #1, and the Parrott Park well.

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. 2-39) for the East Camp bedrock aquifer shows the flow of water from all directions is towards the pit. While there have been short-term influences on water levels in a number of these wells, the overall direction of groundwater flow did not change.



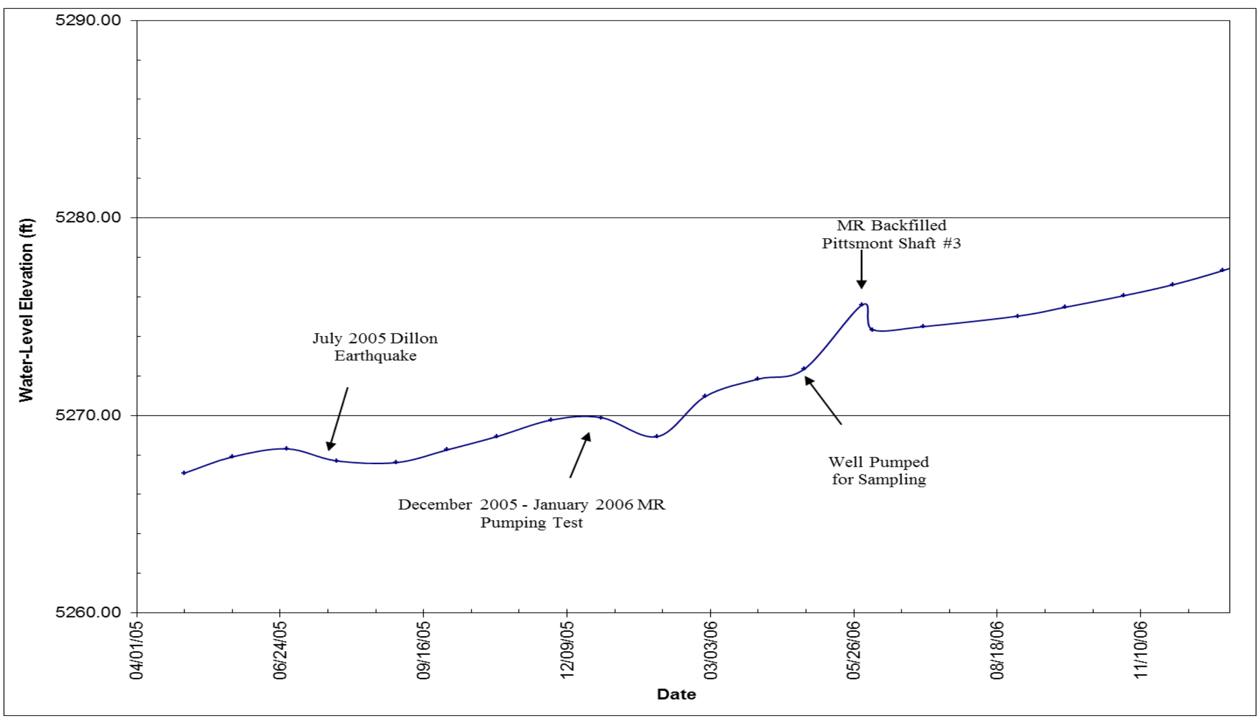


Figure 2-38. Hydrographs for well A comparing (top) daily average water level and (bottom) monthly water level monitoring frequency.

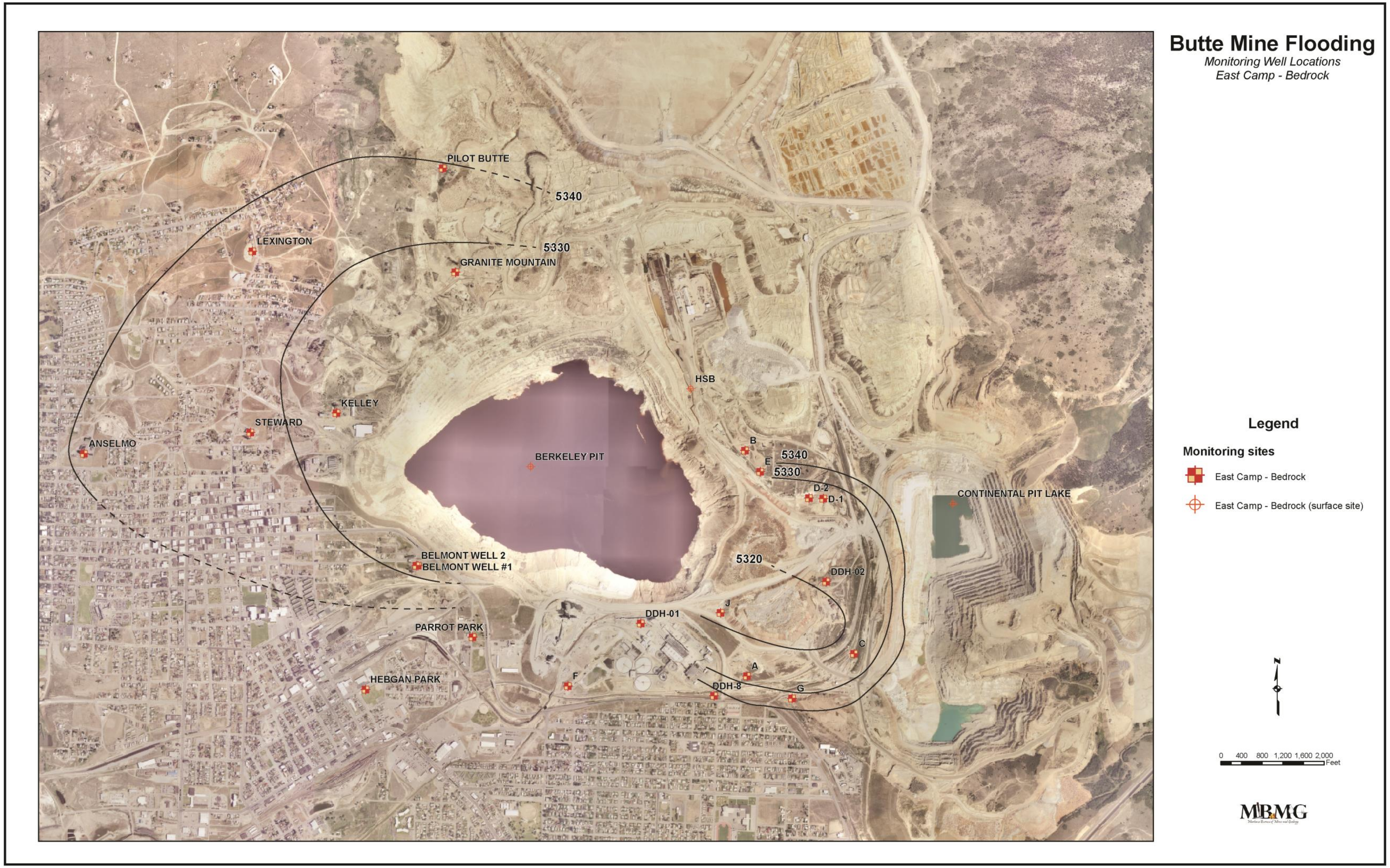


Figure 2-39. Potentiometric map for the East Camp bedrock aquifer, Dec 2013 (contour interval is 10 ft).

Section 2.2.2.1 RI/FS Bedrock Well Water Quality

Water quality in the East Camp bedrock wells has shown little change in recent years. Data collected in 2013 indicate only slight change for most wells. Table 2.2.1.1.1 summarizes the water-quality trends over the past few years; as noted in previous reports, the status of well B changed with respect to MCLs due to the change in the water-quality standard of arsenic (from 18 µg/L to 10 µg/L). In most wells, there was little change in the concentration of dissolved constituents. Arsenic is the only MCL exceeded in the bedrock wells (excluding well J), while iron, manganese, zinc, and sulfate are the SMCLs most often exceeded. In addition, several wells have pH levels below recommended limits.

While a majority of sites exceed one or more secondary standards, the levels of concentrations between wells can vary considerably. Figure 2-40 shows iron and arsenic concentrations for six of the bedrock wells sampled during the spring of 2013. As can be seen in figure 2-40, iron concentrations vary from 1 mg/L to greater than 400 mg/L, while arsenic concentrations vary from 2 µg/L to greater than 1,200 µg/L.

Bedrock well J has the greatest number of water-quality exceedances. Water quality in this well has been very poor since its installation, which was not unexpected considering the close proximity of this well to the pit and the interconnection of adjacent mine workings to the pit. The well is completed approximately 40 ft above workings from the Pittsmont Mine that extend to the pit. Concentrations of iron, sulfate, arsenic, and zinc all increased in 2013 samples. Figure 2-41 is a comparison of selected trace metal concentrations for well A, well J, and the Berkeley Pit sample (2012) collected 1 ft below the water surface. Well A is the farthest south, and concentrations are orders of magnitude less for most analytes; the water quality is similar between the pit and well J. This helps confirm the observations made by monitoring water levels that bedrock groundwater flow is towards the pit and no contamination is leaving the site. With the extremely high concentrations of copper, cadmium, and zinc in the pit water and well J, any migration of this water away from the pit would be easily detected in other well water samples.

Table 2.2.1.1.1 Exceedances and recent trends for East Camp bedrock wells, 1989 through 2013.

Well Name	Exceedances (1 or more)	Concentration Trend	Remarks
A	Y	Unchanged	Arsenic (MCL), iron, manganese, sulfate (SMCL).
B	Y	Unchanged	Arsenic (MCL), iron, manganese, sulfate (SMCL).
C	Y	Unchanged	PH, iron, manganese, sulfate (SMCL). Zinc concentrations variable, exceed SMCL occasionally.
D-1	Y	Unchanged	No longer sampled, replaced by well D-2.
D-2	Y	Unchanged	Arsenic (MCL), pH, iron, manganese, sulfate, zinc (SMCL).
E	Y	Unchanged	Sampled every 2 years; arsenic (MCL), iron, manganese, sulfate (SMCL).
F	Y	Unchanged	Sampled every 2 years, arsenic (MCL), iron, manganese, sulfate (SMCL).
G	Y	Unchanged	PH, iron, manganese, sulfate (SMCL).
J	Y	Variable	Very poor quality water; arsenic, cadmium, lead, uranium (MCL); iron (increasing), manganese, sulfate (increasing), copper (downward trend), and zinc (increasing) (SMCL).

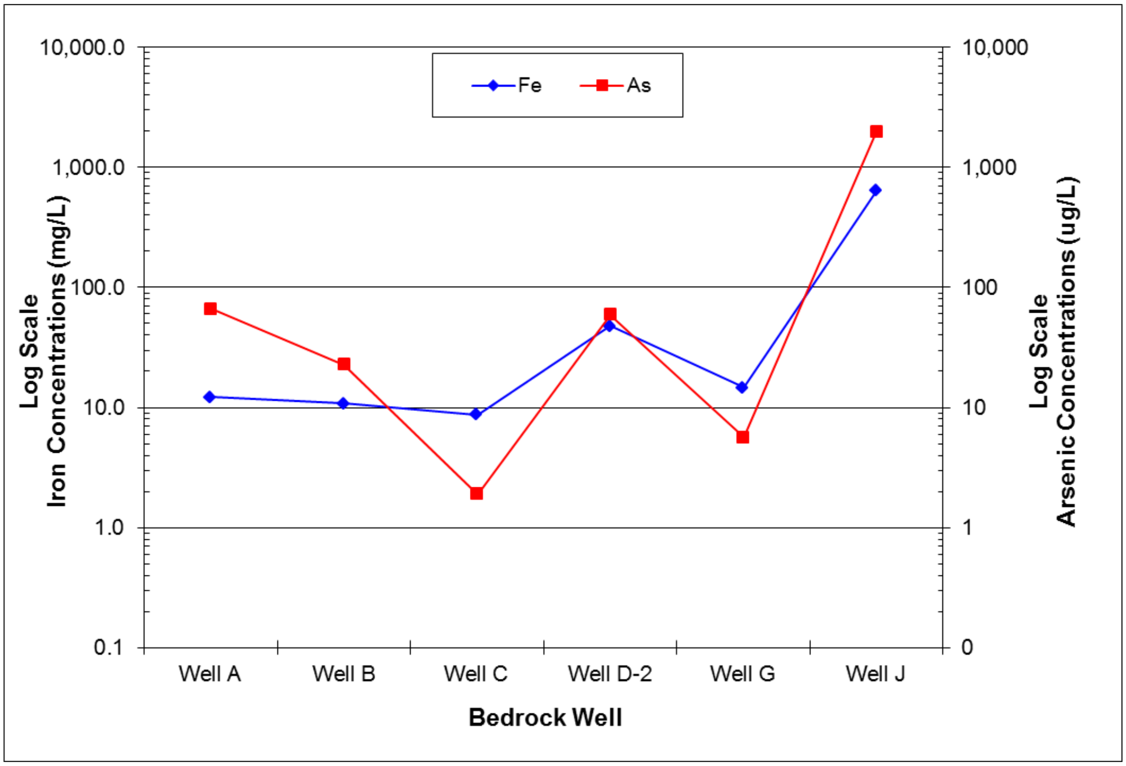


Figure 2-40. Bedrock well iron and arsenic concentration comparisons, spring 2013.

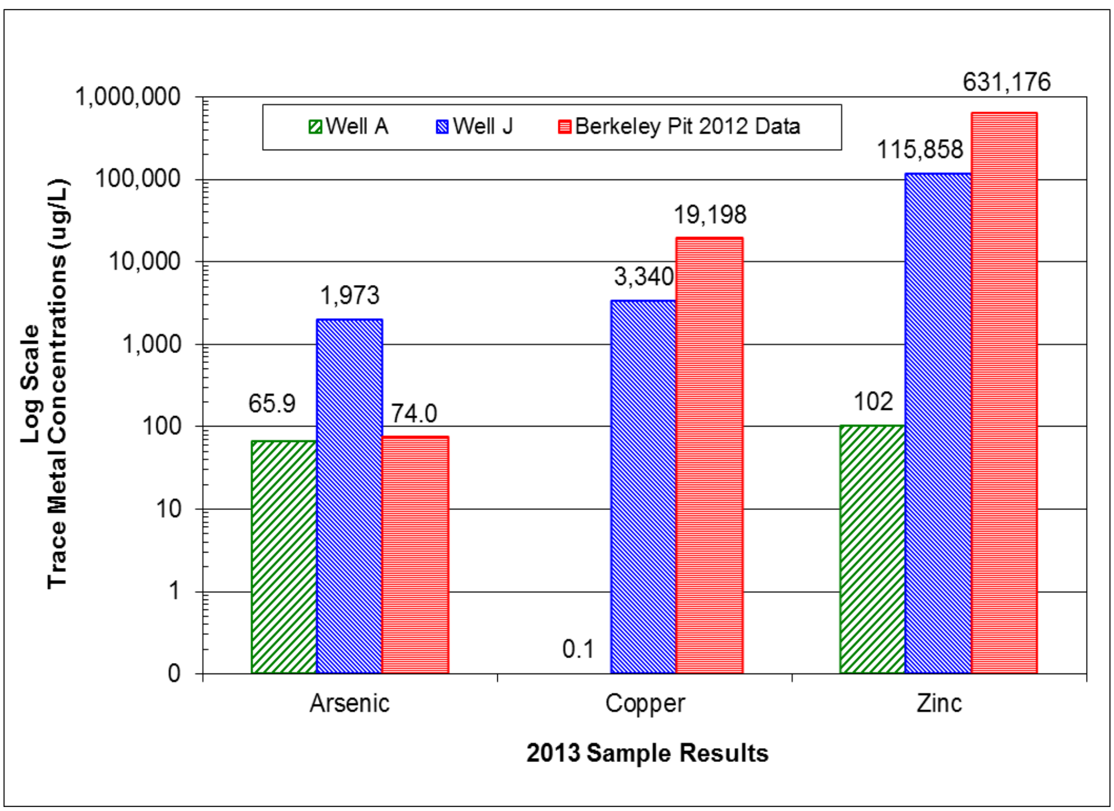


Figure 2-41. Selected trace metal comparisons among bedrock wells A, J, and the Berkeley Pit 1 ft depth sample.

Section 2.2.3 DDH-Series Wells

Water-level monitoring of the DDH-series wells continued. Five bedrock wells originally comprised the DDH well monitoring network; however, for various reasons this network now consists of only two wells, DDH-2 and DDH-8, as well DDH-1 is no longer suitable for monitoring. MR performed site maintenance and cleanup around the concentrator facility during 2007 and it appears this work led to the accidental plugging of the well DDH-1 borehole. For the year 2013, water levels rose 6.76 and 3.08 ft, respectively, in the two remaining DDH wells. The rate of rise in DDH-2 is consistent with those of the RI/FS bedrock wells and East Camp mine shafts. Figure 2-42 is a hydrograph for well DDH-2, showing water-level increases. Once again, precipitation does not show any effect on water-level rise. Well DDH-8 had an unexplained water-level increase during August 2005; its water level rose over 52 ft during the month. During this time the 2-inch PVC casing was removed and a submersible pump was installed to test the water for possible irrigation use. The water-level rise began prior to the well pumping and continued after its completion. Nothing out of the ordinary was noted during the pumping to account for the abnormal water-level change. During the remainder of the year water-level changes were similar to those of the other DDH-series wells. The water level rise in this well during 2013 was one-half (3.08 ft) the other bedrock wells and the water-level elevation was over 50 ft higher than the other bedrock wells due to the unexplained 2005 increase. It is important to note that the DDH wells were not installed for monitoring purposes; they are old exploration holes that extend several thousand feet below ground surface and have various size casings installed. Due to completion uncertainties and the drilling techniques, it is not unexpected to have problems occur with these wells. In the past, another well (DDH-6) had to be plugged and abandoned due to casing integrity problems.

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

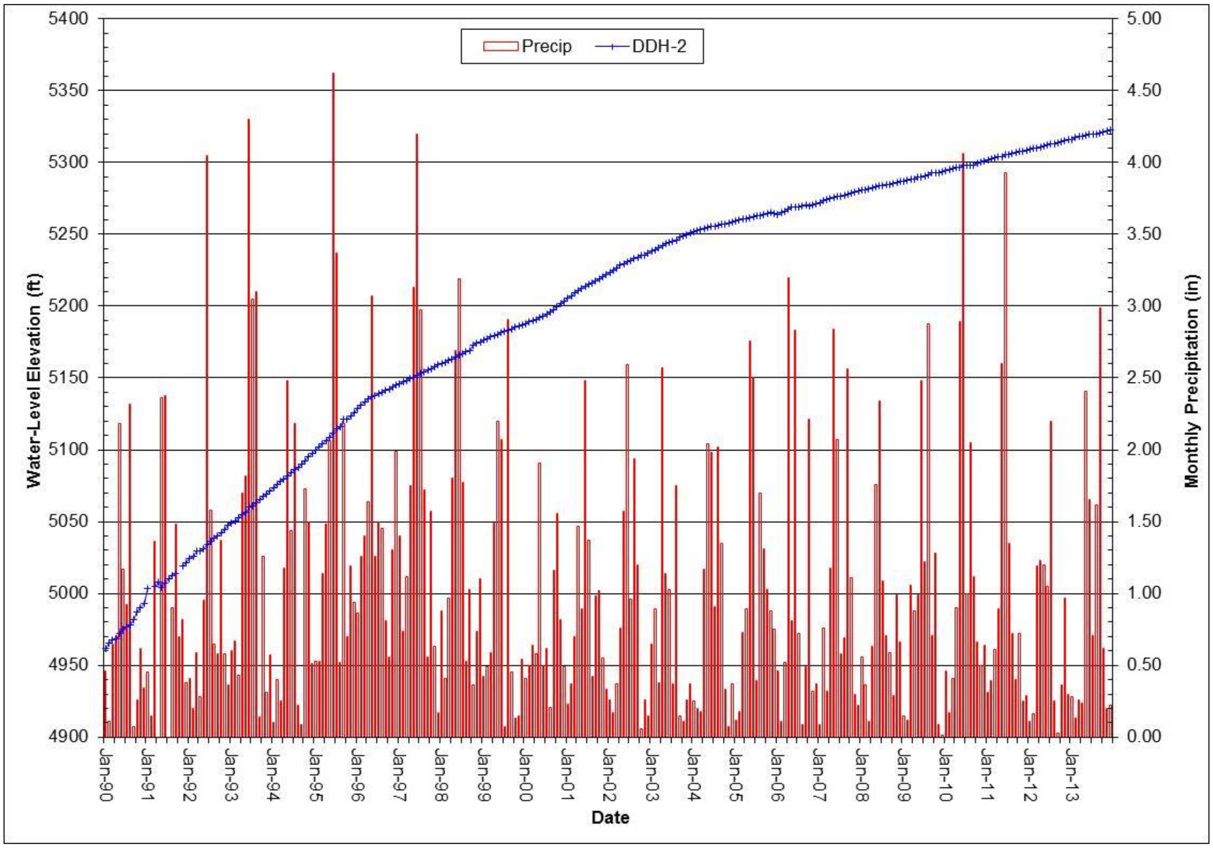


Figure 2-42. Water-level hydrograph for bedrock well DDH-2.

Section 2.3 Berkeley Pit and Horseshoe Bend Drainage

The Berkeley Pit water-level elevation was surveyed each month to coincide with monthly water-level monitoring in wells and mine shafts. The hydrograph in figure 2-43 shows the pit's water-level rise since 1995.

The overall trend is similar to that of previous years (7.25 ft average elevation rise per year since 2004). Four noticeable changes in figure 2-43 show the influence of physical changes on water-level rise. 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 1996; the second is an almost instantaneous water-level rise from the September 1998 landslide; 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; and the fourth shows the decrease in filling rate as a result of the HSB water-treatment plant coming online in November 2003 and the diversion of HSB drainage water away from 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 became operable. This represents an average flow of 1,820 gpm during the period of mine suspension. The overall Berkeley Pit water-level rise for 2013 was 8.12 ft, compared to 6.74 ft for 2012; the rotational slump that occurred on February 8, 2013 resulted in a 0.60 ft water-level rise in the pit. Table 2.3.1 summarizes the changes in handling HSB water and other events that influenced changes in Berkeley Pit water-level filling rates.

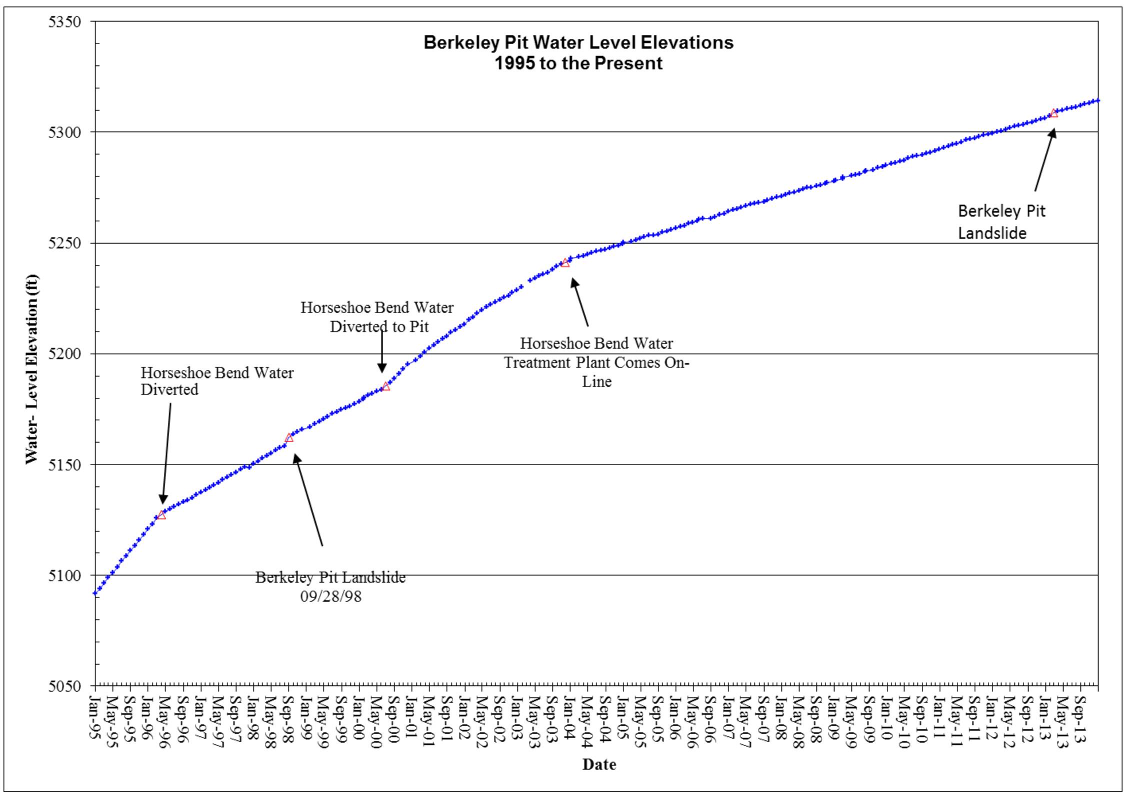


Figure 2-43. Water-level hydrograph of Berkeley Pit, 1995–2013.

Table 2.3.1 Timeline of Events impacting Berkeley Pit Filling Rates.

Date	Event	Impact
July 1983–April 1996	Horseshoe Bend Drainage water and water from precipitation plant ponds diverted to Berkeley Pit.	Increases pit water-level filling rate.
April 1996	HSB water diverted to MR mining operations for treatment and disposal in Yankee Doodle Tailings Pond.	Slows the pit filling rate.
September 1998	Berkeley Pit southeast corner landslide	3-plus foot water-level increase.
June 2000	MR suspends mining operations; HSB water diverted to Berkeley Pit. Water from Continental Pit diverted to Berkeley Pit.	Increases pit water-level filling rate.
November 2003	MR resumes operations and HSB water-treatment plant comes online.	Slows the pit filling rate.
February 2013	Rotational slump in southeast corner of Berkeley Pit.	0.60 ft water-level increase.

In 2012, two minor landslides occurred on the high wall of the southeast corner of the Berkeley Pit. Both events (August 22, 2012 and November 3, 2012) displaced an unknown but minor volume of material from the high wall into the Berkeley Pit. However, the material displaced by the landslides was insignificant and did not impact water levels in the Berkeley Pit, the underground mine workings, the bedrock system, or the surrounding alluvial aquifer. The rotational slump that occurred on February 8, 2013 deposited more waste and alluvial material than the 2012 landslides, resulting in noticeable water-level increases in the Berkeley Pit and several nearby bedrock wells (fig. 2-43). Photographs showing the southeast corner of the Pit before and after the August event and the February event are in figure 2-44.

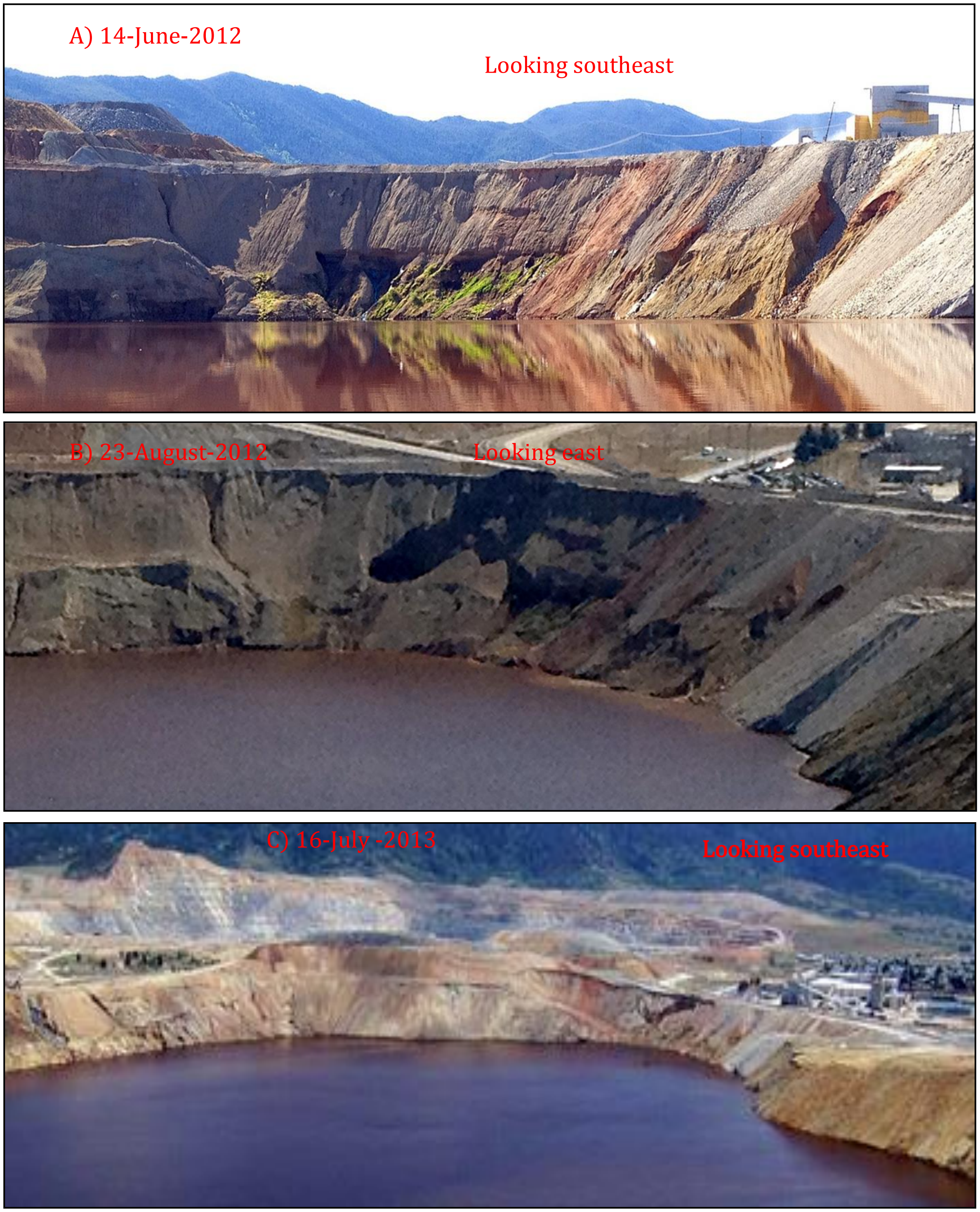


Figure 2-44. Pictures of the southeast corner of the Berkeley Pit prior to the occurrence of the 2012 landslides (A), and after the August 2012 (B) and February 2013 (C) events.

The 2002 CD contains a stipulation that the water level in the Berkeley Pit must remain below those of other East Camp monitoring sites, referred to as the points of compliance. The CD identified four mines and four bedrock monitoring wells as the points of compliance. They are shown in Table 2.3.2 along with their December 2013 water-level elevations and the distance below the CWL. The Berkeley Pit water-level elevation is included with this table as a reference only. Based upon this information the current compliance point is the Pilot Butte Mine, which is located to the north of the pit.

Table 2.3.2. East Camp Points of Compliance and Depth Below CWL, December 2013.

Point of Compliance	December 2013 Water-Level Elevation (ft)	Depth Below CWL (ft)
Anselmo Mine	5336.65	73.35
Granite Mountain Mine	5328.43	81.57
Pilot Butte Mine	5338.84	71.16
Kelley Mine	5325.29	84.71
Belmont Well #2	5326.16	83.84
Well A	5328.03	81.97
Well C	5323.98	86.02
Well G	5334.26	75.74
Berkeley Pit (not a compliance point)	5314.36	95.64

Flow monitoring of the Horseshoe Bend drainage continued throughout 2013. As discussed in previous reports, the 90^0 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 have been no major disruptions of monitoring activities since then. Ice build-up on the holding pond and bio-fouling of the transducer used to measure flow were ongoing problems associated with monitoring at this site. However, more frequent site visits to clean the transducer and note gauge height readings helped to minimize problems. During portions of late 2007, backwater conditions occurred periodically from a buildup of iron-hydroxide inside the influent pond inlet pipe that may have produced erroneous high flow measurements at the weir. The 2007 average daily flow rate was 3,297 gpm, an increase of almost 500 gpm from 2006. The 2013 average daily flow rate was 2,969 gpm, a decrease of 620 gpm from the prior year. A total of 1.55 billion gallons of water flowed through this site in 2013 for treatment in the HSB water treatment plant. Figure 2-45 shows the daily average flow rate from July 2000 through December 2013.

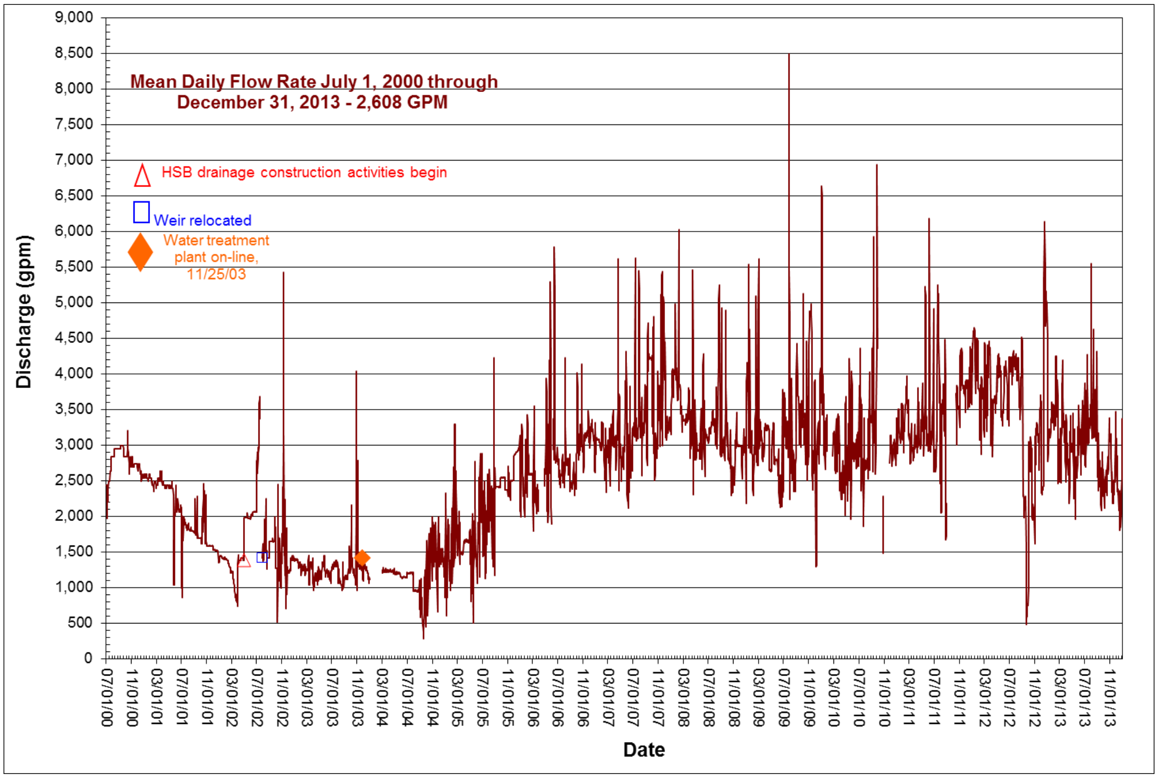


Figure 2-45. Horseshoe Bend Drainage flow rate, July 2000 through December 2013.

A non-contact radar system (Radar Level Sensor™) was installed during the fall of 2011 to collect more reliable flow data at the weir station. The new system replaced the need for placement of a transducer in the water. A signal is emitted onto the water surface (16 pulses per second) and the distance to the water surface is calculated over a 25-second interval ever hour. Figure 2-46 shows the new system's installation. A new staff gauge was installed at the same time and the pool area behind the weir plate was cleaned of sediment that had accumulated over the previous 8 years.

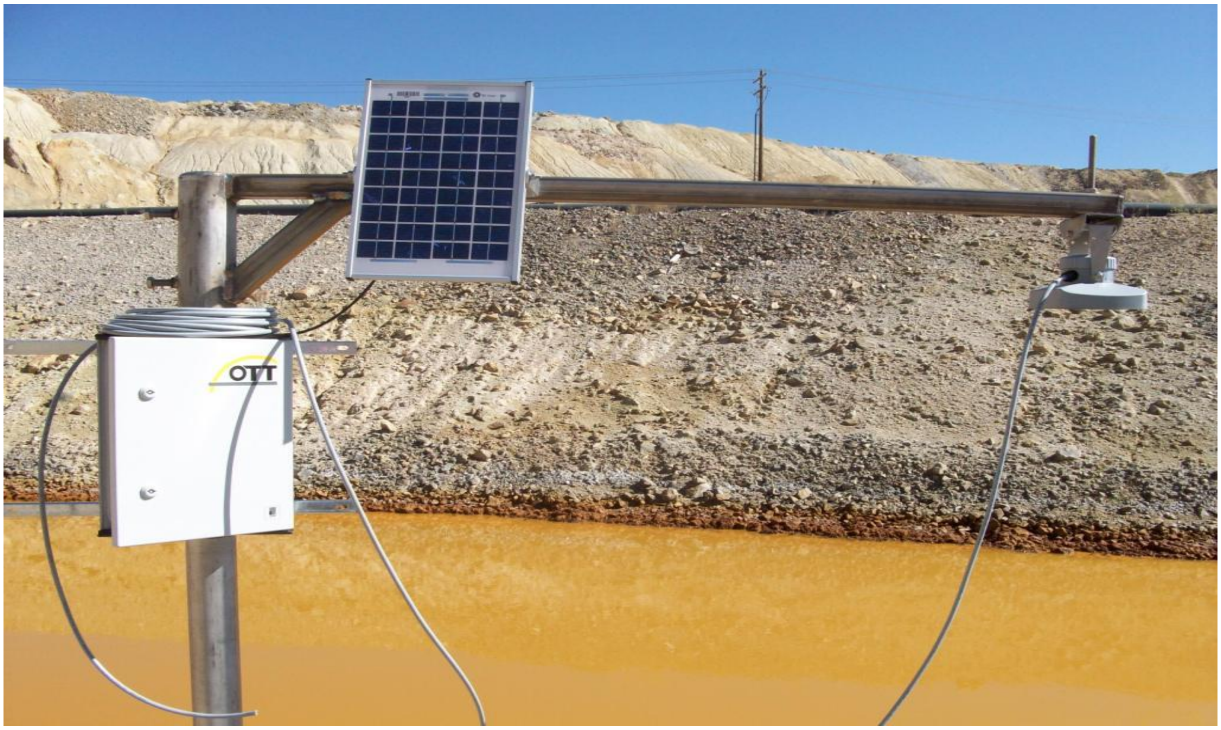


Figure 2-46. Radar system installation at the Horseshoe Bend weir monitoring station.

Flows measured at the HSB Falls flume averaged 76 gpm for 2013, a decrease of 39 gpm (66 percent) from the 2012 average. The 2010–2013 flows were considerably less than prior years and the historic flow rate of 1,000 gpm or more reported by MR. Figure 2-47shows both historic flow rates when MR operated this site and current flow rates since the MBMG began monitoring. The decreased flow from this site greatly exceeds any change in flow seen for the entire HSB drainage; it is possible the sources that have contributed to the HSB Falls seeps are emanating at different locations since there is no corresponding significant drop in the overall flow in the HSB drainage.

Based upon the flow data recorded during both the 2000–2003 mine suspension and flows since then, the operation of the Yankee Doodle Tailings Dam as a disposal area for mill tailings is very important to the flow of water from the HSB drainage.

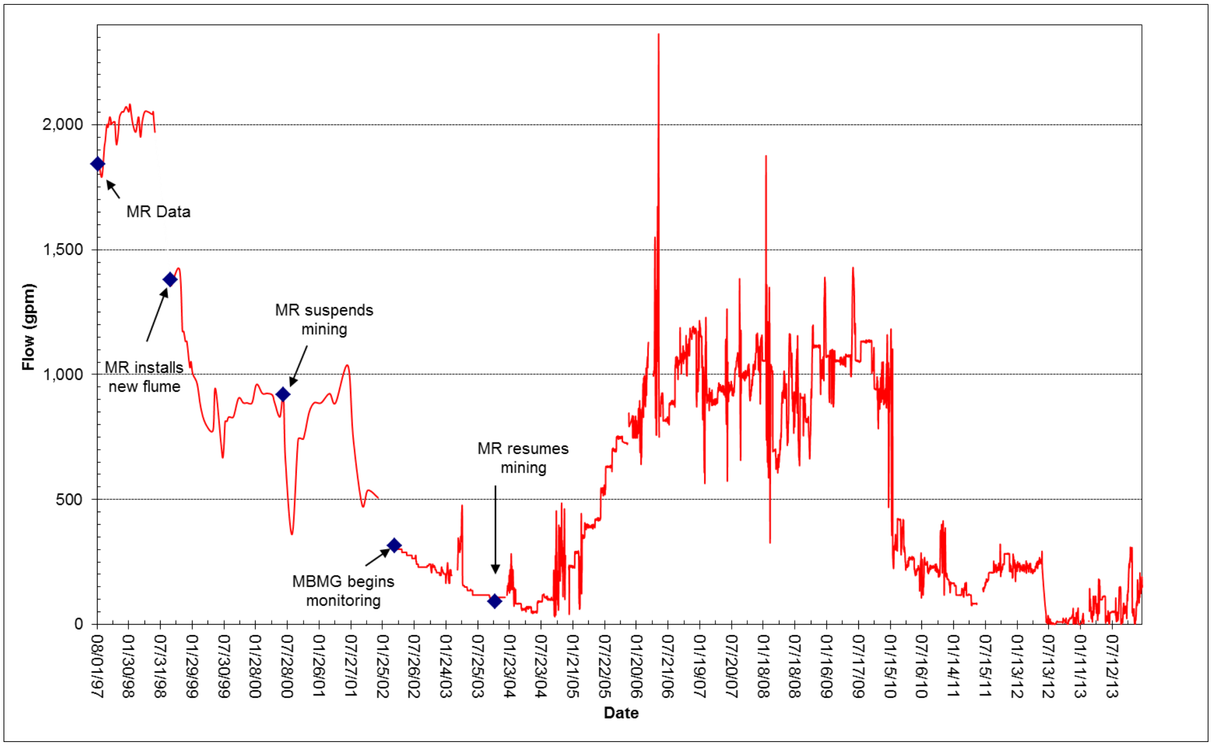


Figure 2-47. Horseshoe Bend Falls long-term daily average flow rates, including both MR and MBMG data.

Section 2.3.1 Berkeley Pit and Horseshoe Bend Drainage Water Quality

(No water sampling or vertical profiling of the Berkeley Pit occurred during 2013 due to safety concerns following the February 2013 slump and the potential for additional slumping. The sections below are from the 2012 report and refer to 2012 activities and sample results.)

Water-quality sampling of the Berkeley Pit occurs twice per year during late spring and late fall, with samples collected at a minimum of three depths. In addition to collecting samples for inorganic analysis, a vertical profile throughout the upper portion (0–650 ft) of the water was performed that measures *in situ* physical parameters. The physical parameters measured are: pH, specific conductance, temperature, oxidation-reduction potential, and dissolved oxygen. Turbidity is measured periodically.

Water-quality samples were collected monthly from the Horseshoe Bend drainage weir used for flow monitoring. This site is just upstream of the influent pond associated with the HSB water treatment plant. Therefore, this water is representative of the water entering the plant for treatment.

Section 2.3.1.1 Berkeley Pit Water-Quality Sampling and Monitoring Overview

It took 19 months (April 1982–November 1983) for the flooding underground mine waters to reach the elevation of the bottom of the Berkeley Pit, however, water had been accumulating in the pit bottom from contaminated surface water sources that were diverted into the pit in 1982 and again in 1983 for containment. The first water samples were collected from the pit in the fall of 1984. These samples and the 1985 samples were collected using a helicopter that hovered above the water surface (figure 2-48), with a point-source bailer lowered from the helicopter into the pit water. Sampling in 1986 and 1987 used a helicopter to ferry in boats that were used for sample collection. Much more accurate sampling and vertical profiling of the pit water column were accomplished during these events. By the summer of 1991 the water level within the pit reached a point that old haul roads could safely be reopened, allowing sample crews to drive to the water's edge. Since that time samples have been collected from a temporarily installed stationary platform or boats, which allowed the collection of high-quality data.

MR purchased a pontoon boat in 1996 for use in their waterfowl-monitoring program and they have allowed the MBMG use of this boat for monitoring and sampling activities since. MR installed a new boat dock on the south side of the pit the summer of 2011 (fig. 2-49) that provides much safer access to the boat for sampling and monitoring purposes.

Figure 2-48. 1985 Berkeley Pit sampling event.

Figure 2-49. Boat dock, with MR pontoon boat used for Berkeley Pit sampling Newly installed (2011).

Section 2.3.1.2 Berkeley Pit Water Chemistry

Currently the Berkeley Pit water is approximately 850 ft deep, consisting of roughly 42.5 billion gallons of low pH, high saline water. Since flooding of the Berkeley Pit commenced in 1982, the MBMG has been the primary agency that has consistently collected, analyzed, and interpreted the data. Prior to 2001, water-quality samples were collected when deemed necessary, i.e., during the RI/FS investigation, with records going back as far as November 1984. Water quality in the Berkeley Pit has been monitored on a semi-annual basis since the spring of 2001, as per terms of the 2002 CD. This report focuses primarily on the data collected since that time, as it is consistent and precise data. Data collected prior to 2001, though accurate, are not as consistent as the semi-annual monitoring which began in 2001, and for the most part are excluded from this report. Records dating back to November 1984 are published and can be found on the MBMG Ground-Water Information Center (GWIC) website (GWIC, 2012). A publication by Gammons and Duaime (2006) focuses on the long-term changes in the limnology and geochemistry of the Berkeley Pit Lake System.

Throughout the years, changes in water quality in the Berkeley Pit may be linked to a number of factors including seasonal changes, turnover events (both seasonal and physical), formation of ice on the surface water during the winter, occurrence of landslides, MR copper (Cu) recovery operations, dumping of high-density sludge into the Berkeley Pit from the HSB water treatment plant, and the diversion of HSB water into and away from the pit surface water. The following sections attempt to determine the factors associated with some of the recent water-quality changes.

Section 2.3.1.3 Physical Parameters

Physical parameters (pH, SC, Eh, and temperature) are measured *in situ* on a semi-annual basis using Hydrolab multi-parameter sampling equipment from 0 to 600 ft below water surface. Depth profiles for the 2012 sampling event are presented in figure 2-50, and long-term (2002–2012) changes can be found in figure 2-51. Unfortunately, only one (spring) sampling event was conducted on the Berkeley Pit in 2012; the pontoon boat used for sampling was removed for repairs prior to the fall event in 2012, and the MBMG could not access the site. Grab samples from both the south shore of the pit surface and influent samples from the Cu-recovery pipeline were collected in the fall of 2012.

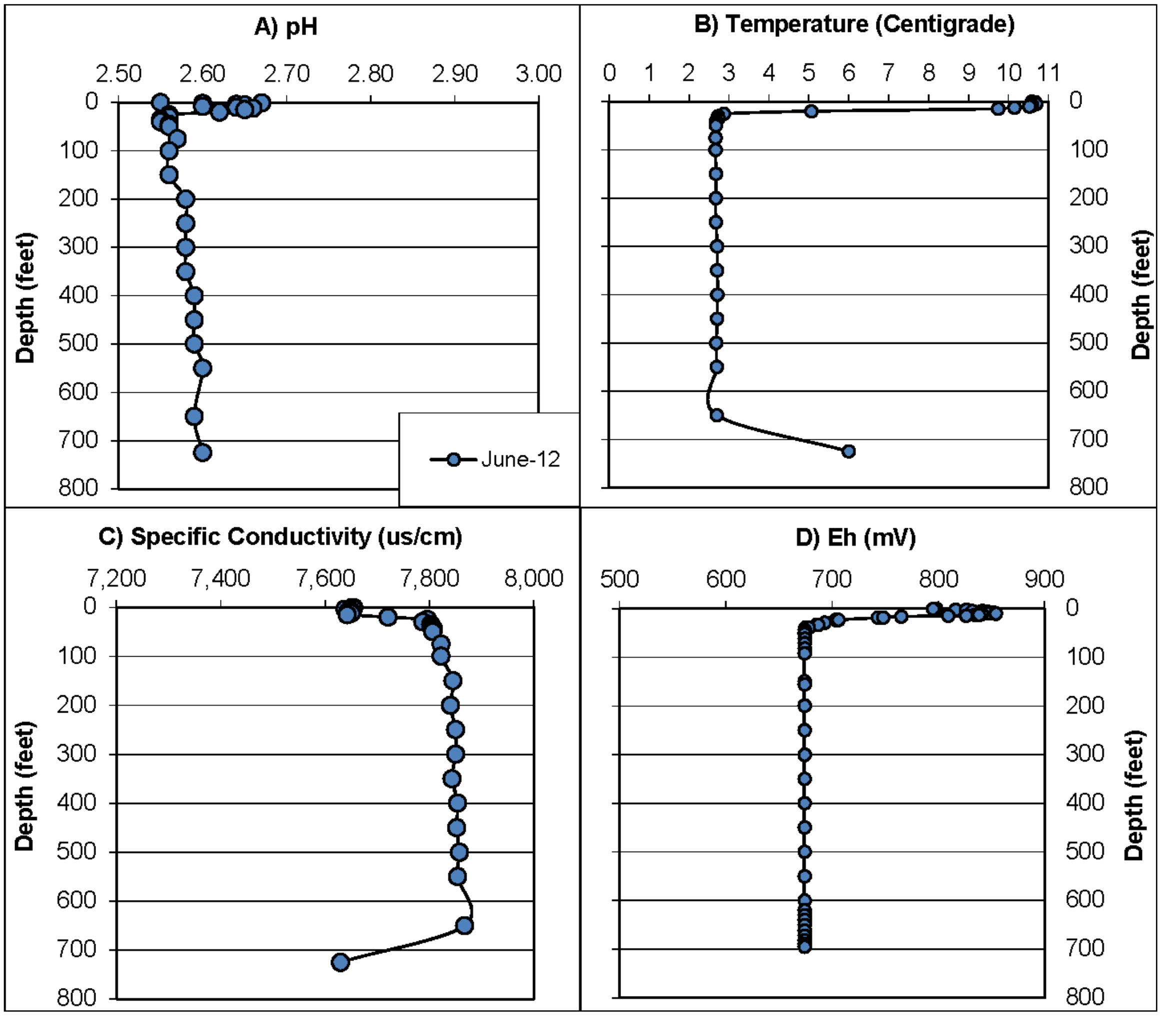
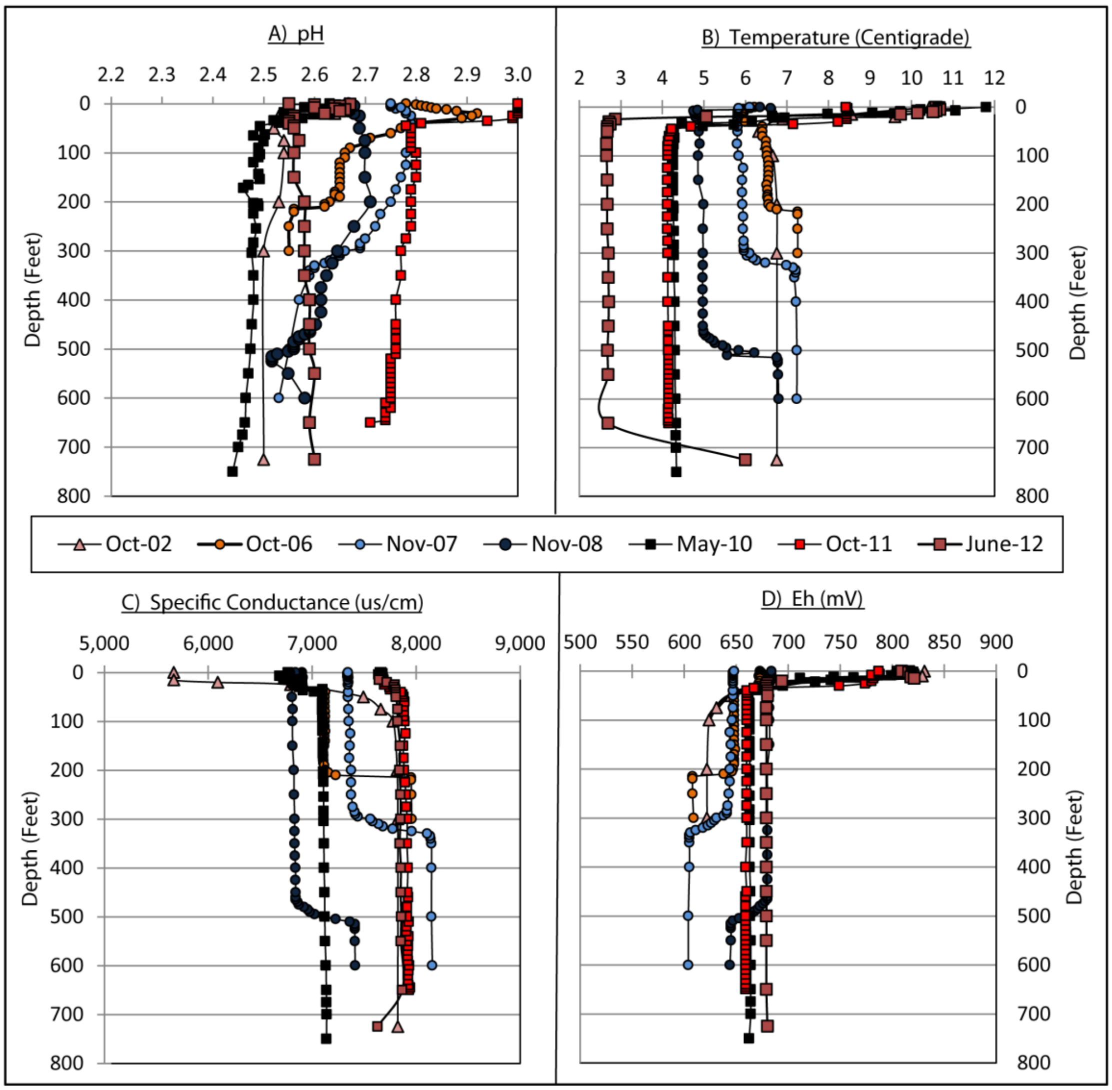


Figure 2-50. 2012 spring depth profiles for pH (A), temperature (B), SC (C), and Eh (D) in the Berkeley Pit Lake System.

Depth profiles of pH (A), SC (C), and Eh (D) were similar to those observed in 2002, prior to the reestablishment of the Cu-recovery operation. Other than changes observed in the surface waters (upper 50 ft) caused by wind-driven effects, and temperature and dissolved oxygen concentrations impacts on the solubility of iron, Berkeley Pit depth profiles remained homogeneous below 45 ft. A chemocline, similar to the one observed between 2003 and 2009 (as noted by rapid changes in pH, SC, Eh, and temperature over depth), was not observed in 2012. Temperatures at depth (between 25 and 650 ft) were measured at values (3°C) less than the maximum thermal density (4°C) of water (fig. 2-50B). Due to depth limitations on the water-quality meter, the sample collected below 650 ft had to be brought to the surface, and therefore the thermal profile (> 650 ft) was apparently affected by the warm atmospheric temperature on the day of sampling, and is not considered representative. The presence of lighter, colder water (<4°C) at depth is the first evidence reported that demonstrates that physical turnover occurs in the Berkeley Pit Lake System. Physical turnover of a lake may be caused by extreme wind conditions or landslide events, and it has never been documented in the Berkeley Pit prior to this event. Prior to this event, it was believed that the surface area to total depth ratio was too low, and that physical turnover in the Pit was unlikely.

Figure 2-51. Long-term changes in depth profiles for selected parameters in Berkeley Pit Lake. All data from all years are representative of fall sampling events, and were collected by the MBMG.



Profiles collected in the fall (2010 and 2012 values represent spring monitoring) are shown for 6 years (2002, 2006, 2007, 2008, 2010, 2011, and 2012) in figure 2-51. All data were collected by members of the MBMG staff. Profiles collected in 2002 represent a time when HSB water was being diverted into the Berkeley Pit, and is representative of the 3-year period when HSB water was allowed to pool in the Berkeley Pit surface water, and copper recovery operations were suspended. In November 2003, the HSB treatment plant went online, capturing and treating HSB water, and in January 2004 Montana Resources began pumping at depth for Cu-recovery operations.

Seasonal temperature profiles (fig. 2-51B) suggest that a thermocline exists in the surface waters (upper 50 ft) during the summer and winter months. During winter, colder air temperatures influence the shallow waters, creating a seasonal shallow epilimnion. Inversely, warmer air temperatures in the summer create thermal stratification with warmer waters on top of colder, creating thermal stratification of the surface water. During early spring and late fall, the effects of air temperature create water temperatures in the shallow epilimnion that are constant with the metalimnion waters, and mixing between the first two zones (seasonal turnover) was possible.

Prior to fall 2009, a chemical density stratification boundary known as the chemocline was observed at varying depths of the water column, creating a meromictic lake with two different water qualities located above and below the chemocline. The depth of the chemocline in the Berkeley Pit was defined by rapid changes in the depth profile of pH, SC, Eh and temperature. The column of water above the chemocline, referred to as the mixolimnion, was distinguished from the water column below the chemocline (monimolimnion) by higher values of pH, lower specific conductivity, lower concentrations of dissolved metals, and higher oxidation-reduction potential. Between 2003 and 2009, the depth of the chemocline increased as a direct result of the pumping from the MR Cu-recovery operations (fig. 2-52). Evidence of the increasing depth of the chemocline is noted in all depth profiles, and has been discussed in previous reports (Duaime and Tucci, 2007, 2008, 2010, 2011). The effects of the Cu-cementation process on the chemocline are best observed in the SC profile (fig. 2-50C). Prior to January 2004, the depth of the chemocline, though variable, remained less than 50 ft below water surface. Since that time, pumping (>10,000 gpm for 7 years) from the Cu-recovery process rapidly decreased the depth at which the chemocline was observed at an average rate of 60 ft per year. This rate of decline increased with time, as the diameter of the pit narrowed with depth (fig. 2-52).

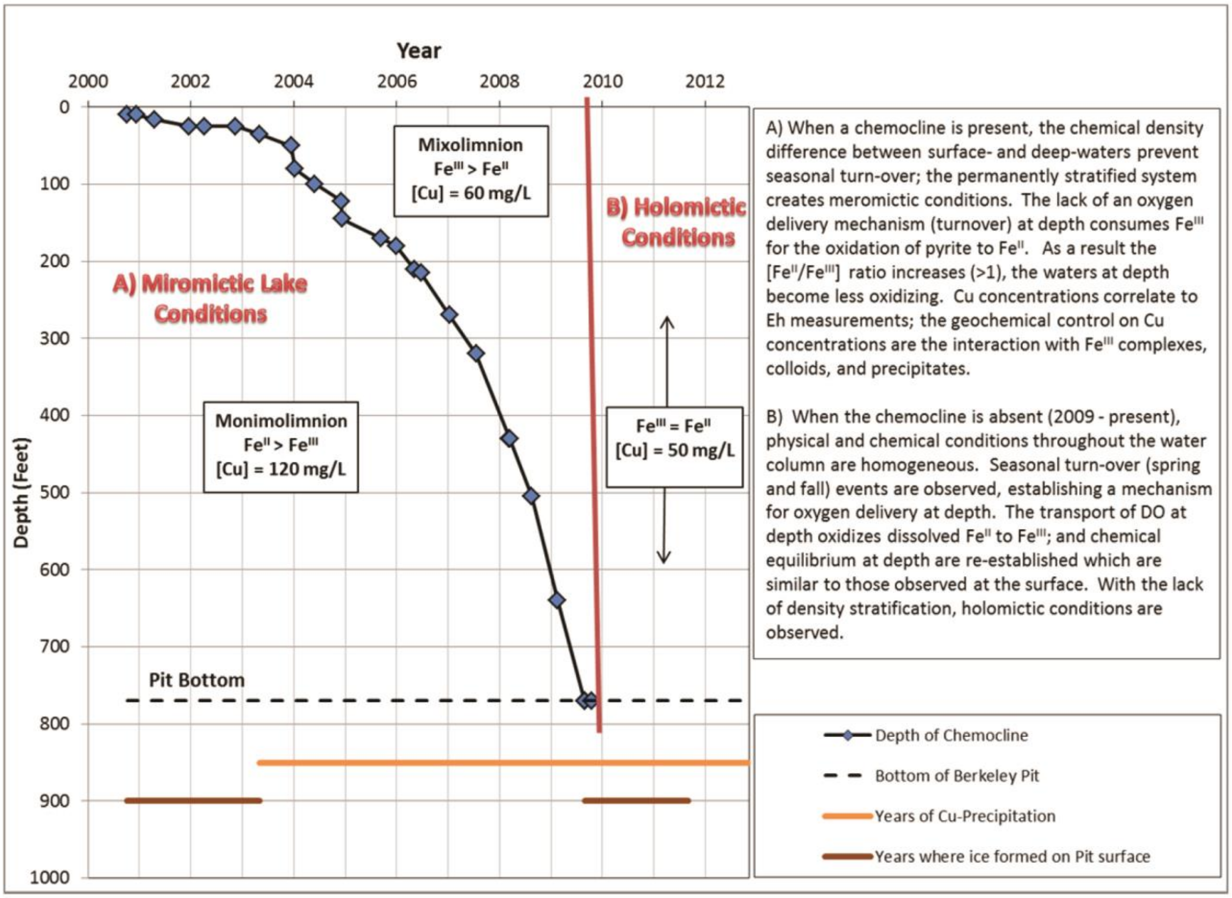


Figure 2-52 Role of the chemocline/chemical density stratification in the Berkeley Pit.

As of November 2009, the density stratification boundary known as the chemocline was pumped to extinction. Subsequent profiling data collected between 2009 and 2012 have consistently shown the absence of the chemocline. The effects of the extinction of the chemocline has resulted in the observation of dimictic (turnover twice a year, once in spring, once in fall) lake turnover and more homogenous water quality in the Pit with respect to depth. As a result, the Pit has transitioned from a miromictic (fig. 2-52A; chemically stratified conditions, no lake turnover) lake to a holomictic (fig. 2-52B) lake.

The presence/absence of the chemocline has greatly impacted the temperature of Berkeley Pit water at depth (all water below the chemocline). The chemical density stratification in water quality above and below the chemocline (2002–2009) prevented complete top-to-bottom turnover of the Pit. Water temperature below the chemocline was influenced by the warmer groundwater entering via mine shafts. In 2009 the chemocline dissipated, and seasonal turnover impacts were noted in temperature profiles at depth. Between 2009 and 2011, water temperatures at depth were measured at 4^{o}C, the temperature where water is most dense, indicating that seasonal turnover was occurring in the Berkeley Pit. In June 2012, the temperature of the water at depth in the Pit (between 25 and 650 ft) was measured at 3^{o}C. The presence of lighter, colder water at depth indicates that at least one physical turnover event occurred in the Berkeley Pit prior to June 2012. This is the first occasion where a physical turnover (as indicated by the presence of water temps at depth $<4^{o}$C) event has been recorded in the Berkeley Pit Lake System. Both seasonal and physical turnover events have an impact on the water quality of the Berkeley Pit at depth.

Depth profiles of SC (fig. 2-51C) and Eh (fig. 2-51D) since fall 2009 indicate homogeneous water-quality conditions throughout the water column. Relatively homogeneous physical parameters with respect to depth are indicative that seasonal turnover is occurring, creating a well-mixed water column. Without thermal or density stratification, the Berkeley Pit should remain a chemically homogeneous mixture with respect to depth, experiencing two to several turnover events per year.

Physical mixing caused by wind-driven or landslide events would increase the frequency of turnover events. The frequency and extent of mixing will depend on seasonal effects and the magnitude of the wind-driven/landslide events on the Pit. As a result of turnover, the water quality of the deeper pit zone has changed drastically, as dissolved oxygen is more readily introduced at depth. The Fe II/Fe III ratios at depth has decreased (fig. 2-51B), which has affected the solubility of metals, including copper. The lack of a chemocline has had a positive impact on water quality at depth, but it has also decreased the efficiency of MR's Cu-recovery process.

As a general rule, pH in the Berkeley Pit remains between 2.4 and 2.8. At depth, little change has been noted over the years. With respect to pH, the Berkeley Pit is a well-buffered system. The presence of secondary iron minerals, such as schwertmannite and k-jarosite, are in chemical equilibrium with respect to solid/aqueous concentrations, and the buffering capacity of aqueous sulfate are the geochemical processes which have kept the pH constant over the years.

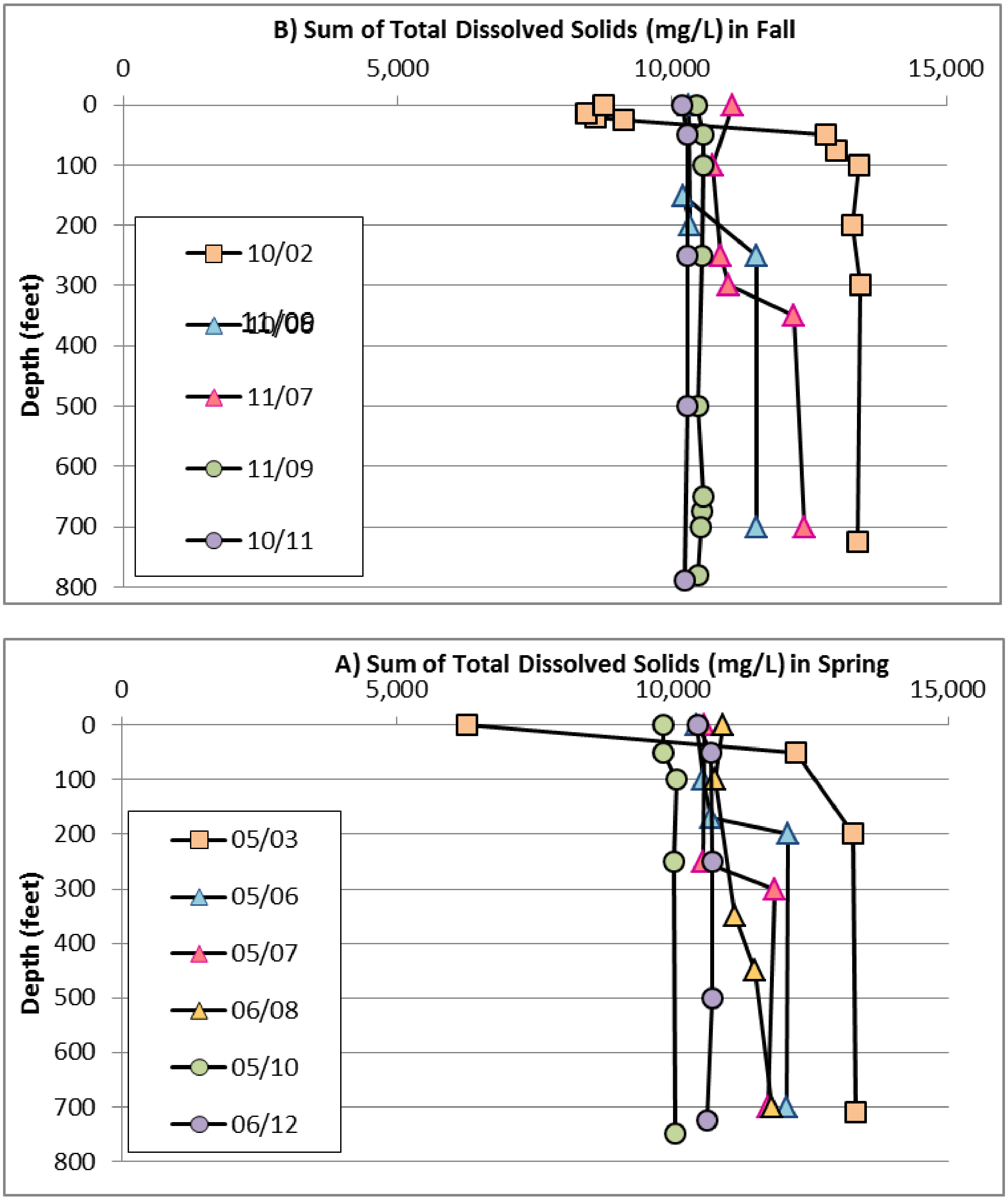


Figure 2-53. Depth profiles of the measured concentration of total dissolved solids in Berkeley Pit water over time. A) TDS during the spring monitoring events between 2002 and 2012. B) TDS during the fall monitoring events between 2002 and 2012).

Section 2.3.1.4 Chemical Parameters

Depth profiles for total dissolved solids in the Berkeley Pit over time (between 2002 and 2012) are given in figure 2-53. Total dissolved solids are the sum of all dissolved substances contained in the Berkeley Pit and are a good measurement to calculate the overall water quality of the Pit over time. The TDS profiles in both spring (fig. 2-53A) and fall (fig 2-53B) sampling events have decreased an average of 25 percent between 2002 and 2012.

Notable changes in the chemistry of the Berkeley Pit have occurred as a result of Cu-recovery activities and diversion of HSB water away from the Berkeley Pit since November 2003. Water-quality samples for chemical analysis were collected by the MBMG at a minimum of three depths on a semi-annual basis, and results were published on the MBMG GWIC online database (GWIC, 2011). This database contains a large amount of data pertaining to the water quality of the Berkeley Pit. This section discusses some of the recent water-quality changes in chemical parameters that have been observed.

The Cu-recovery process extracts water at a depth >700 ft below the water surface. This water is then passed over scrap iron where the copper plates onto the iron through a process known as oxidative-reductive ion exchange. Dissolved iron replaces the copper in solution, and this iron-rich, low copper-depleted water is discharged to the surface water of the pit. The chemical equation for this process is described below:

$$Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Cu(s)$$

The chemistry of these waters is illustrated in table 2.3.1.4.1. Two sampling events were conducted in 2012; samples were collected of Pit water, influent Cu-recovery samples, and Cu-precip effluent samples. Influent samples are consistent with the depth from which they were extracted (~ 700 ft below surface (fbs)). As a result of the ion exchange process, effluent samples are lower in Cu concentrations and higher in Fe concentrations than influent samples. Effluent samples consistently have lower arsenic concentrations, higher pH, and lower acidity than influent samples.

Table 2.3.1.4.1 Berkeley Pit Lake System Current Water composition.

	pH	SC	TDS	Total Acidity	Fe	Cu	Zn	As	SO_4
June 2012 Sampling Event									
Precip-in	2.71	7,672	10,843	3,672	241	51	592	62	8,203
Precip-out	3.14	7,647	10,826	3,359	386	16	588	41	8,076
BP Surface	2.55	7,652	10,463	3,563	211	49	631	74	7,740
BP 700 fbs	2.6	7,629	10,629	3,584	260	54	633	70	7,849
December 2012 Sampling Event									
	pH	SC	TDS	Total Acidity	Fe	Cu	Zn	As	SO_4
Precip-in	2.7	7,642	12,403	4,588	203	49	579	63	9,799
Precip-out	3.13	7,483	12,158	3,651	308	16.8	575	50	7,499
BP Surface	2.61	7,632	12,229	3,651	204	49	589	64	9,560
BP 700 fbs									

All data shown in this table are from 2012 semi-annual sampling events. All data are in mg/L except pH (standard units) and SC (µs/cm@25^{0}C).

The Cu-recovery process recycled deep Berkeley Pit water to the Berkeley Pit surface at an approximate rate of 11,000 gpm. This process has been in operation since 2004, and has had significant impacts on the chemistry of the Pit at all depths. The high concentrations of dissolved iron in the effluent return water from the Cu-cementation plant has significantly increased the precipitation and formation of secondary iron precipitates throughout the water column. The increased formation of secondary iron precipitates (fig. 2-54), such as schwertmannite ($Fe_8O_8(OH)_6SO_4$) and K-jarosite ($KFe_3(OH)_6(SO4)_2$), is the leading factor contributing to the changes in water quality seen in the Berkeley Pit since 2004. Since the initiation of Cu-precipitation in the Berkeley Pit (fall 2003), roughly 170 million pounds of Fe has precipitated as secondary iron precipitates in 11 years. Without the presence of a chemocline (fall 2009), Fe-precipitates do not redissolve during settlement, representing a permanent removal mechanism. This process is expected to continue as long as the Pit remains holomictic, and MR continues to operate the Cu-precipitation plant. If the Pit becomes stratified, the geochemical conditions observed prior to 2004 are expected to reestablish.

Mining the Berkeley Pit water for copper has had many significant and positive impacts on water quality in the Berkeley Pit. Water quality in Precip Plant influent samples are given in table 2.3.1.4.2. Between 2001 to 2012, significant decreases have been observed for Fe (74 percent), Cu (70 percent), P (88 percent), and As (92 percent). These changes are reflected in Berkeley Pit water quality at all depths. The most significant water-quality changes attributed to the lack of chemical stratification and the Cu-recovery process are described in figures 2-55 through 2-57.

Figure 2-54. Accumulation of secondary iron precipitates in a sediment trap deployed in the Berkeley Pit for 150 days.

Table 2.3.1.4.2 Water-quality changes to Precipitation Plant influent.

Date	pH	SC µs/cm	TDS mg/L	Fe mg/L	Cd mg/L	Cu mg/L	Zn mg/L	P mg/L	As µg/L	SO4 mg/L
8/20/2001	2.55	8,610	12,610	932	2.07	167	626	0.8	731	9,160
2/24/2003	2.4	7,645	12,490	899	2.01	156	513	0.6	750	9,250
7/8/2005	3.01	7,310	13,567	1046	2.11	182	651	0.7	303	9,980
5/18/2007	3.07	8,007	11,901	914	1.73	151	606	<0.5U	97	8,421
6/25/2010	2.57	7,400	11,633	413	2.19	67	606	0.1	96	8,750
6/25/2012	2.71	7,672	10,843	241	2.06	51	592	<0.3U	62	8,203
Percent Decrease	NC	11	14	74	NC	70	NC	88	92	10

The effects of the MR copper cementation plant on dissolved iron are presented in figure 2-55. Decreasing trends were observed at all depths from 2003 to 2012. The most significant decreases were seen at depth. Between 2009 and 2012 (extinction of the chemocline), significant decreases in Fe concentrations were observed at all depths, indicating that dissolved Fe concentrations have yet to reach equilibrium, and future changes in the geochemistry of the Berkeley Pit can be expected.

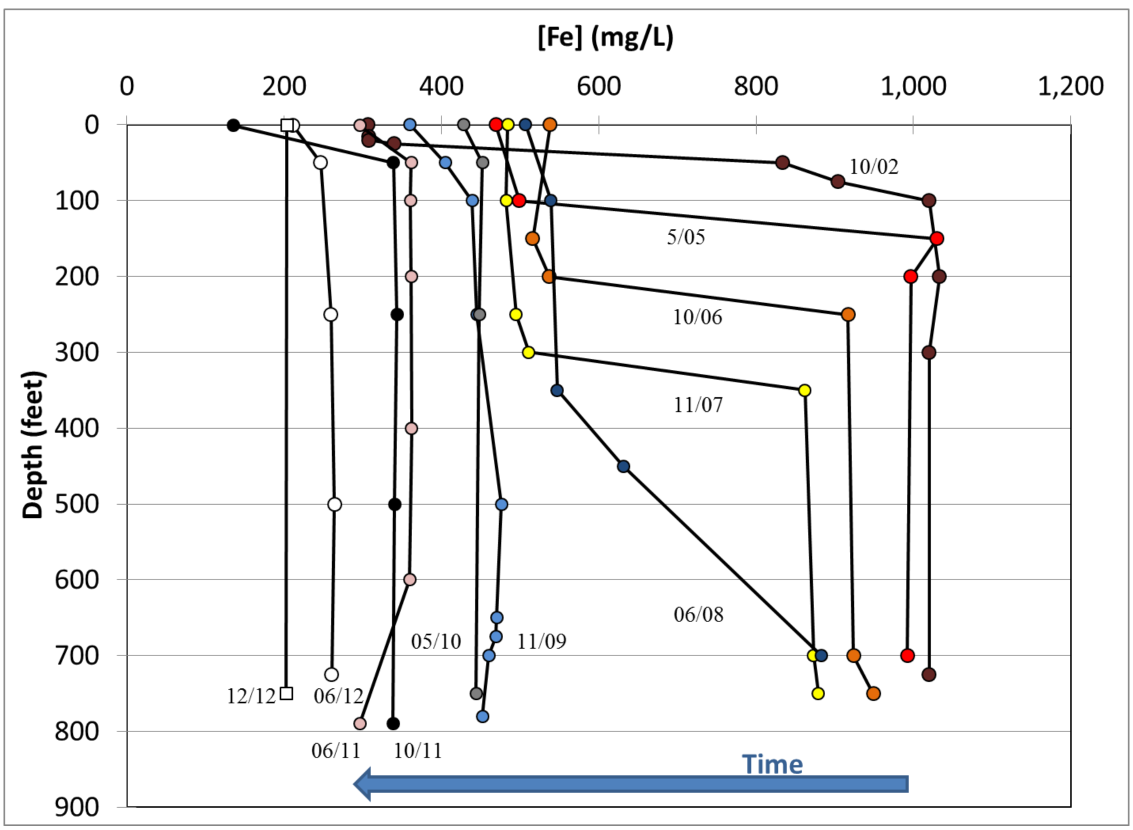


Figure 2-55. Effects of MR Cu-Precipitation Plant on dissolved iron.

Changes in dissolved iron speciation in the surface water and at depth are presented in figure 2-56. Significant decreases were observed in ferrous iron (Fe II) from 2008 to 2012 at depth. These observations do not coincide with increases observed for ferric iron; rather, concentrations of Fe III at depth have decreased slightly since 2011. These observations are consistent with changes observed by increases in the Eh (fig. 2-49D) at depth over the same time period. As of November 2009, concentrations of Fe II $<$ Fe III in deep Pit samples, reversing a trend (Fe II $>$ Fe III) observed since fall 2003. Also, as of November 2009, concentrations of Fe III have been decreasing in surface-water samples. These Fe speciation trends observed since fall 2009 correlate well with the extinction of the chemocline, and are most likely decreasing as a result of dissolved oxygen delivery during seasonal and physical turnover events.

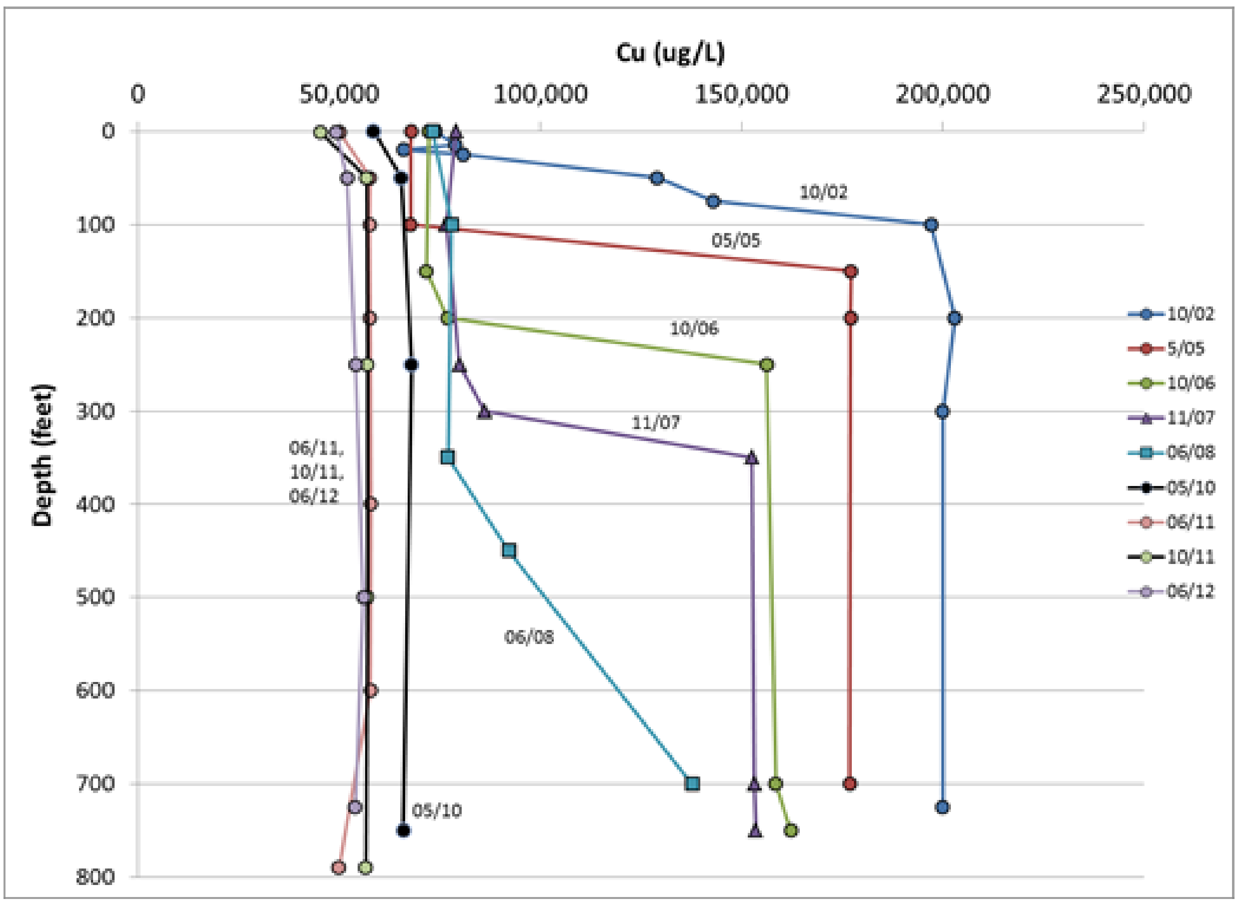
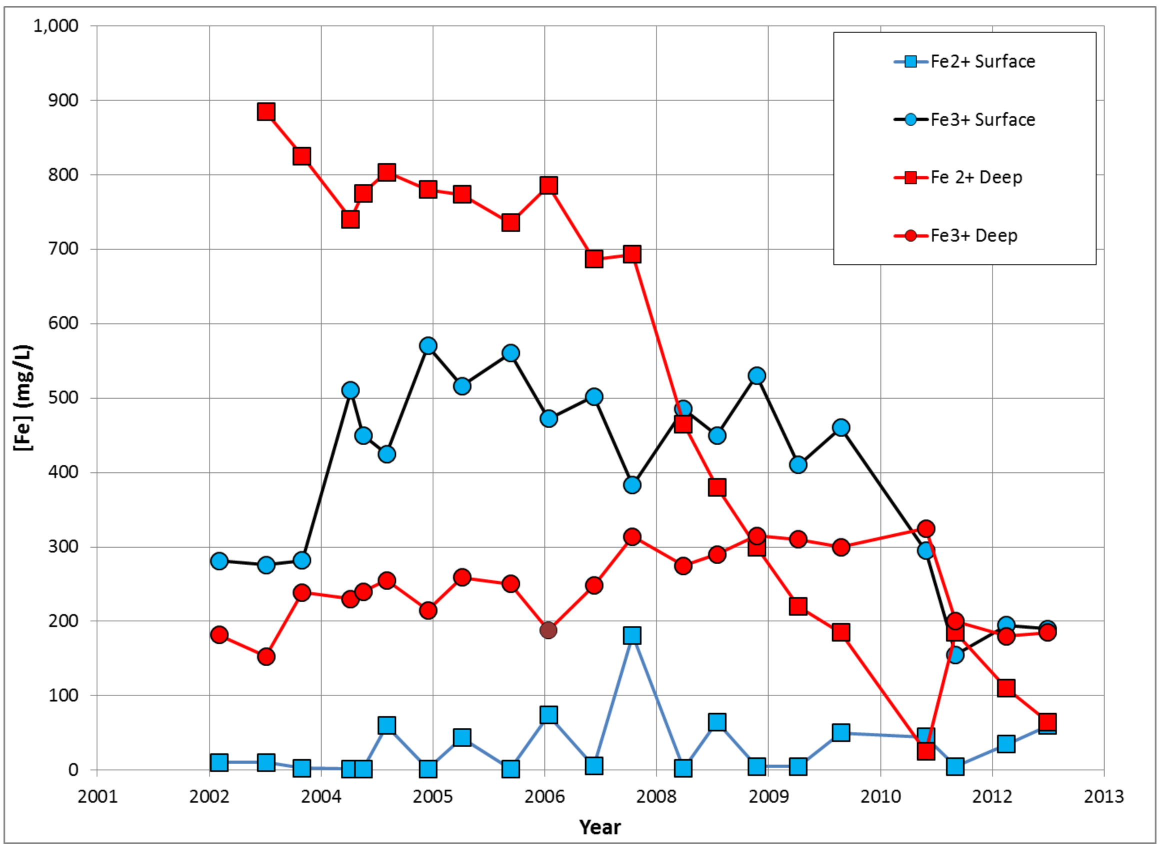


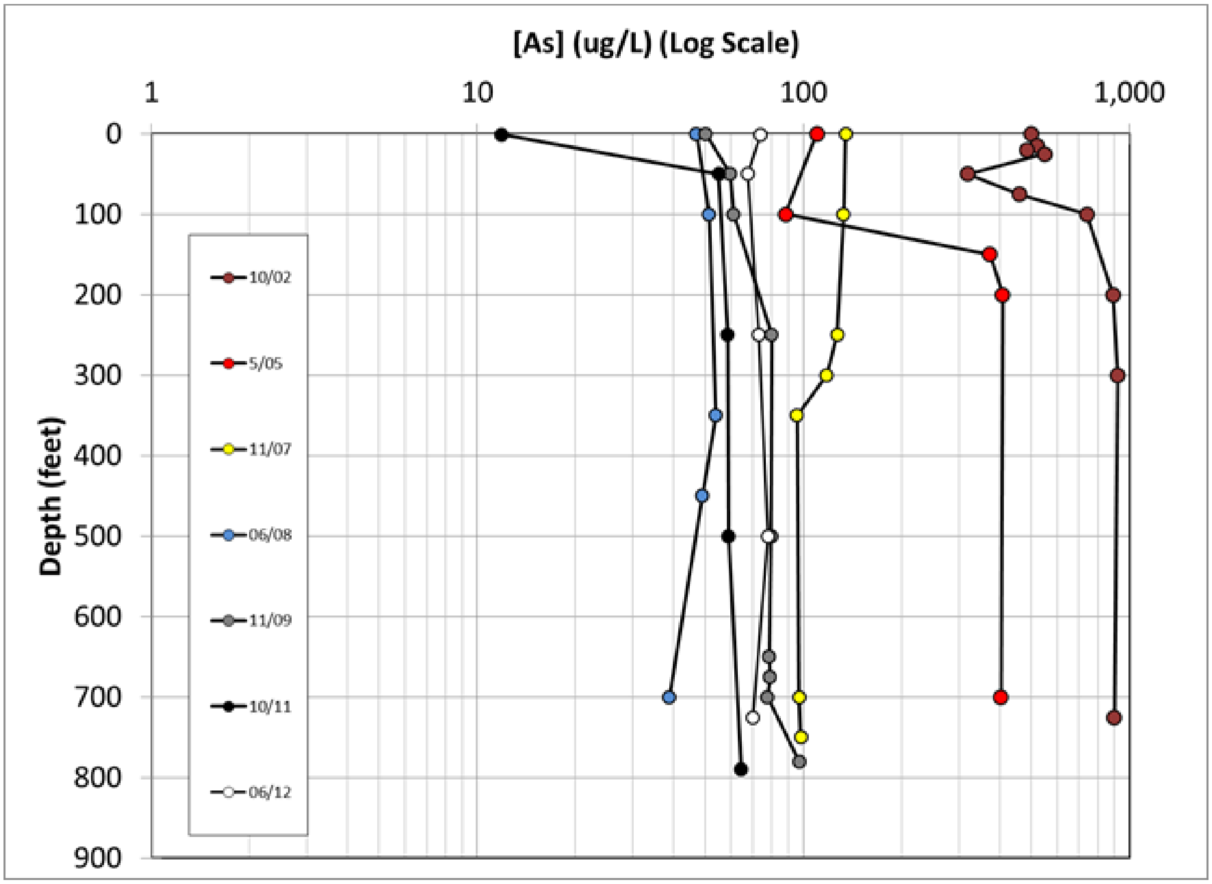
Figure 2-56. Effects of MR Cu-cementation process on Fe speciation.

The effects of the MR copper cementation plant on dissolved copper are presented in figure 2-57. Decreasing trends were observed at all depths from 2008 to 2011. Most significant decreases were seen at depth. The decrease in Cu is explained by the permanent removal of dissolved Cu from the Cu-recovery plant and also the co-precipitation of copper onto secondary iron precipitates. The geochemical control on dissolved Cu at all depths appears to be the increased rate of production of secondary Fe-precipitates. As of November 2009, homogeneous water-quality conditions with respect to Cu are present throughout the water column, and concentrations have remained stable at ~50 mg/L since June 2011. Overall, concentration of Cu in the Berkeley Pit decreased 60 percent since 2002.

Figure 2-57. Effects of MR Cu-Precipitation Plant on dissolved copper.



Arsenic concentrations, more than any other dissolved contaminant, have shown decreasing trends at all depths over time. Concentrations of As have decreased by more than an order of magnitude. Figure 2-58 portrays trends in arsenic at all depths since 2002. The significant decrease in As concentrations is explained by the co-precipitation of arsenic onto secondary iron precipitates



through the Cu-Precip Plant and the Pit itself, and can be directly and indirectly attributed to the Cu-precipitation process. Mining the copper in the Berkeley Pit has significantly removed a major contaminant of concern. Concentrations of As have appeared to stabilize at all depths since June 2008.

Figure 2-58. Effect of MR Cu-precipitation on dissolved As at all depths.

Arsenic concentrations reached their maximum values during the later period of mine suspension. Following the resumption of mining and the diversion of HSB water away from the pit, arsenic concentrations in the surface water began to decrease (2002 sampling event), and further decreases in arsenic concentrations at all depths are shown in later sampling events. Similarly, phosphate concentrations (PO_4) show the same decreasing trends, suggesting PO_4 is co-precipitating as well.

Nine years of Cu recovery by MR have resulted in the elimination of the chemocline and significant decreases in both Cu and Fe concentrations (70 percent reductions), and dissolved P and As concentrations have decreased by an order of magnitude. Decreases in major trivalent and divalent cations, such as Fe and Cu, have had a positive impact on total acidity of the Berkeley Pit. Total acidity is described below:

$[H+ + HSO_4^-] + 2[Fe^{2+} + Cu^{2+} + Zn^{2+} + Mn^{2+}] + 3\ [Fe^{3+} + Al^{3+}]$.

By this equation, it would appear that 9 years of MR's Cu recovery process have resulted in a 12 percent decrease in total acidity in the Berkley Pit (fig. 2- 59) . A decrease in total acidity results in a significant cost benefit, as less lime is needed to treat pit water at the Horseshoe Bend Treatment Plant. To confirm the decrease in acidity calculated from the equation above, acidity titration experiments of Pit water are now being conducted by the MBMG. Assuming a 2:1 acid:lime neutralization ratio, and 3.5 MGD Berkeley Pit treatment volume, the decrease in Berkeley Pit total acidity would result in a 25 tons of lime per day savings (fig. 2-59).

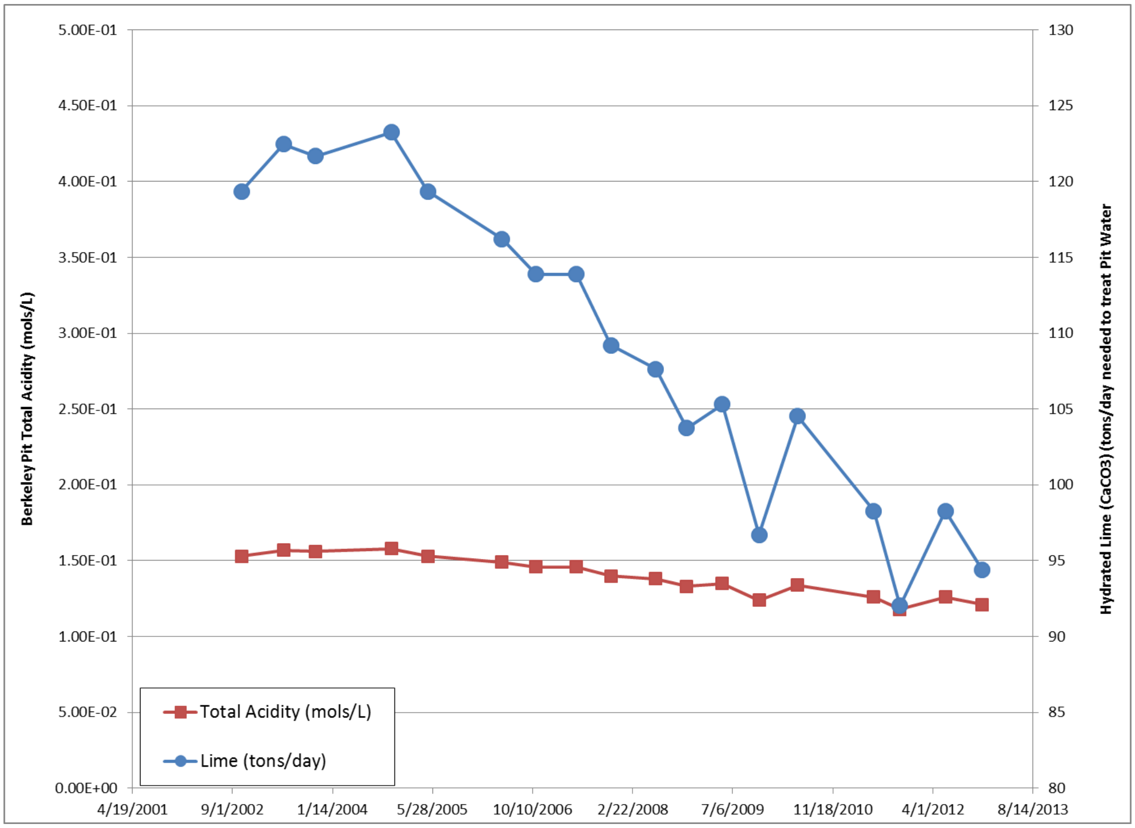


Figure 2-59. The decrease in calculated total acidity in Berkeley Pit water over time (red) corresponds to a considerable reduction in lime use per day (in blue) in the HSB treatment plant during remedy. The reduction of lime needed would equate to 25 tons/day.

Section 2.3.2 Horseshoe Bend Water Quality

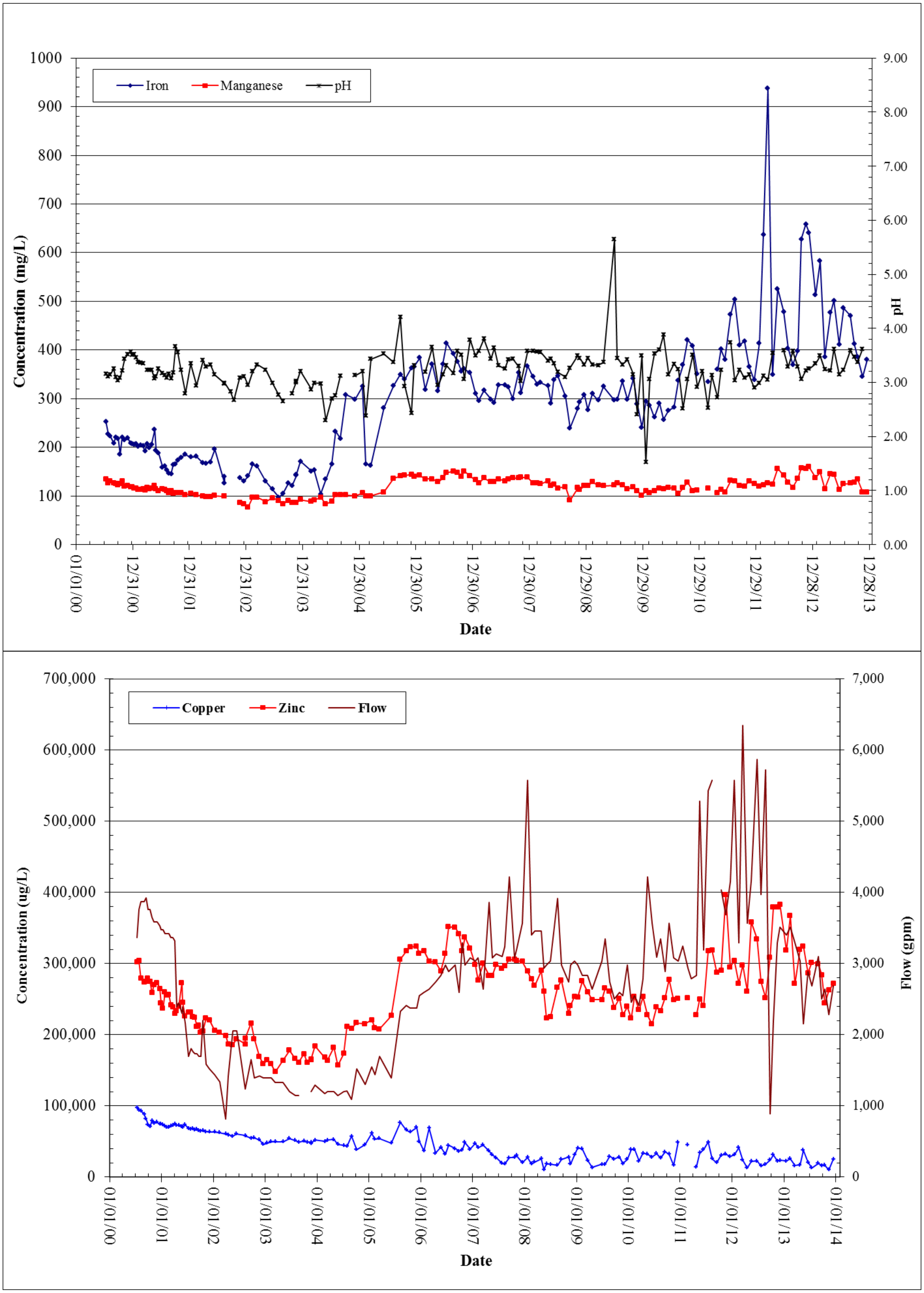
Monitoring of the HSB drainage began in July 2000 following MR's temporary suspension of mining. Similar to the changes seen in flow rates during the period of mine suspension, concentrations in a number of the trace metals decreased also. Metal concentrations began to increase in mid-2004 when flow rates increased (fig. 2-60). Copper and zinc concentrations increased through early and mid-2006, respectively, before declining. Copper concentrations are currently less than one-third those seen in 2000, while zinc concentrations are similar to 2000 concentrations.

In August 2012, MR increased leaching operations, using a significant volume of Horseshoe Bend Water as leachate solution. As a result, the water quality of Horseshoe Bend water has degraded since that time. As of December 2013, the water quality of the HSB drainage has reversed its previously reported trend (Duaime and Tucci, 2010, 2011), and is currently slightly more degraded and significantly more acidic (total acidity) than the water quality of the Berkeley Pit (table 2.3.2.1).

Table 2.3.2.1 Selected chemistry from Berkeley Pit and Horseshoe Bend waters.

Area	pH (S.U.)	TDS (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Al (µg/L)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)	Total Acidity (mg/L)
Berkeley Surface	2.61	12,229	9,560	304	266,192	48,607	23	588,577	3,651
Precip Plant-Influent	2.7	12,403	9,799	203	266,088	48,514	18	579,144	3,651
HSB	3.25	16,498	13,453	641	547,525	23,580	<0.6	383,331	5,895

Figure 2-60.



Horseshoe Bend water-quality comparisons of selected constituents, 2000–2013.

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring continued during 2013 in the three mine shafts and six monitoring wells (fig. 3-1) that constitute the West Camp system. Pumping activities were temporarily suspended on July 8, 2013 to allow water levels to rise in the West Camp System to an elevation 10 ft higher than the CWL elevation specified in the 2002 CD; pumping resumed on September 17, 2013. EPA and DEQ granted a temporary waiver to allow the exceedance. Pumped water continued to be diverted to the Lower Area One-Butte Treatment Lagoons site. Water was first diverted to this site during March 2002. The volume of water pumped was just over 164.5 acre-ft, or 59 acre-ft less than that pumped in 2012. Water-level increases throughout the underground mine system ranged from 11.5 ft to 12.49 ft. Water levels at the end of 2013 were 1 ft above this site's critical water-level elevation.

Section 3.1 West Camp Underground Mines

Water levels in the West Camp Mine system continue to be controlled by pumping facilities located at the BMF-96-1D and BMF-96-1S site. ARCO had a dedicated well drilled for dewatering (pumping) purposes in the fall of 1997, which 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. The pump and pipeline at the Travona Mine were left intact, however, allowing it to serve as a backup pumping system. The pump station and support system were modified and upgraded by ARCO during the latter portion of 2011 (figs. 3-2 through 3-5). Additional water-level monitoring began prior to the start of the 2013 West Camp Study and continued throughout the remainder of the year to ensure water levels were maintained at appropriate levels; figure 3-6 shows water levels in the Travona, Ophir, and well BMF96-1D throughout 2013.

The quantity of water pumped was less than that for any of the past 10 years. Table 3.1.1 shows the annual amount of water pumped in acre-ft, the change in acre-ft from the previous year, and the percent change from 1996 (the first full year of continuous pumping). Figure 3-7 shows the amount of water pumped annually and the percent of average annual precipitation since 1982.

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

Figure 3-2. West Camp pump station 1997–2011.

Figure 3-3. West Camp pumping well, discharge line, and monitoring well exposed during 2011 construction activities.

Figure 3-4. West Camp construction activities showing new pump station foundation and infrastructure improvements surrounding pumping well and discharge line.

Figure 3-5. New West Camp pump station, 2011.

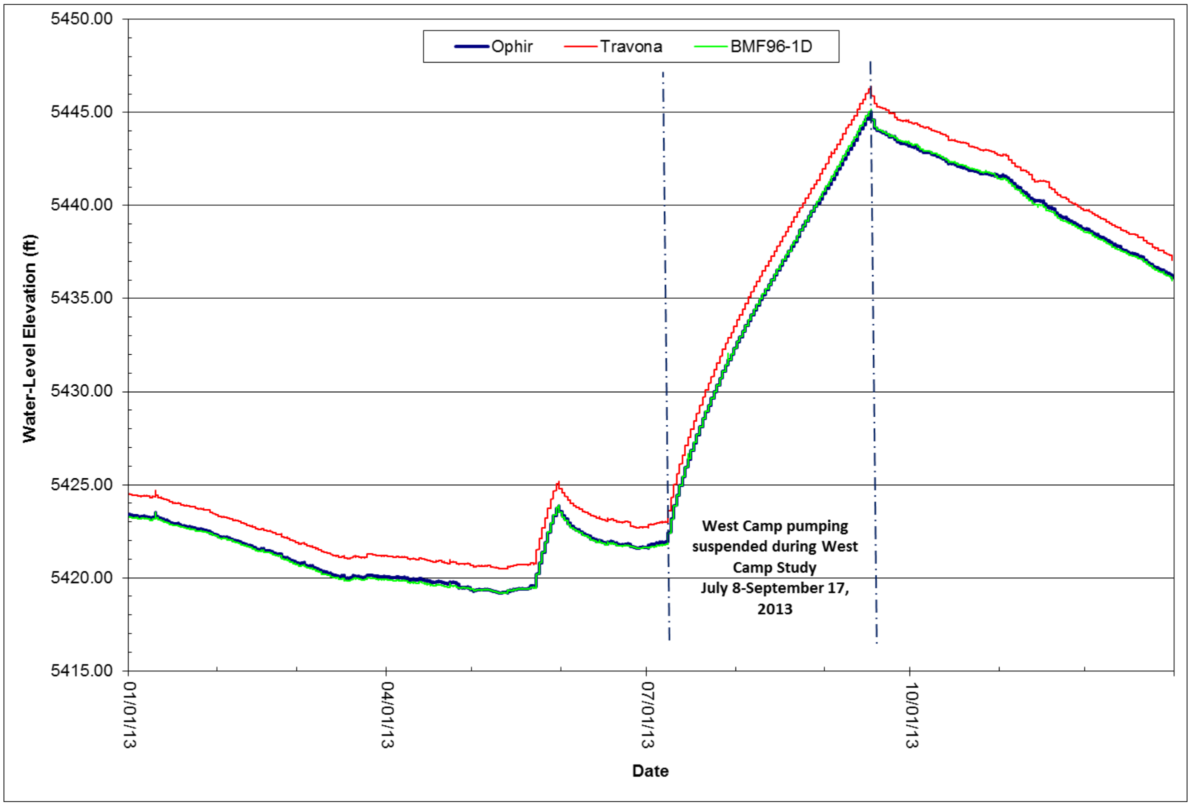


Figure 3-6. Hydrograph showing water levels in the Travona Mine, Ophir Mine, and well BMF96-1D throughout 2013.

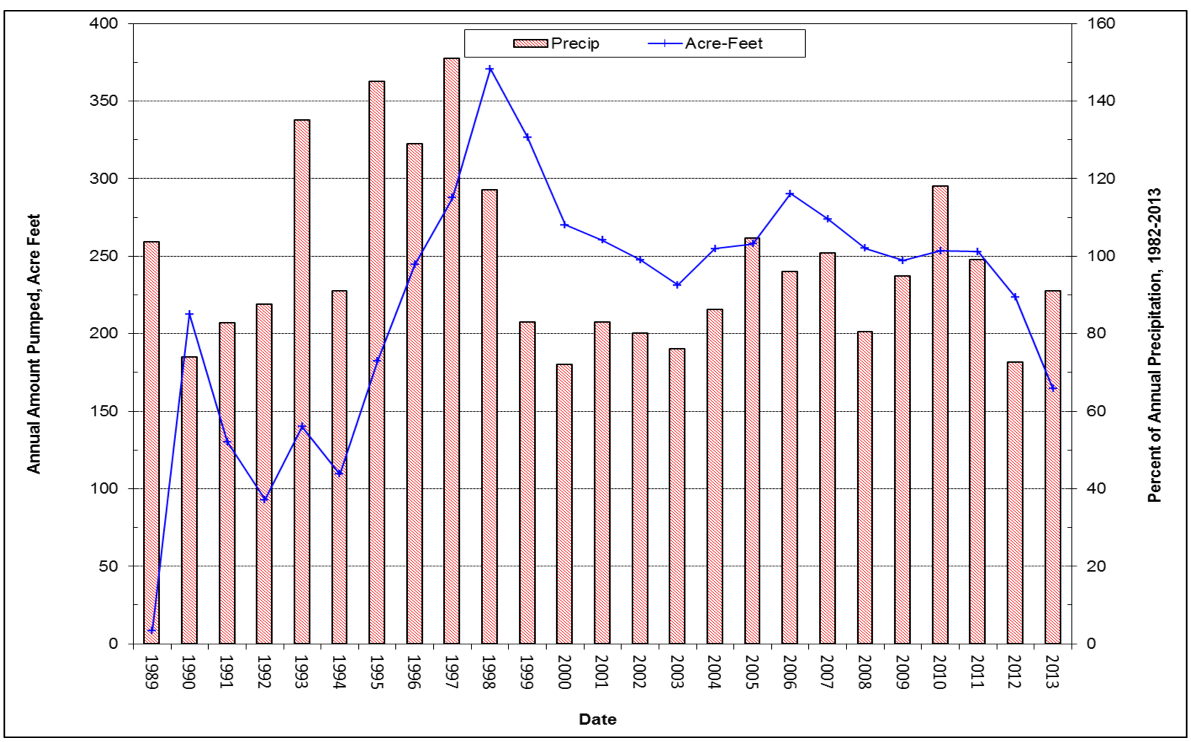


Figure 3-7. Annual amount of water pumped from the West Camp system.

Table 3.1.1 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
2004	254.70	+23.26	104
2005	257.82	+3.12	105
2006	290.33	+32.51	119
2007	273.96	-16.37	112
2008	255.16	-18.79	104
2009	247.03	-8.13	101
2010	253.49	6.46	104
2011	252.93	-0.56	103
2012	223.64	-29.29	91
2013	164.53	-59.11	67

All three mines had a net water-level increase between 11.52 ft and 12.49 ft during 2013. Water-level changes in the West Camp mines reflect changes in pumping rates in the WCPW and precipitation amounts. Figure 3-8 shows annual water-level changes for the West Camp sites. Water levels are just over 1 ft above the West Camp action level of 5,435 ft stipulated in the 1994 ROD and 2002 CD.

Water-level elevations for the three West Camp mines are shown in figure 3-9. 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.

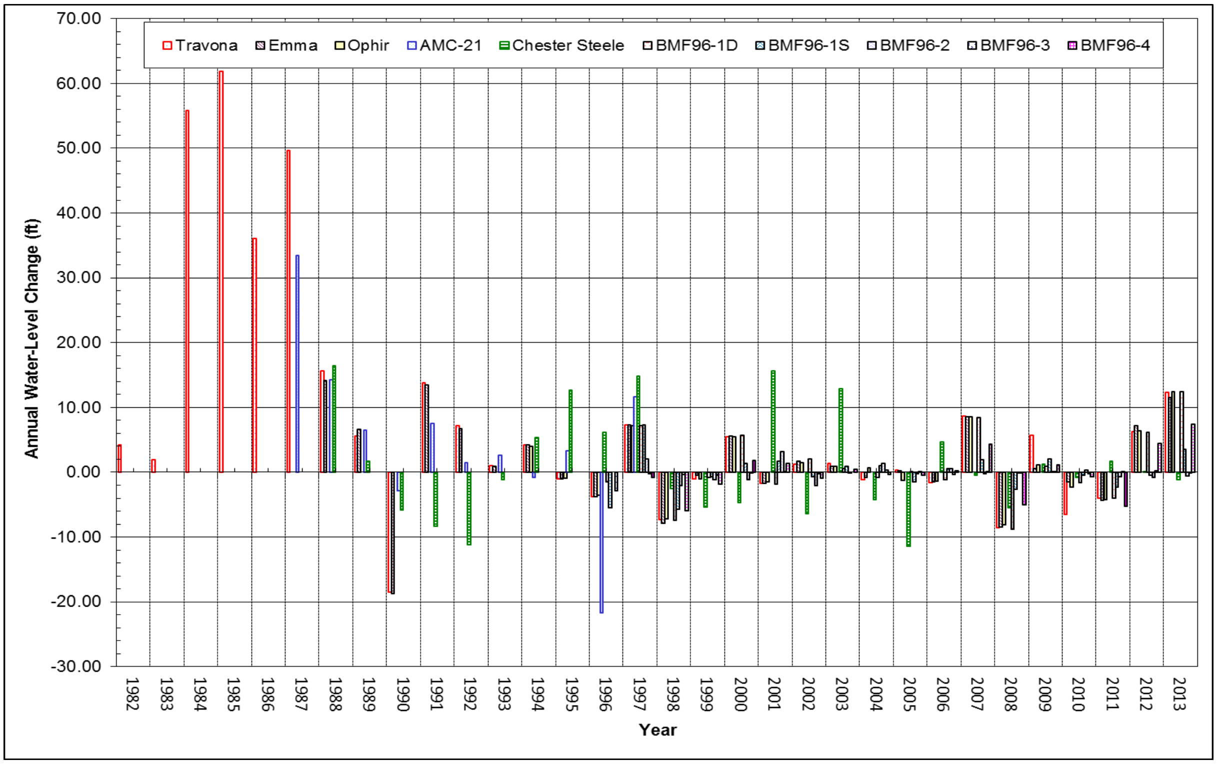


Figure 3-8. Annual water-level changes for West Camp site.

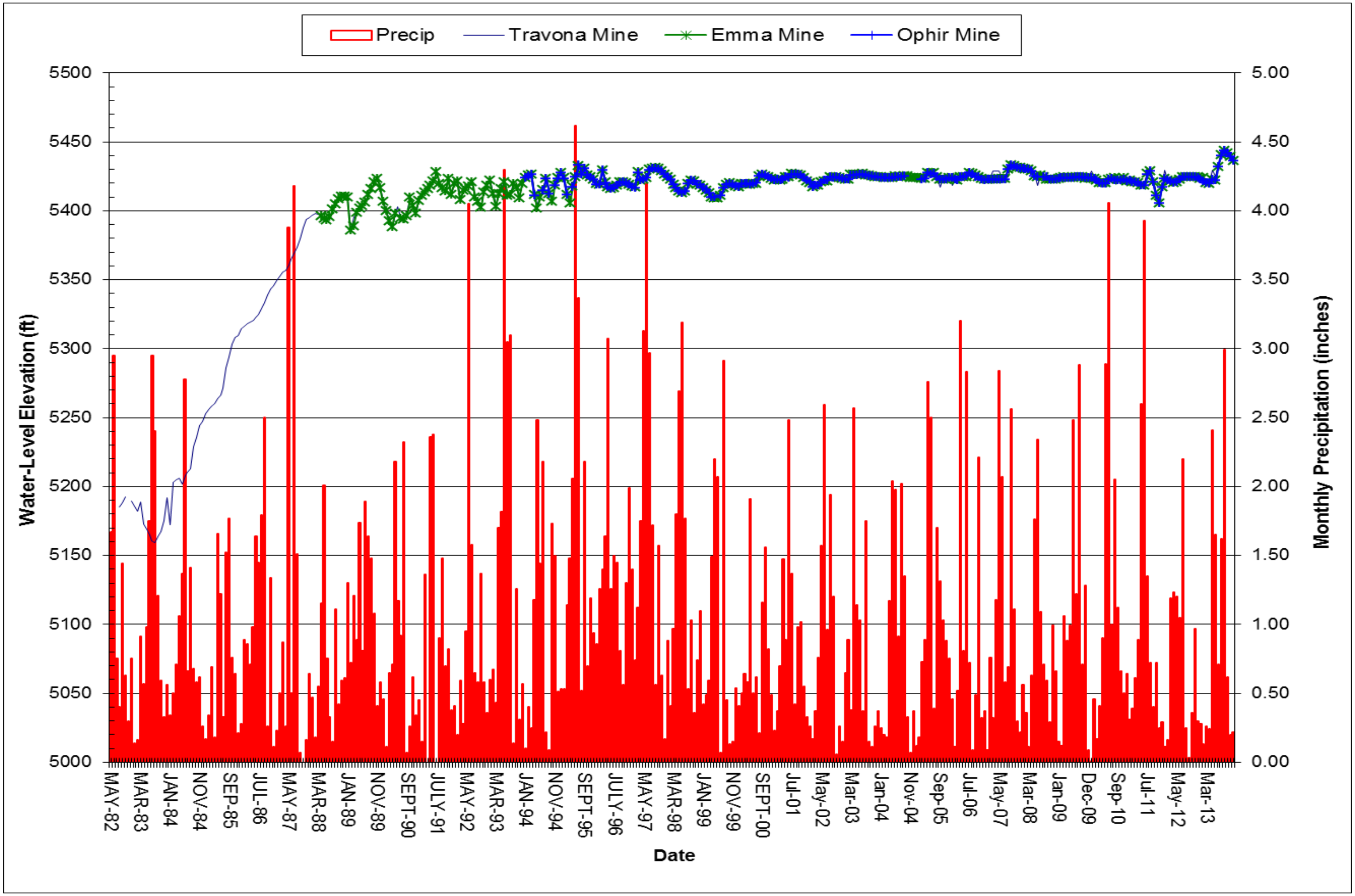


Figure 3-9. Water-level hydrographs for West Camp mines.

Section 3.2 West Camp Monitoring Wells

Water levels increased in three of the six BMF96 West Camp wells during 2013. Well BMF96-1D, which was completed into the Travona Mine workings, had a water-level change (increase) similar to the West Camp mines. The influence of the suspended pumping during the summer of 2013 was noticeable in water levels in wells BMF96-1D and BMF96-4. These annual water-level changes are shown in table 3.2.1 and figure 3-8.

Figure 3-10 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 operations have on the system and how interconnected the wells are to the mine workings. This is an important trend since well BMF96-4 was not completed into mine workings. It is, however, in the area of the historic 1960s flooding problems that led the Anaconda Company to install well AMC-21 for control of water levels in the West Camp (fig. 3-11). (See Duaime and others, 1998 for a greater discussion of historic flooding problems in the West Camp System). There is a lag time between the responses seen in these two wells, which is most likely due to the fact that 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 operations at the WCPW. There was no change in longer term trends in any of these wells from those described in the previous reports, with the exception of the temporary water-level increases during the summer 2013 suspension of pumping.

Water levels in wells BMF96-2 and BMF96-3 are 20 ft to 50 ft higher than those in wells BMF96-1D and BMF96-4, and when plotted with the other BMF96 wells, initially appeared to show little change (fig. 3-12). However, since 2002, water levels in these two wells appear to follow trends similar to the other wells. When these wells are plotted separately (fig. 3-13), 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 ft below ground surface, their water levels are less than 20 ft below ground surface. Water-level trends during 2013 in these wells for the most part were similar to those seen the previous several years. No response was seen in these wells due to the reduced pumping activities the summer and fall of 2013. Water levels rise with precipitation and with infiltration from snowmelt, which is shown by the early season (March–April) water-level increases.

Table 3.2.1 Annual water-level changes for the West Camp sites (ft).

Year	Travona	Emma	Ophir	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								
1988	15.69	14.20		16.42					
1989	5.67	6.60		1.79					
1990	-18.42	-18.66		-5.77					
1991	13.88	13.52		-8.28					
Change Years 1–10	**226.72**	**15.66**		**4.16**					
1992	7.21	6.79		-11.20					
1993	1.01	0.93		-1.11					
1994	4.24	4.26	4.00	5.36					
1995	0.98	-1.00	-0.96	12.72					
1996	3.72	-3.76	-3.56	6.14	-1.50	-5.41	0.00	-2.85	
1997	7.29	7.28	7.22	14.82	7.20	7.36	2.13	-0.19	-0.80
1998	-7.31	-7.88	-7.20	-2.51	-7.35	-5.63	-2.00	-0.26	-5.88
1999	-0.97	-0.47	-1.03	-5.37	-0.82	-0.61	-1.15	-0.38	-1.76
2000	5.56	5.61	5.53	-4.64	5.70	1.45	-1.13	-0.07	1.86
2001	1.65	-1.70	-1.52	15.61	-1.78	1.70	3.23	0.10	1.40
Change Years 11–20	**-10.68**	**10.06**	**2.48**	**29.82**	**1.45**	**-1.14**	**1.08**	**-3.65**	**-5.18**
2002	1.33	1.74	1.51	-6.35	2.03	-0.62	-2.06	-0.21	-0.93
2003	1.45	0.95	0.87	12.94	0.56	0.96	-0.01	0.00	0.54
2004	-1.06	-0.72	0.73**	-4.22	-0.72	1.03	1.41	0.33	-0.31
2005	0.39	0.22	-1.30	-11.35	0.03	-1.42	-0.23	0.18	-0.47
2006	-1.62	-1.49	-1.33	4.76	-1.15	0.65	0.59	-0.31	0.20
2007	8.68	8.56	8.57	-0.41	8.49	1.93	-0.17	0.13	4.41
2008	-8.57	-8.39	-8.15	-5.41	-8.71	-2.65	-0.14	-0.06	-4.96
2009	5.68	0.56	1.09	1.26	0.91	2.05	0.04	0.10	1.22
2010	-6.47	-1.46	-2.27	-0.82	-1.61	-0.41	0.42	-0.23	-0.60
2011	-3.99	-4.27	-4.17	1.77	-3.99	-2.23	-0.67	0.09	-5.24
Change Years 21–30	**-4.18**	**-4.30**	**-4.45**	**-7.83**	**-4.16**	**-0.71**	**-0.82**	**0.02**	**-6.14**
2012	**6.25**	**7.22**	**6.43**	**0.12**	**6.20**	**-0.46**	**-0.82**	**0.21**	**4.47**
2013	**12.35**	**11.52**	**12.49**	**-1.11**	**12.49**	**3.59**	**-0.56**	**-0.07**	**7.50**
Change Years 31–40	**18.60**	**18.74**	**18.92**	**-0.99**	**18.69**	**3.13**	**-1.38**	**0.14**	**11.97**
Net Change*	**251.82**	**40.16**	**16.95**	**25.16**	**15.98**	**1.28**	**-1.12**	**-3.49**	**0.65**

(Minus sign (-) indicates a decline (drop) in water level.)

*Total water-level change is that measured. Access or obstructions occasionally prevent water-level measurements. **Vandalism to Ophir Mine monitoring point resulted in no water levels being obtained for the last quarter of 2004.

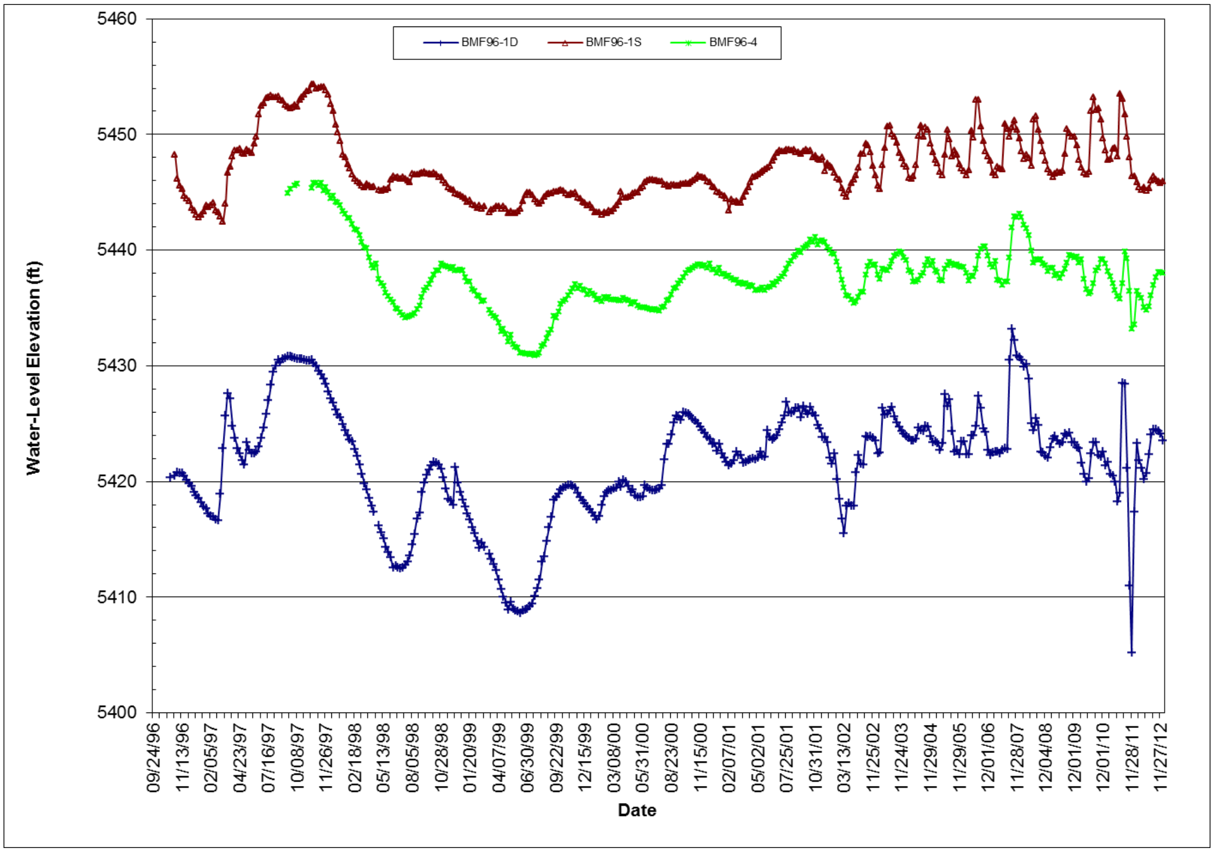


Figure 3-10. Water-level hydrographs for West Camp wells BMF96-1D, BMF96-1S, and BMF96-4.

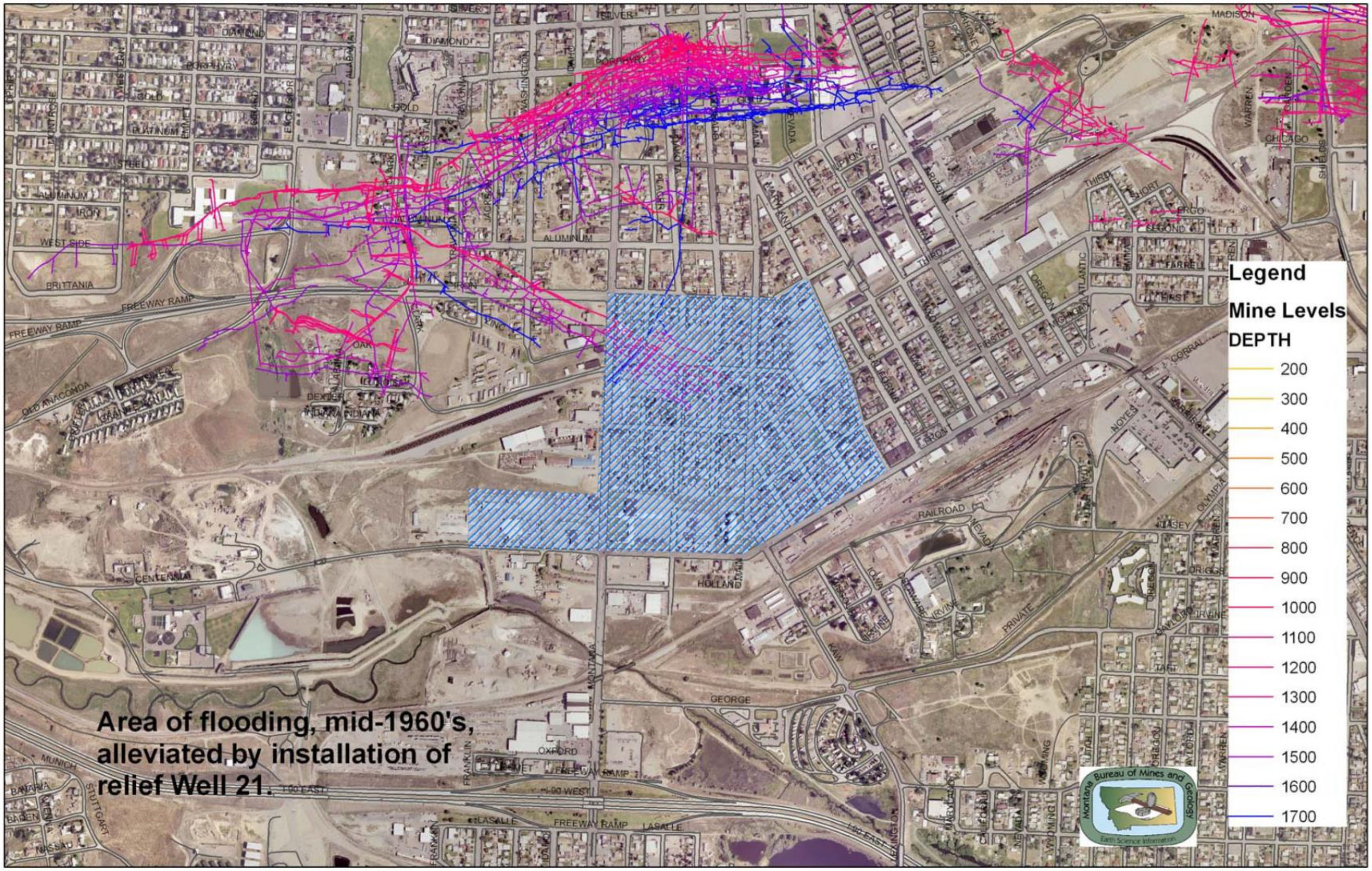


Figure 3-11. Area of the West Camp affected by basement flooding problems, 1960s. Blue hatch area outlines problem locations.

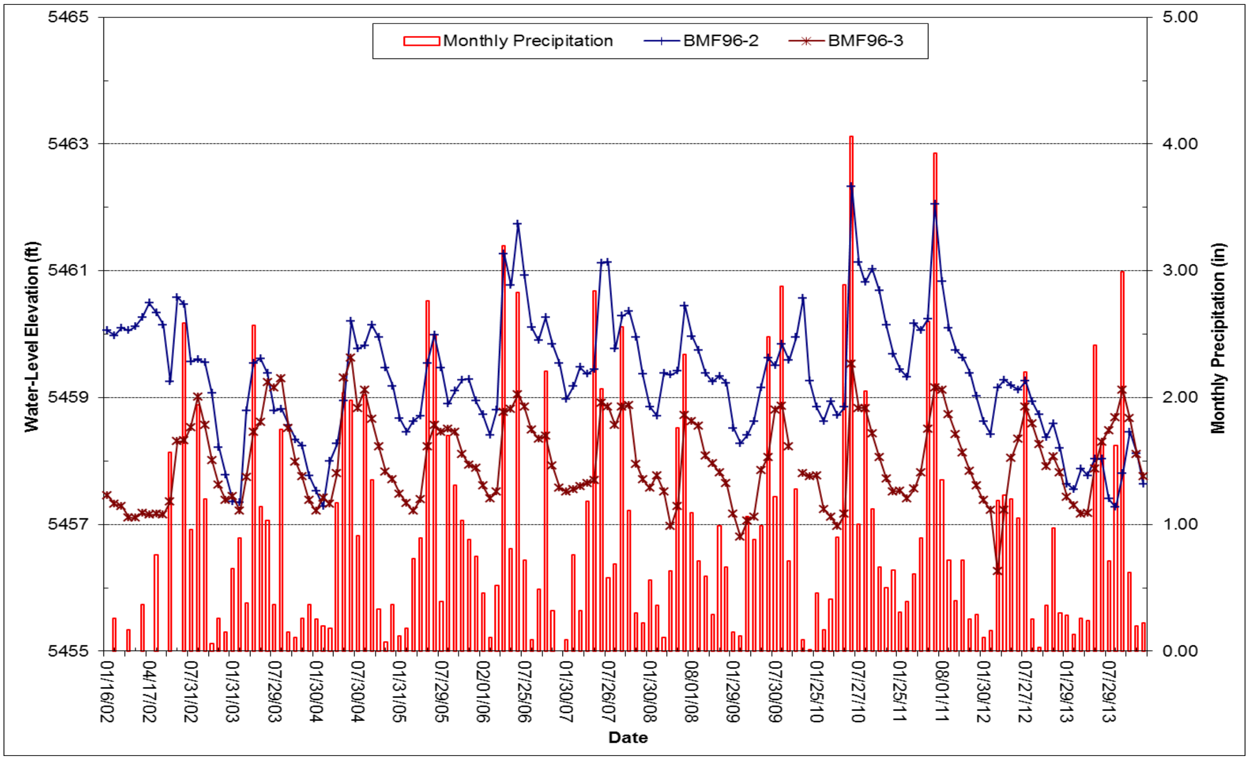


Figure 3-12. Water-level hydrographs for BMF96-series wells.

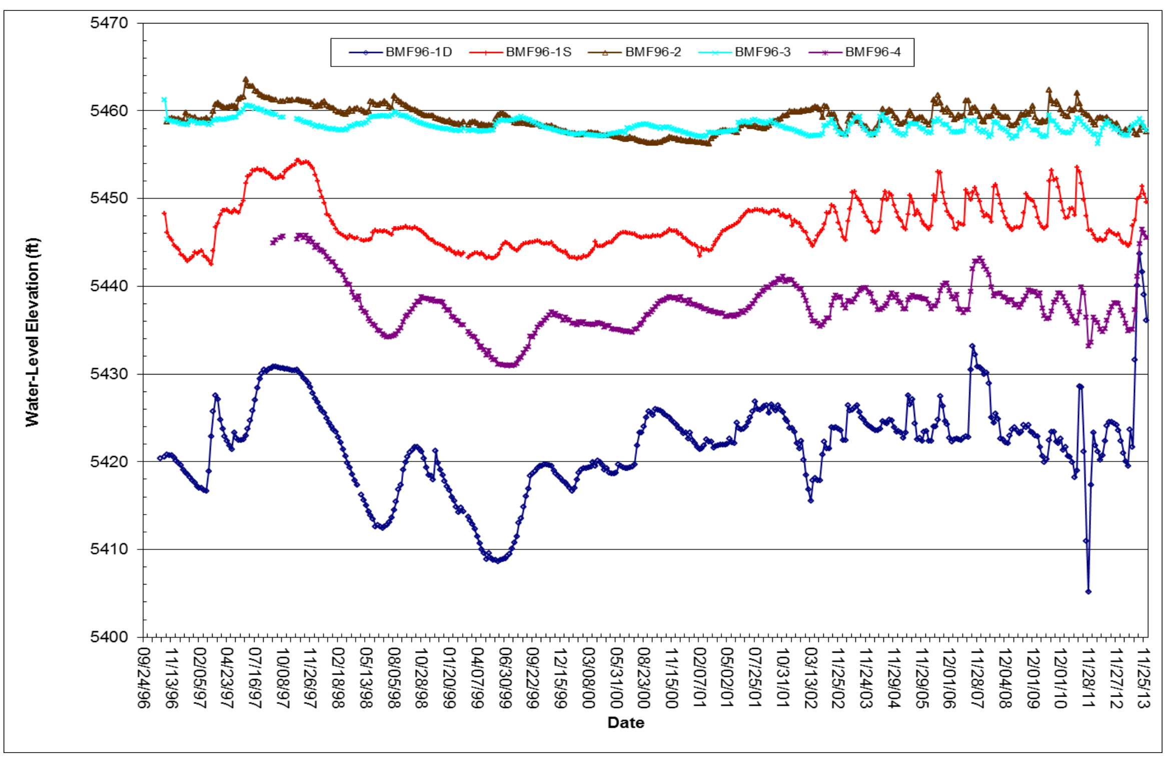


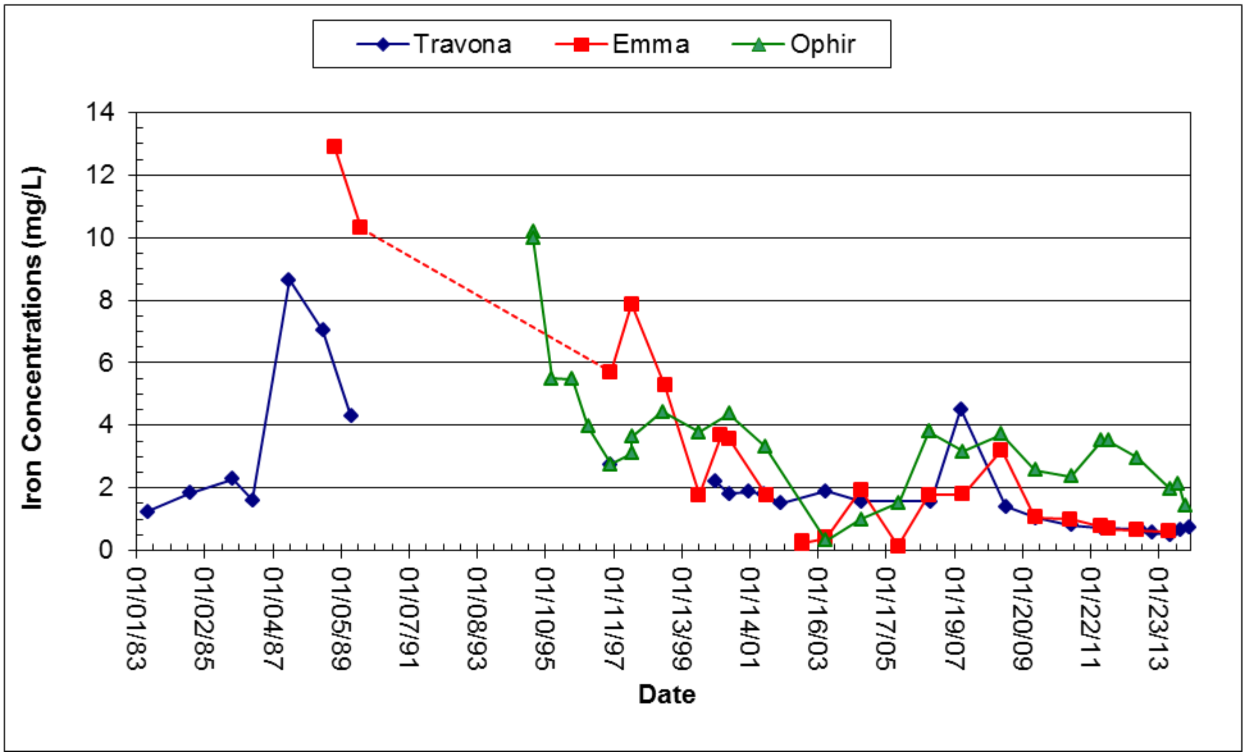
Figure 3-13. Water-level hydrographs for wells BMF96-2 and BMF96-3, 2002–2013.

Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

Water-quality data for the West Camp monitoring system in 2013 are again limited to well BMF96-04 and the three West Camp mines (Travona, Emma, and Ophir). These four sites were sampled during the spring sample event and during the West camp Study. Additional water-quality sampling was conducted as part of the West Camp Study with samples collected before, during, and after pumping changes from the BMF96-series wells, Travona Mine, and Ophir Mine. Results from this sampling were summarized in the Data Summary Report (MBMG, 2014) prepared as part of the study.

With the exception of arsenic (100 µg/L in the Travona Mine and about 15 µg/L in the Emma Mine), the concentrations of most dissolved constituents are similar in the West Camp mines (figs. 3-14 and 3-15). Zinc concentrations increased at the Ophir Mine during the 2013 West Camp Study; however, concentrations are below standards.

The concentrations of most dissolved metals in well BMF96-4 are low and continued to exhibit a slight downward trend, or remained stable, through 2013 (fig. 3-16). Concentrations of zinc showed some variation from 2003 to 2007; however, concentrations are well below the SMCL standard and have returned to pre-2003 levels. Arsenic concentrations continue to range between 3 and 7 µg/L.



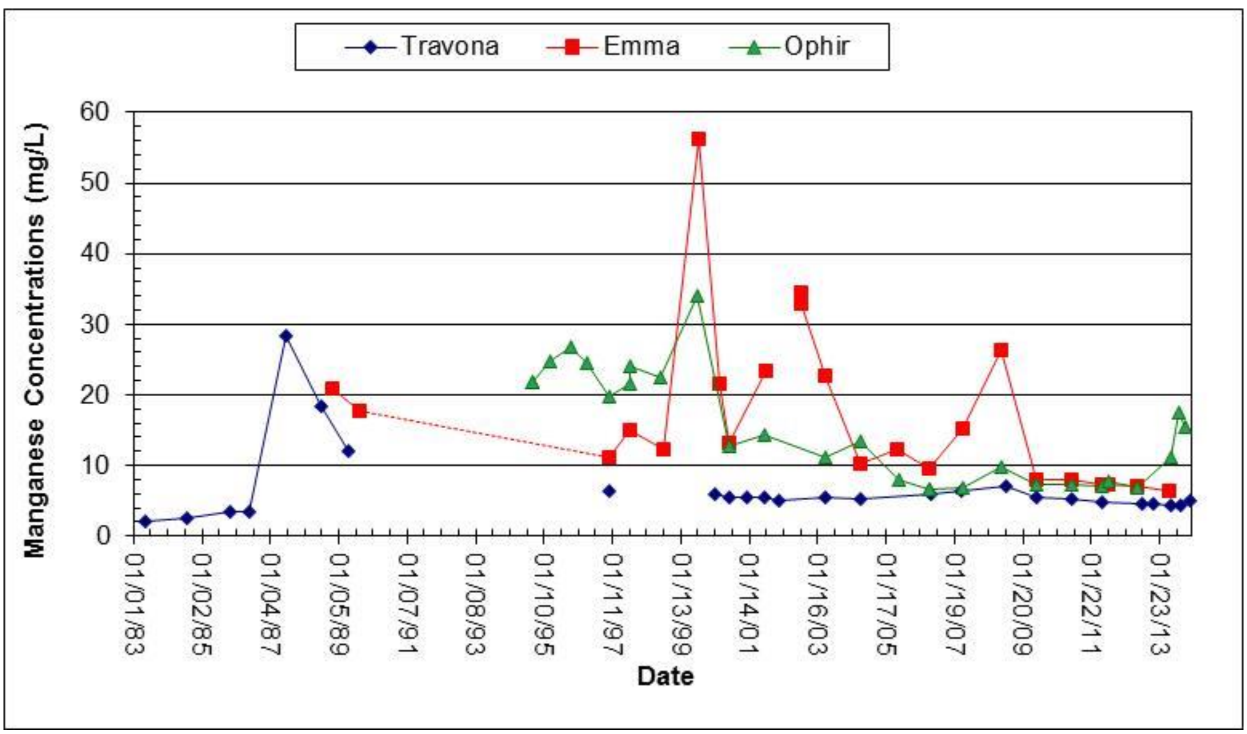
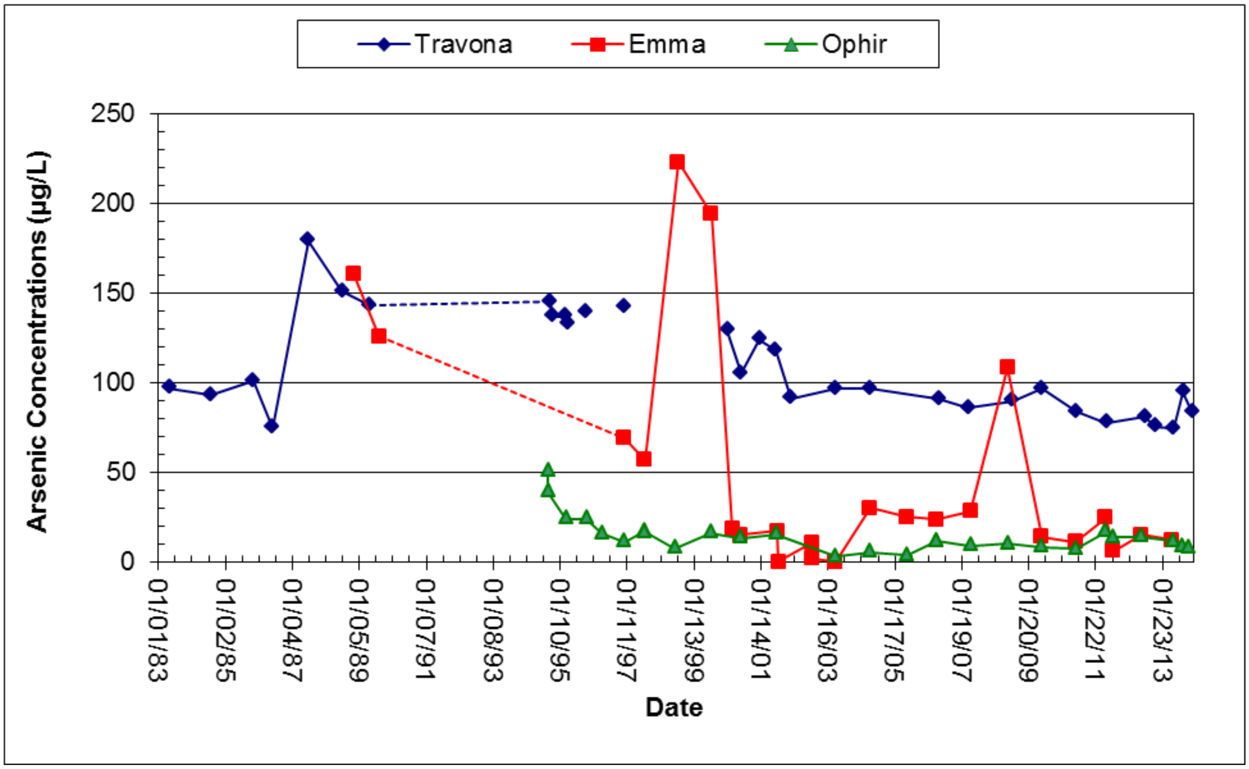


Figure 3-14. Iron and manganese concentrations in the West Camp mines.



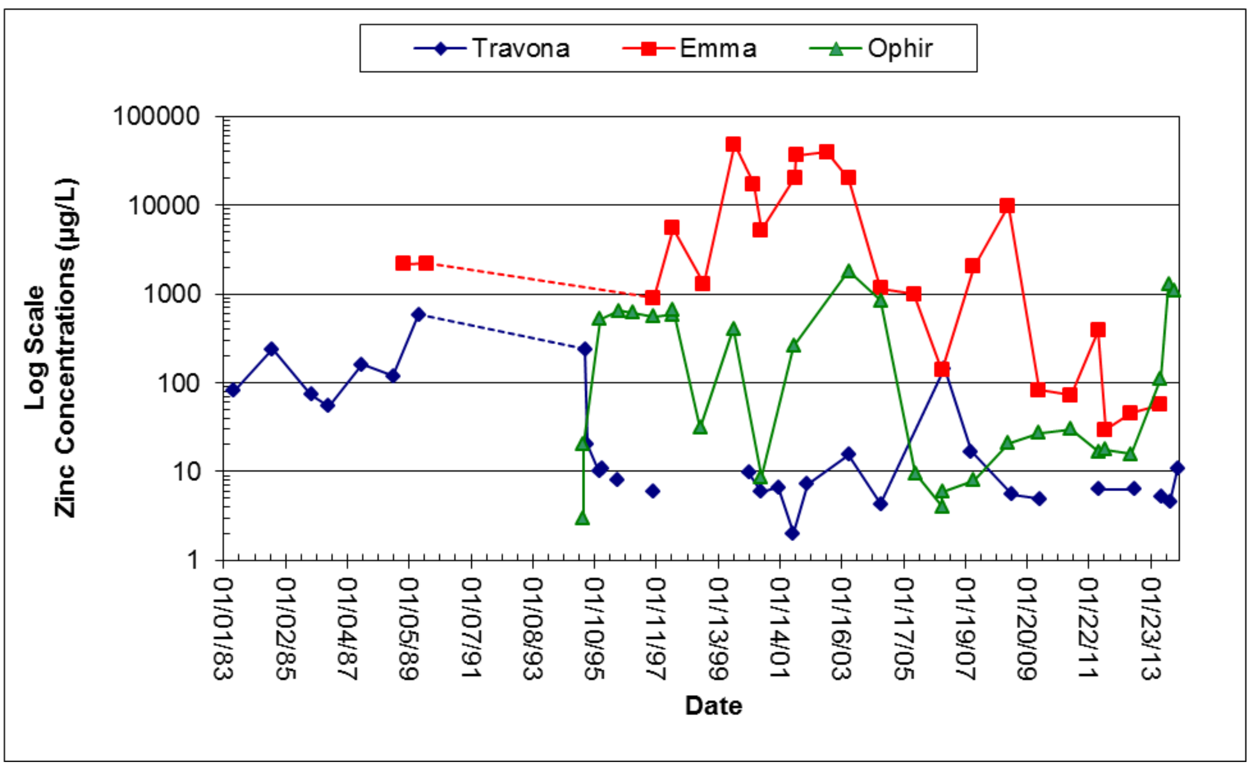
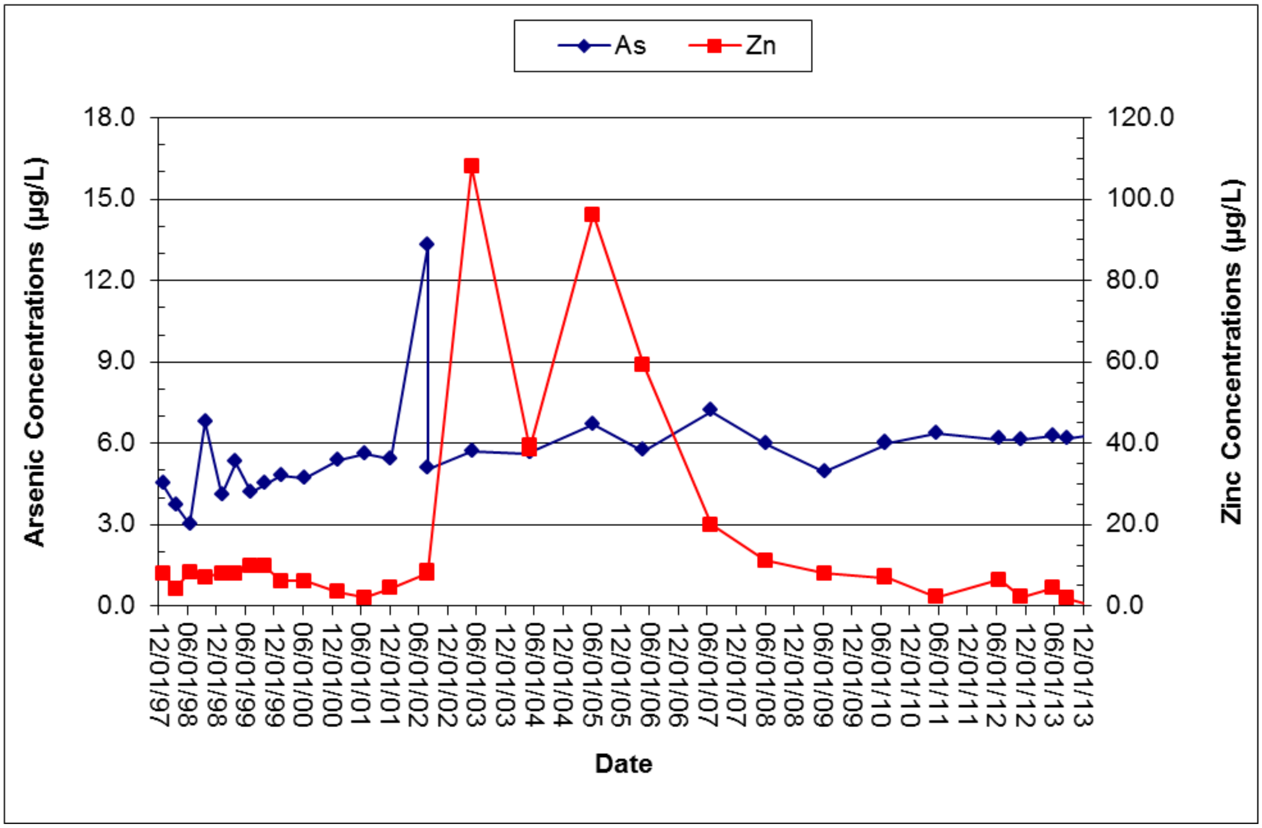


Figure 3-15. Arsenic and zinc concentrations in West Camp mines.



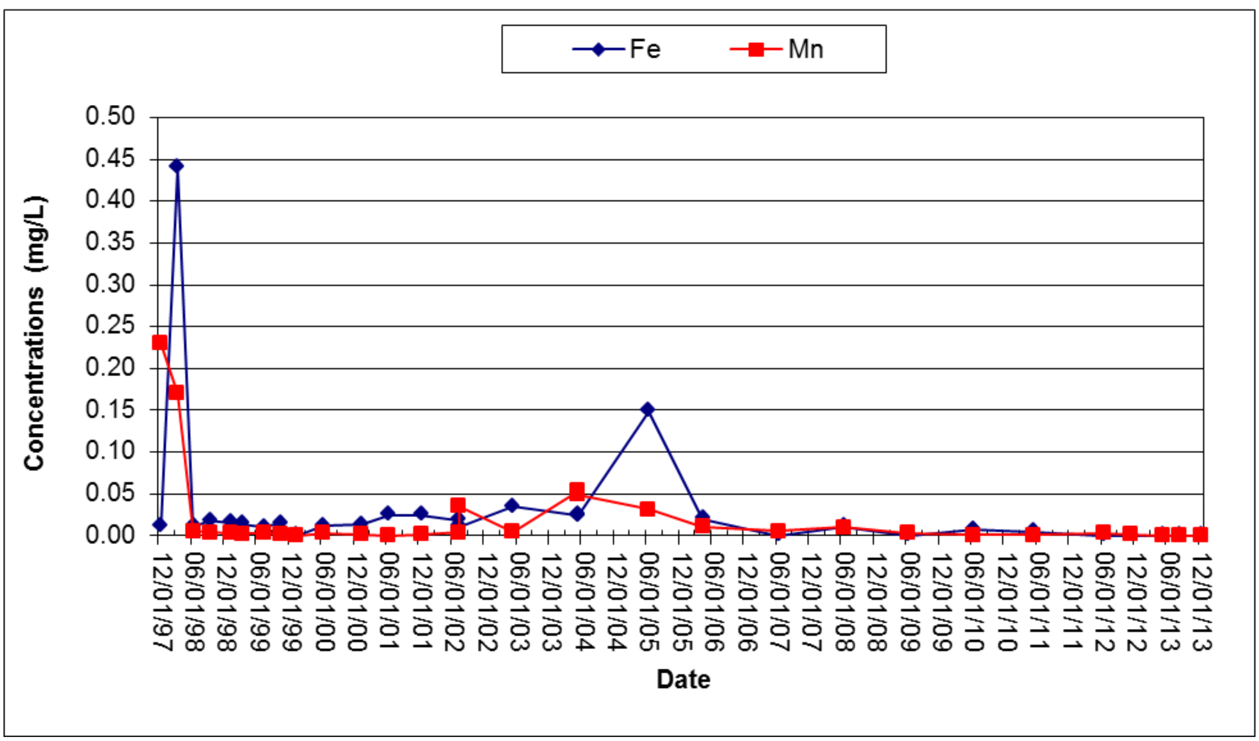


Figure 3-16. Selected water chemistry for West Camp well BMF96-4.

SECTION 4.0 OUTER CAMP SYSTEMS

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 was believed that water levels in the Outer Camp System were 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.

Section 4.1 Outer Camp System Water Levels

Outer Camp water levels rose in 2003 for the first time in 5 years; however, water levels declined in all but one site during 2004 and at all sites in 2005. This trend reversed itself in 2006 with water levels rising at all four locations, followed by increases in three of the four sites in 2007; the magnitude of the rise was much less than that seen in 2006. Water levels declined at three of the four Outer Camp sites for 2008 at levels similar to or greater than the 2007 increases. From 2009 to 2011, water levels have increased in at least three of the four sites; water levels decreased at all four sites in 2012–2013. Water-level changes in 2013 varied from a decline of 2.88 ft in the Montana Tech well to a decline of 4.98 ft in well S-4. Table 4.1.1 contains yearly water-level change data, while figure 4-2 shows these changes graphically.

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 from 2001 through 2004, rising in the spring and declining throughout the winter. However, the 2005 water-level rise was less than the previous 2 years, although precipitation amounts were higher. The 2006 water-level response was similar in the spring, with water levels beginning to rise in April; however, a corresponding decline in the fall did not occur. Instead, water levels continued to rise into the late fall–early winter before leveling off, rising again in the spring and summer of 2007, before leveling off once more during the late fall–early winter. Water levels in 2008 and 2009 showed more of a seasonal trend. Water levels began to rise in early 2010 and continued to rise through the remainder of the year and through the fall of 2011, before falling. Water-levels declined throughout all of 2012–2013, showing no seasonal trend in the Montana Tech well or the Orphan Boy Mine.

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

Table 4.1.1 Annual water-level changes for the Outer Camp sites (ft).

Year	Orphan Boy	Marget Ann	Well S-4	MT Tech Well
1987	2.40			
1988	2.14			
1989	3.83	-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
Change Years 1–10	**20.43**	**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
2004	NA	-2.18	-3.07	0.23
2005	-0.56	-3.01	-2.85	-1.97
2006	4.51	8.66	7.18	5.44
Change Years 11–20	**6.78**	**7.59**	**10.96**	**0.26**
2007	1.86	1.14	-0.32	1.85
2008	-1.05	0.56	-0.04	-1.68
2009	-0.27	1.09	0.60	0.99
2010	3.14	2.37	4.52	4.72
2011	5.64	7.86	12.08	4.28
2012	-5.77	-6.21	-7.66	-4.76
2013	-3.50	-3.91	-4.98	-2.88
Change Years 21–30	**0.05**	**2.90**	**4.20**	**2.52**
Total Change*	**27.26**	**33.10**	**25.78**	**10.66**

(Minus sign (-) indicates a decline (drop) in water level.)

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

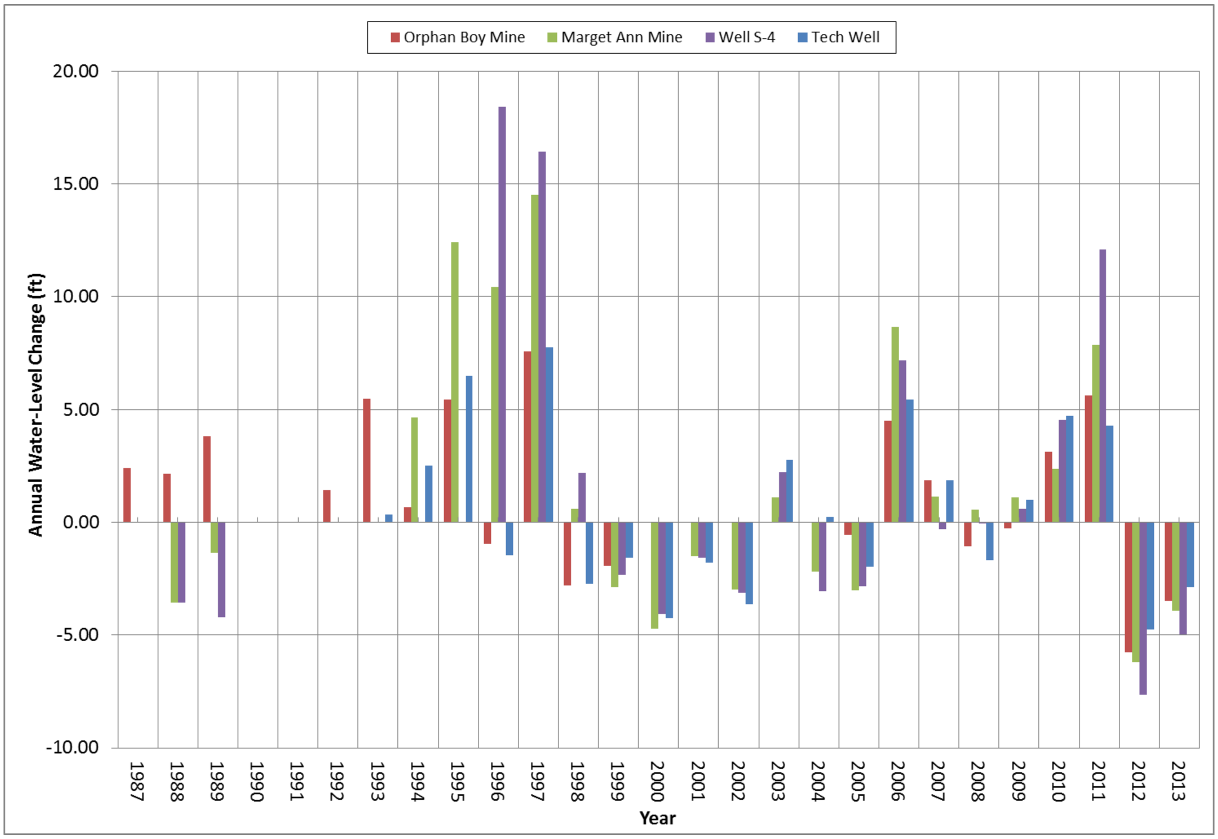

Figure 4-2. Outer Camp sites annual water-level change.

The water level in the Marget Ann Mine declined 3.91 ft during 2013, continuing the 2012 trend; this is a change following 6 years of water-level increases. The water level in well S-4 decreased by 4.98 ft during 2013, also continuing the 2012 downward trend seen in the Marget Ann Mine, following 3 years of increased water levels. 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 water levels continued to rise regardless of precipitation trends the remainder of the year. During 2004 and 2005, water levels declined steadily throughout the year regardless of precipitation events. This trend reversed itself in 2006 and continued throughout 2010 with water levels rising in the spring (April), before leveling off and declining in the late fall–early winter. Water levels began to rise in early spring and continued throughout late summer 2011, before falling. This decline continued throughout all of

2013. The 2011 water-level rise in both sites was the largest increase seen during the period of monitoring. Considerable precipitation occurred in May and June 2011, which may account for the large increases in water levels at these two sites. This is the same trend observed in the Montana Tech well and Orphan Boy Mine.

Water levels in all four of the Outer Camp sites have a net increase since monitoring began. The increases vary from over 10 ft at the Montana Tech well to over 33 ft in the Marget Ann Mine.

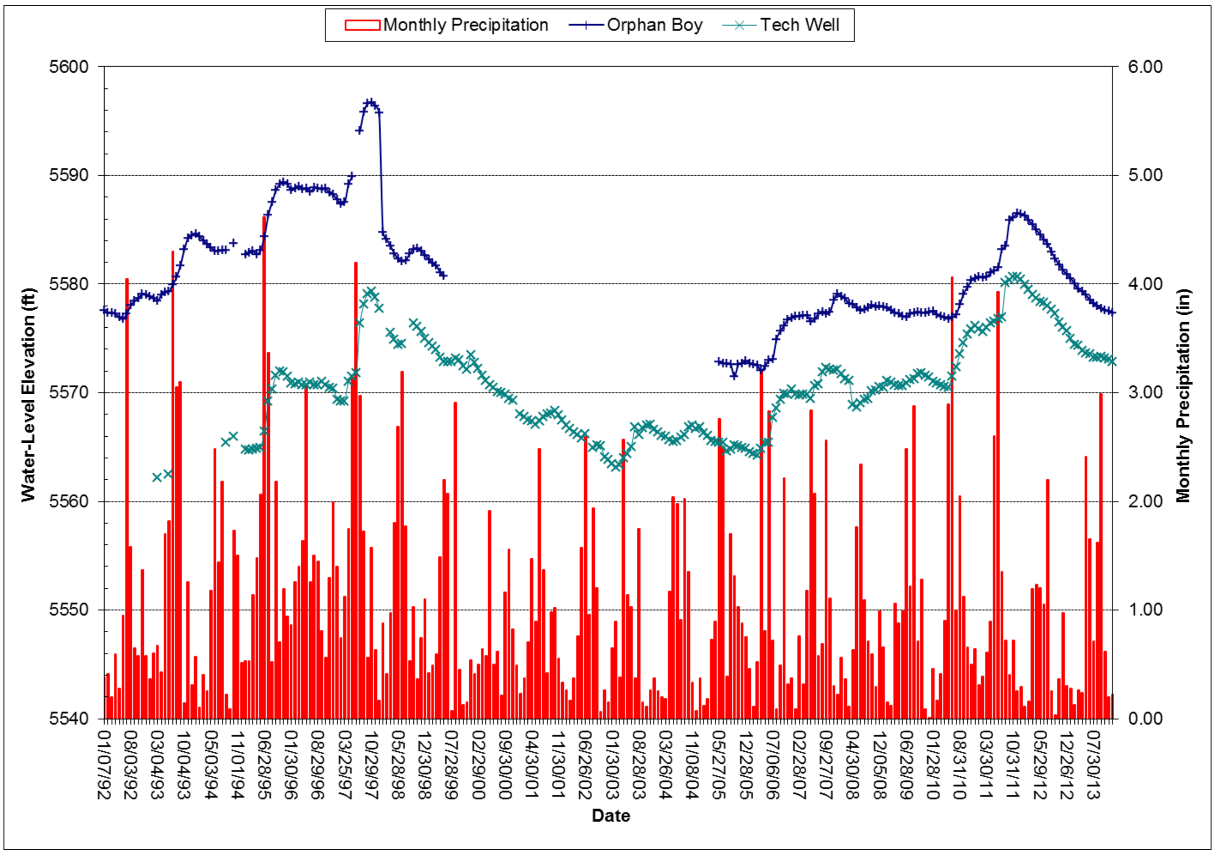

Figure 4-3. Water-level hydrograph for the Orphan Boy Mine and Montana Tech well.

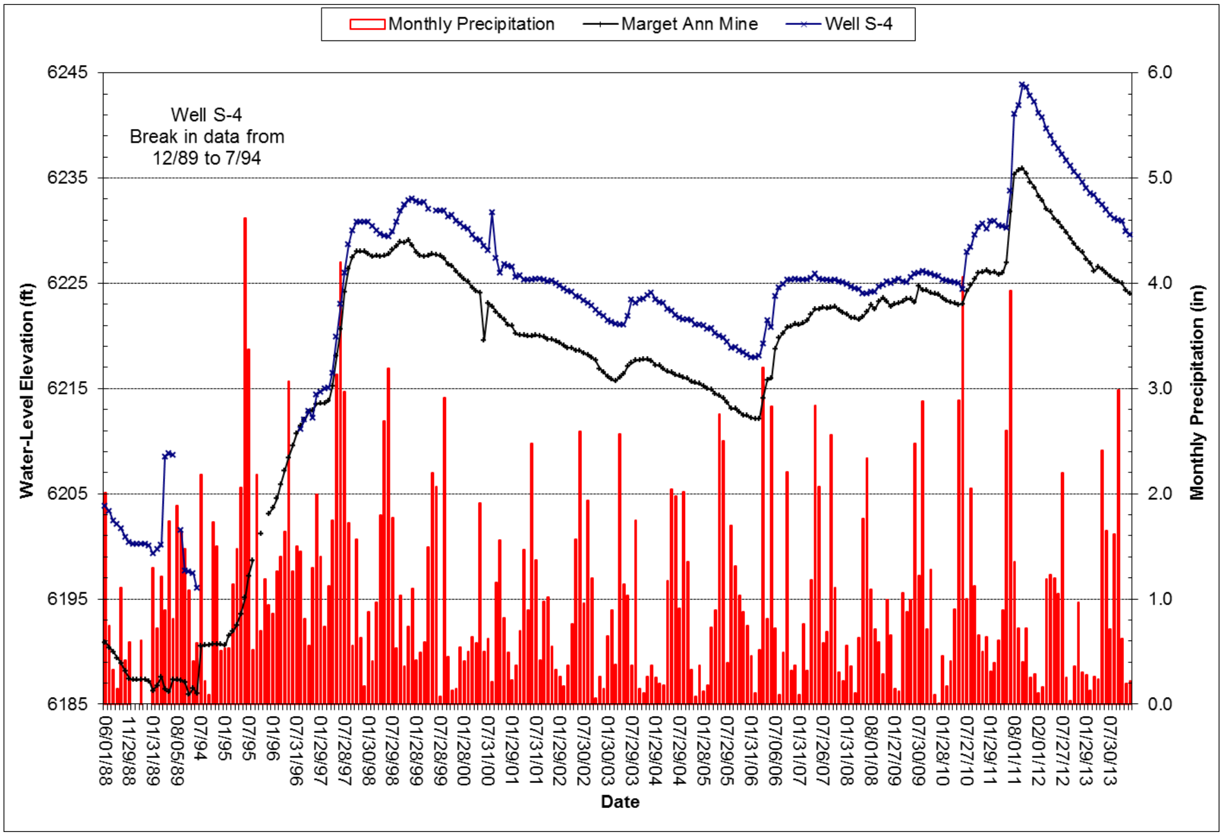

Figure 4-4. Water-level hydrograph for the Marget Ann Mine and well S-4.

Section 4.2 Outer Camp Water Quality

Water-quality samples were collected from all four locations within the Outer Camp System during 2013 (the Marget Ann Mine and Montana Tech well are sampled every other year). The Orphan Boy Mine and Green Lake seep were sampled twice, during both the spring and fall sample events. Figures 4-5 and 4-6 show selected water chemistry for the Orphan Boy Mine. Water-quality trends have been downward or unchanged for the most part, with the exception being zinc, which increased from 2005 to 2010; concentrations varied during 2011–2013. These increases coincide with a change in sampling procedures at this site. The 1987–1998 samples were collected by bailing a sample from the shaft; samples collected since 2005 were obtained by installing a pump into the shaft and pumping for an hour, or more, prior to sampling. It is possible that the change in sampling technique is responsible for the apparent water-quality changes.

Water quality in the Outer Camp is of better quality than that of either the East Camp or West Camp bedrock systems. This is most likely a combination of different geology and equilibrium being reached as a result of the workings in this area being flooded for a longer period of time.

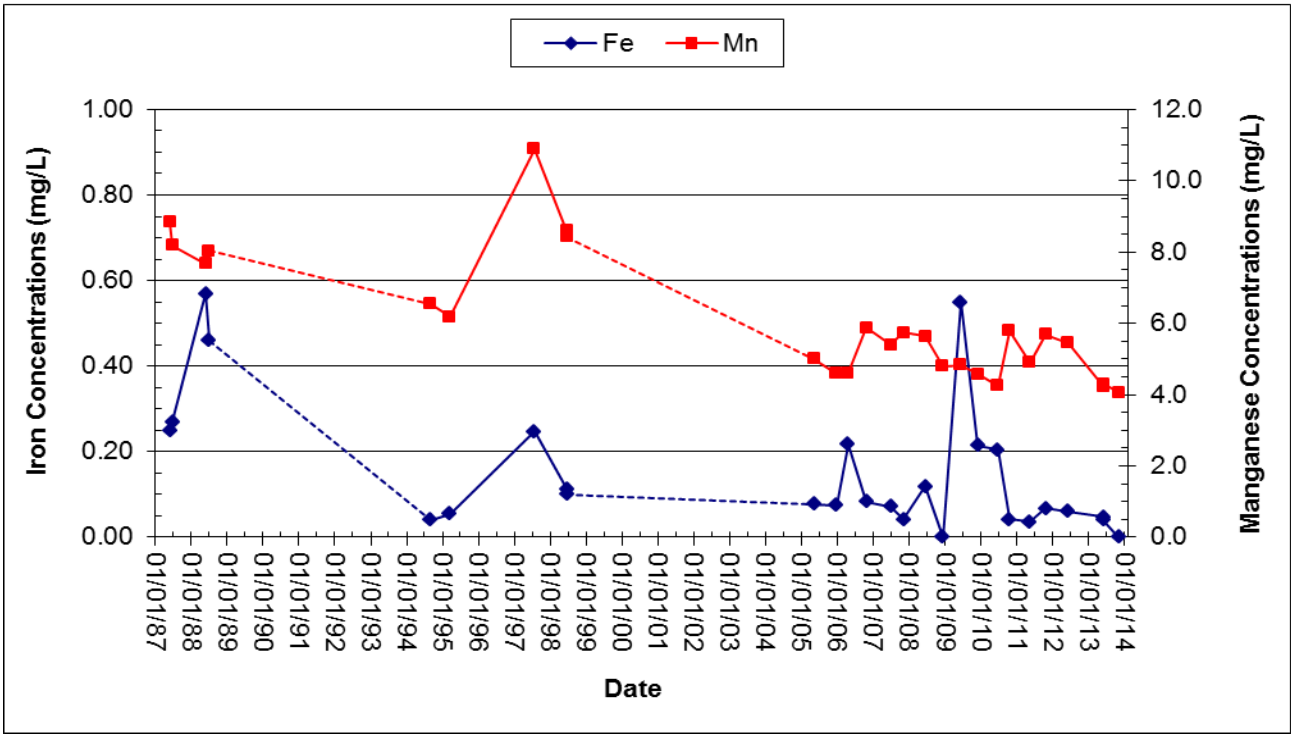

Figure 4-5. Iron and manganese concentrations for the Orphan Boy Mine.

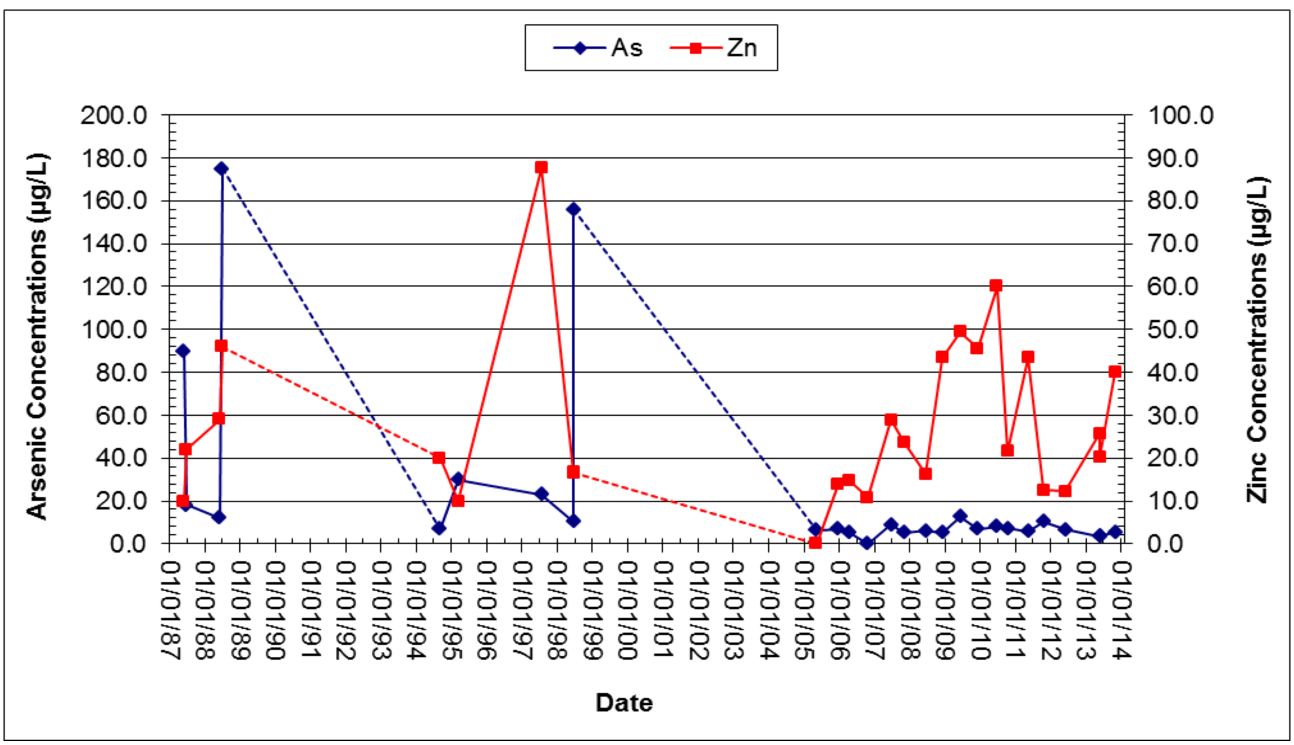

Figure 4-6. Arsenic and zinc concentrations for the Orphan Boy Mine.

SECTION 5.0 PARK WELLS

The locations of the Park monitoring wells are shown in figure 5-1. The Hebgen Park, Belmont Well #1, and Parrot Park wells are bedrock wells and are part of the monitoring program specified in the 2002 CD. All three wells are located at parks within the East Camp System.

Section 5.1 Park Wells Water Levels

Annual water-level changes are listed in table 5.1.1 and shown in figure 5-2. The yearly water-level changes in Belmont Well #1 since 1997 have been much greater than those seen in the other two wells, with several exceptions when changes in the Parrot Park well have been greater. Regardless of whether the change is a rise or fall in water levels, the magnitude of the change is typically much greater in this well; water-level changes have varied anywhere from 10 to 75 ft in a year. Since monitoring began at these sites, water levels have risen between 0.3 ft and 10 ft in the Hebgen and Parrot Park wells, while falling more than 4.7 ft in Belmont Well #1.

Table 5.1.1 Annual water-level change for miscellaneous wells (ft).

Year	Hebgen(1)	Parrot	Belmont Well #1	Year	Hebgen(1)	Parrot	Belmont Well #1
1983				1993	6.27	1.39	
1984				1994	-0.25	5.96	
1985				1995	NA	2.67	
1986				1996	2.75	-1.50	-0.74
1987				1997	4.22	4.75	15.05
1988	1.54	1.43		1998	-0.62	-0.33	-15.13
1989	-2.18	0.42		1999	-2.93	-5.34	14.80
1990	-1.90	5.23		2000	-6.07	1.50	-8.11
1991	3.09	-6.10		2001	0.37	5.47	-0.41
1992	-1.40	0.63		2002	-0.41	-3.27	-24.08
Change Years 1–10	**-0.85**	**1.61**	**---**	**Change Years 11–20**	**3.33**	**11.30**	**-18.62**

(Minus sign (-) indicates a decline (drop) in water level.)

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Figure 5-1. East Camp Park monitoring wells location map.

Table 5.1.1 Annual water-level change for miscellaneous wells (ft) (cont.)

Year	Hebgen(1)	Parrot	Belmont Well #1	Year	Hebgen(1)	Parrot	Belmont Well #1
2003	1.25	3.52	-54.19	2013	**-0.24**	**2.94**	**6.05**
2004	-0.12	-1.12	-39.79	2014			
2005	-2.19	6.76	-5.01	2015			
2006	2.86	6.95	35.07	2016			
2007	1.40	2.44	-12.15	2017			
2008	-0.98	11.20	-9.45	2018			
2009	0.12	-26.99	9.83	2019			
2010	-0.05	-7.59	73.75	2020			
2011	-0.82	2.10	18.17	2021			
2012	-3.32	-3.28	-8.45	2022			
Change Years 21–30	**-1.85**	**-6.01**	**7.78**	**Change Years 31–40**	**-0.24**	**2.94**	**6.05**
Net Change* Years 1–31	**0.39**	**9.84**	**-4.79**				

(Minus sign (-) indicates a decline (drop) in water level.)

(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.

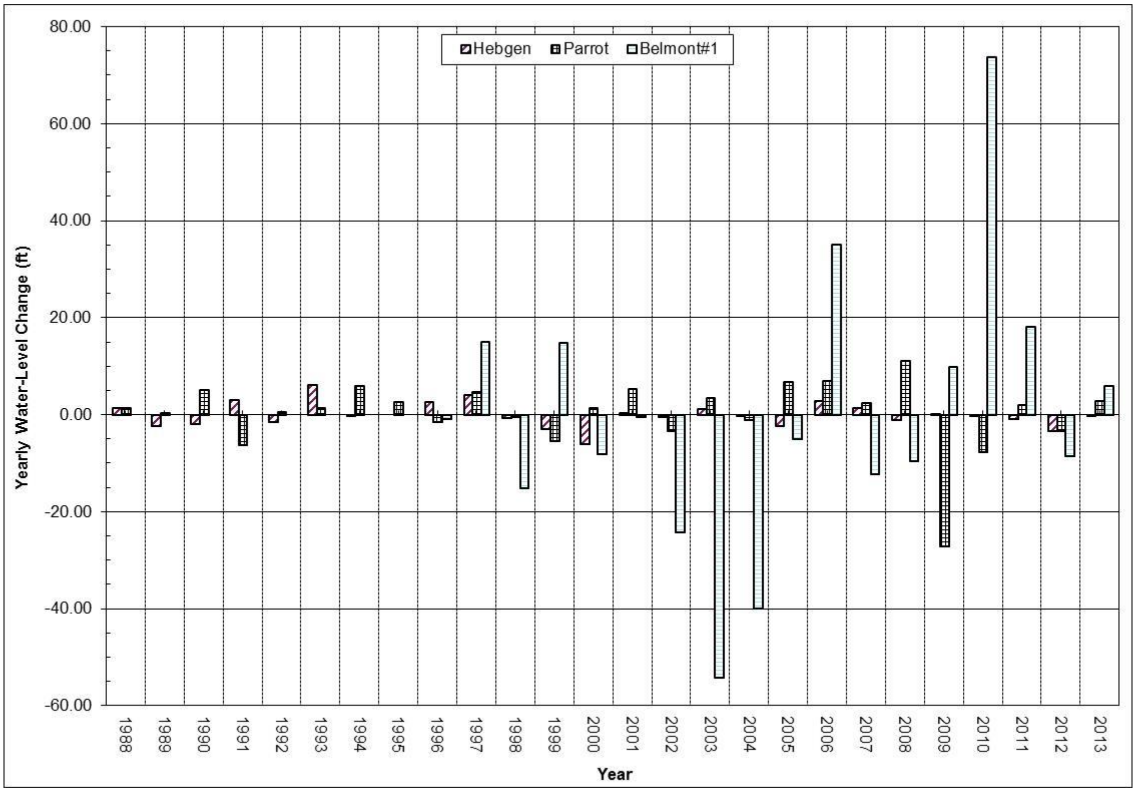

Figure 5-2. Park wells annual water-level changes.

Water-level responses during 2013 at the Hebgen Park well (fig. 5-3) were similar to those seen in prior years. Water levels began to rise during the late spring and continue through the fall, which coincides with both summer precipitation and lawn watering of the park grass. Precipitation, or the lack thereof, 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 a portion of the seasonal increase in water level is due to lawn watering in addition to precipitation. The water level in this well decreased 0.24 ft during 2013; since monitoring began at this site, water levels have increased 0.39 ft.

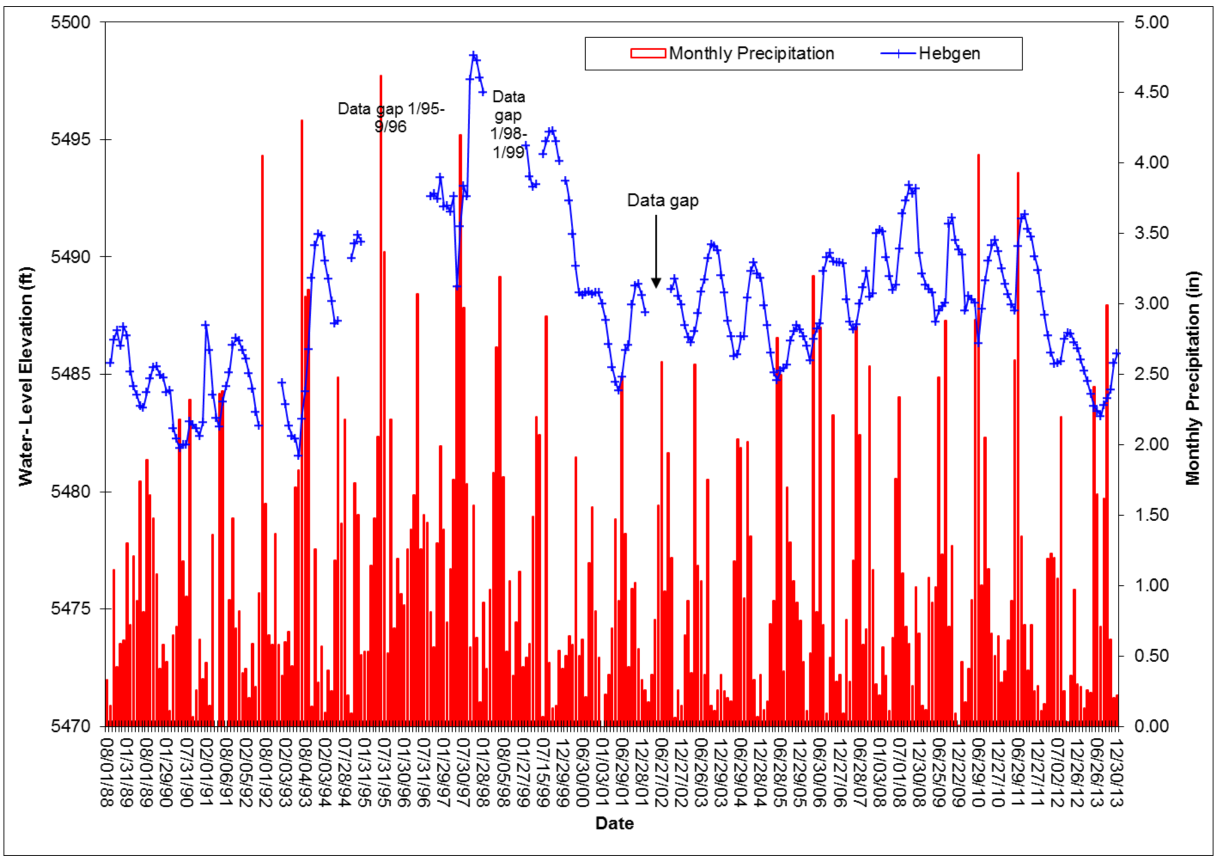

Figure 5-3. Water-level hydrograph for the Hebgen Park well.

The water-level hydrograph for the Parrot Park well is shown in figure 5-4, along with monthly precipitation totals. Water levels declined during most of 2002 before leveling off and rising during December 2002. The 2003 water levels and trends were similar to those of 2000 and 2001; however, 2004 water levels did not show the same level of response to precipitation. Water levels declined the first half of 2004; water levels had a mostly steady increase the remainder of 2004 through May 2009. Beginning in June 2009, water levels began to fall and continued downward throughout the remainder of the year, declining by almost 27 ft for the year. Water levels continued to decline through July 2010 before rising slightly and then declining in December; the 2010 water-level decline was over 7.5 ft The 2011–2013 water levels had more of a seasonal trend. The water level at this site has risen almost 10 ft since monitoring began in 1988.

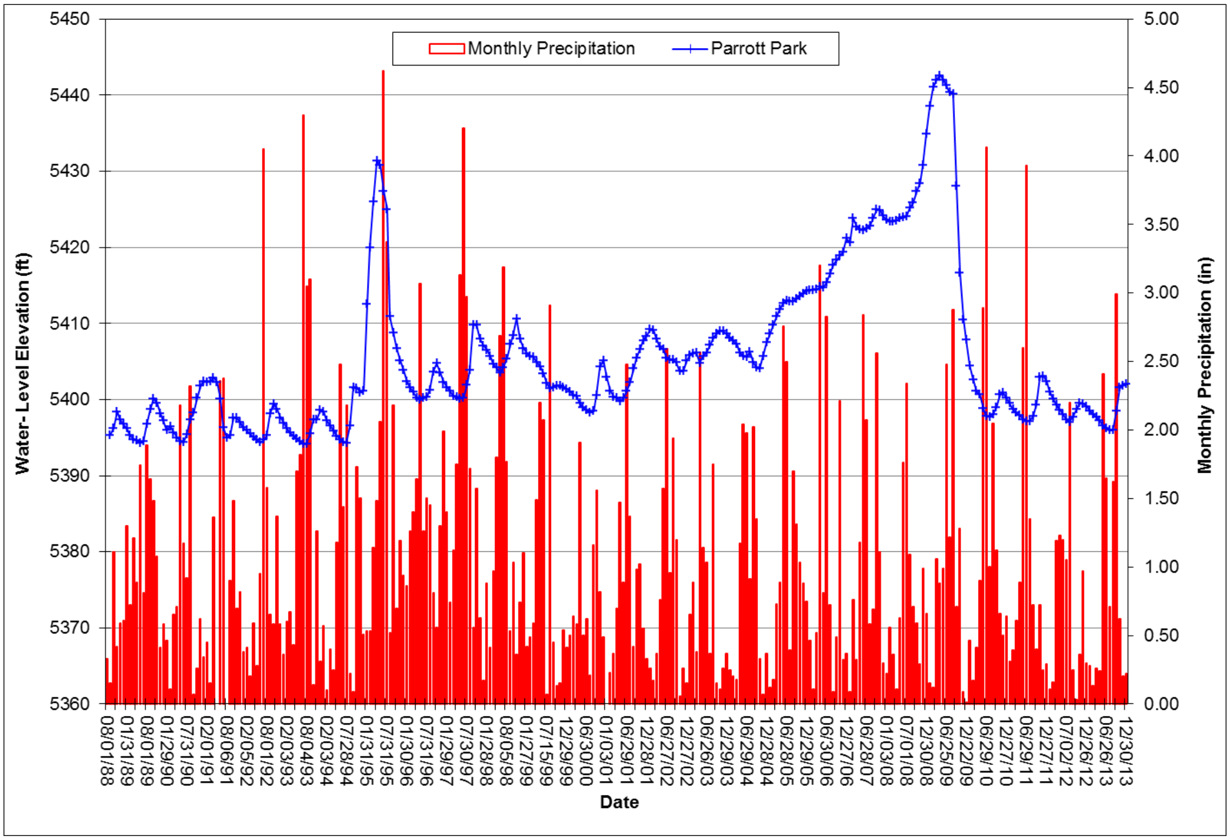

Figure 5-4. Water-level hydrograph for Parrot Park well.

Figure 5-5 is a water-level hydrograph, which shows the recent water-level trends for both the Parrott and Hebgen Park wells. The water-level trend increase seen in the Parrot well from 2004 through 2008 was not seen in the Hebgen well, nor was the decline that began the middle of 2009 and continued into the middle of 2010. Water levels had more of a seasonal trend during 2010–2013. The Hebgen Park well appears to respond more consistently with seasonal conditions (snowmelt, precipitation, and lawn irrigation), while the Parrot Park well water-level variations are not as consistent and do not follow seasonal changes.

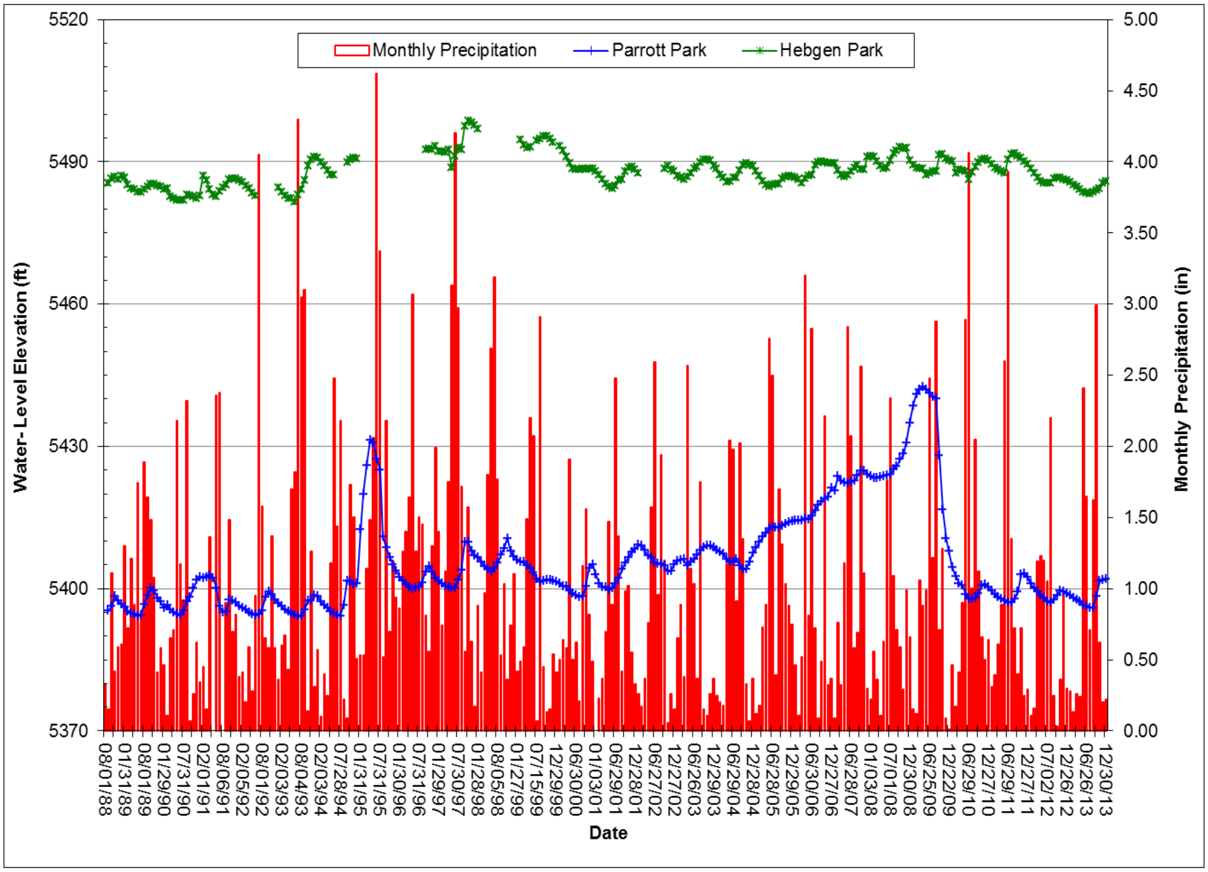

Figure 5-5. Water-level hydrographs for Parrot Park and Hebgen Park wells.

Belmont Well #1 was originally drilled as a replacement well for monitoring the water level in the Belmont Mine. However, during well completion a collapse in the borehole prevented the casing from being installed to the proper depth. Instead of abandoning this well after a new replacement well was drilled, it was kept as a monitoring site since its water level differed from that of the deeper bedrock (mine) system. Water-level changes in this well differ from those seen in any other bedrock well. From 2002 through 2005 water levels declined more than 120 ft, before rising 35 ft in 2006; water levels declined over 12 ft in 2007 and 9 ft in 2008, while rising almost 10 ft in 2009, over 73 ft in 2010, and more than 18 ft in 2011; 2012 water levels decreased more than 8 ft Water levels increased over 6 ft in 2013, continuing a pattern of variability. The water-level changes between 2003 and 2009 initially appeared to show a response to precipitation and/or lawn irrigation, when water levels and precipitation are compared (fig. 5-6); however, when a closer look is taken of the graph, the seasonal water-level increases are 10 to 20 ft or more. This well has been equipped with a pressure transducer to record more frequent water-level changes since 2003.

Figure 5-7 is a hydrograph for this well from the fall of 2003 through 2013, showing daily average water levels. The seasonal water-level changes are more pronounced in this figure, allowing a closer examination of the periods of change. The magnitude of the seasonal rise is greater than would be expected from both precipitation and lawn irrigation even in a bedrock system with low porosity. Since this well's borehole was drilled into the underground mine workings and then collapsed, it is difficult to ascertain what the actual controls on water-level changes are. However, it is important to realize that perched water zones exist in the bedrock system adjacent to the underground mine bedrock system. The water level in this well is 150 ft or more above the water level in the underground mines in this area.

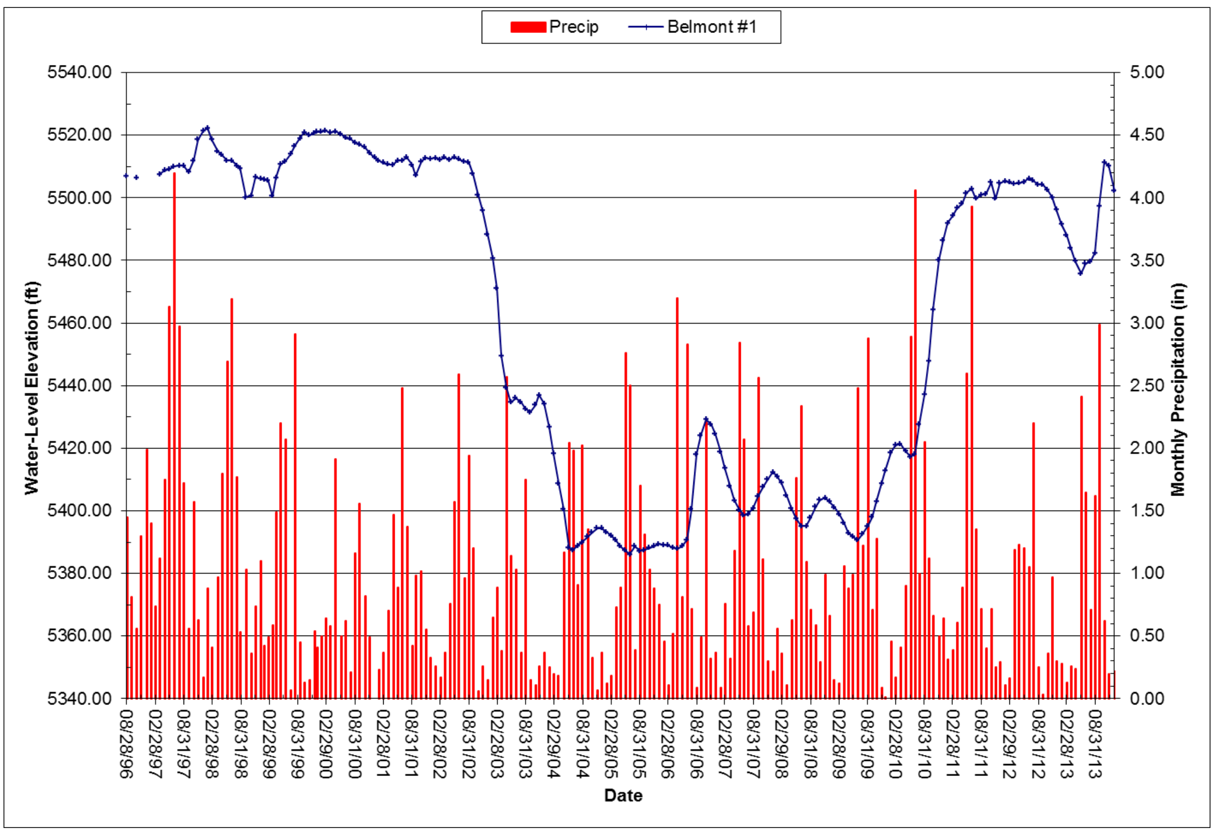

Figure 5-6. Water-level hydrograph for Belmont Well #1.

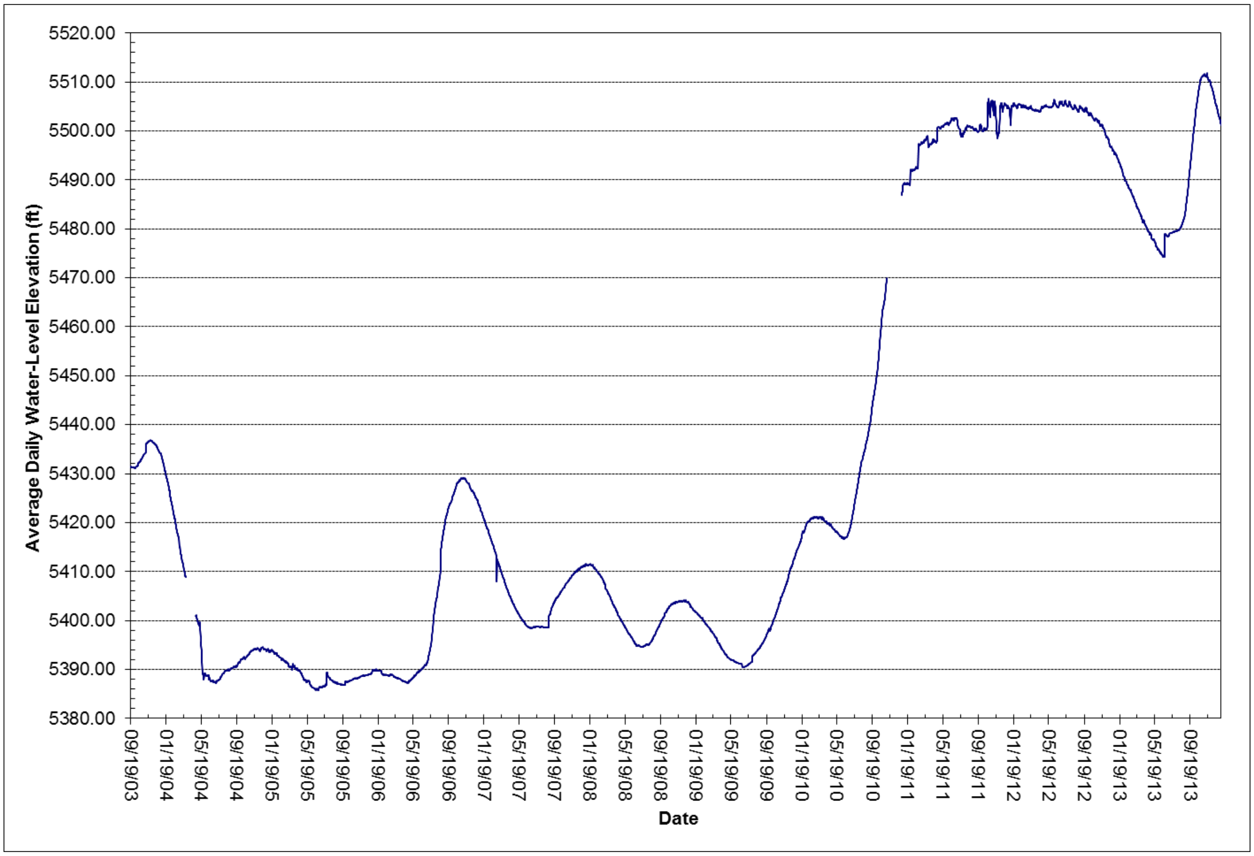

Figure 5-7. Belmont Well #1 Hydrograph showing average daily water-level elevations.

Section 5.2 Park Wells Water Quality

Water-quality samples were collected only from the Parrot Park well during 2013. Figure 5-8 shows concentration trends for cadmium and copper over time for this site, while figure 5-9 shows arsenic and zinc concentrations over time. Arsenic and cadmium concentrations exceed the MCL. Cadmium concentrations declined in 2008 to levels below the MCL, while sample results in 2009–2013 were well above the MCL. Concentrations increased for copper and zinc while remaining similar for cadmium and declining slightly for arsenic in 2013 (figs. 5-8 and 5-9).

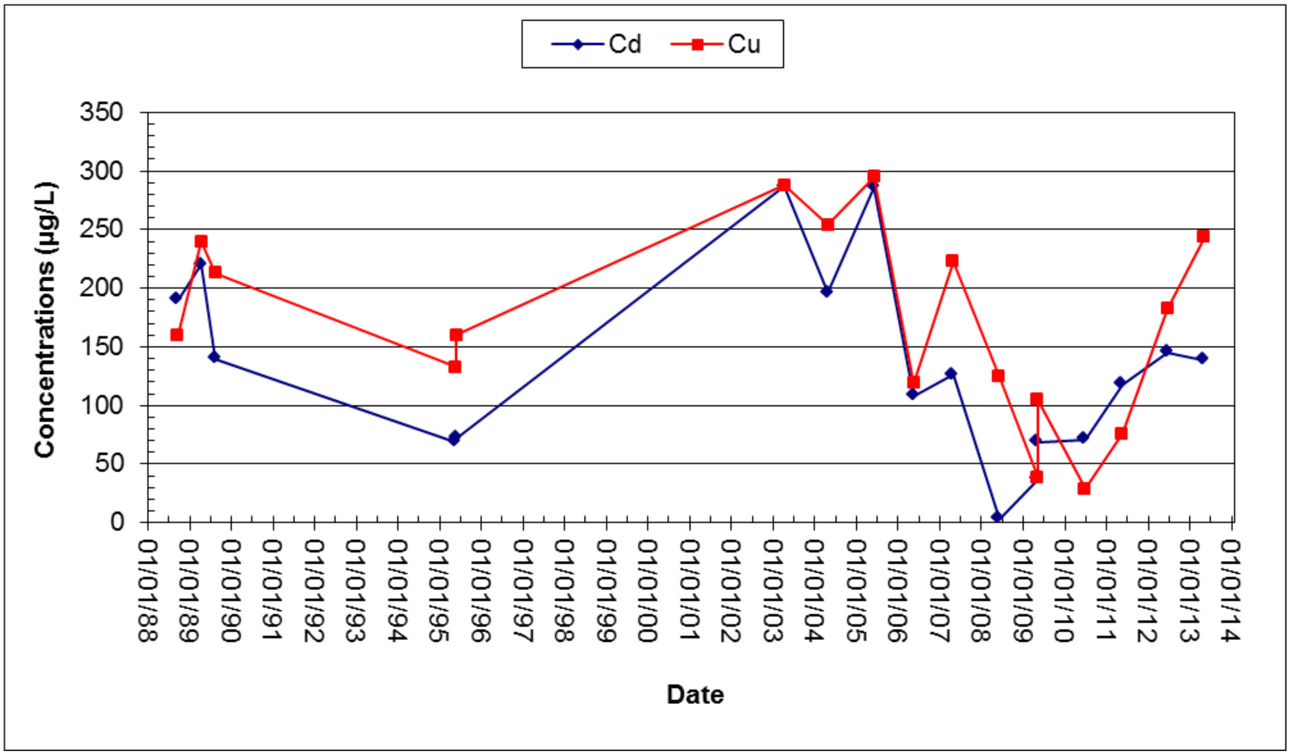

Figure 5-8. Cadmium and copper concentrations for the Parrot Park well.

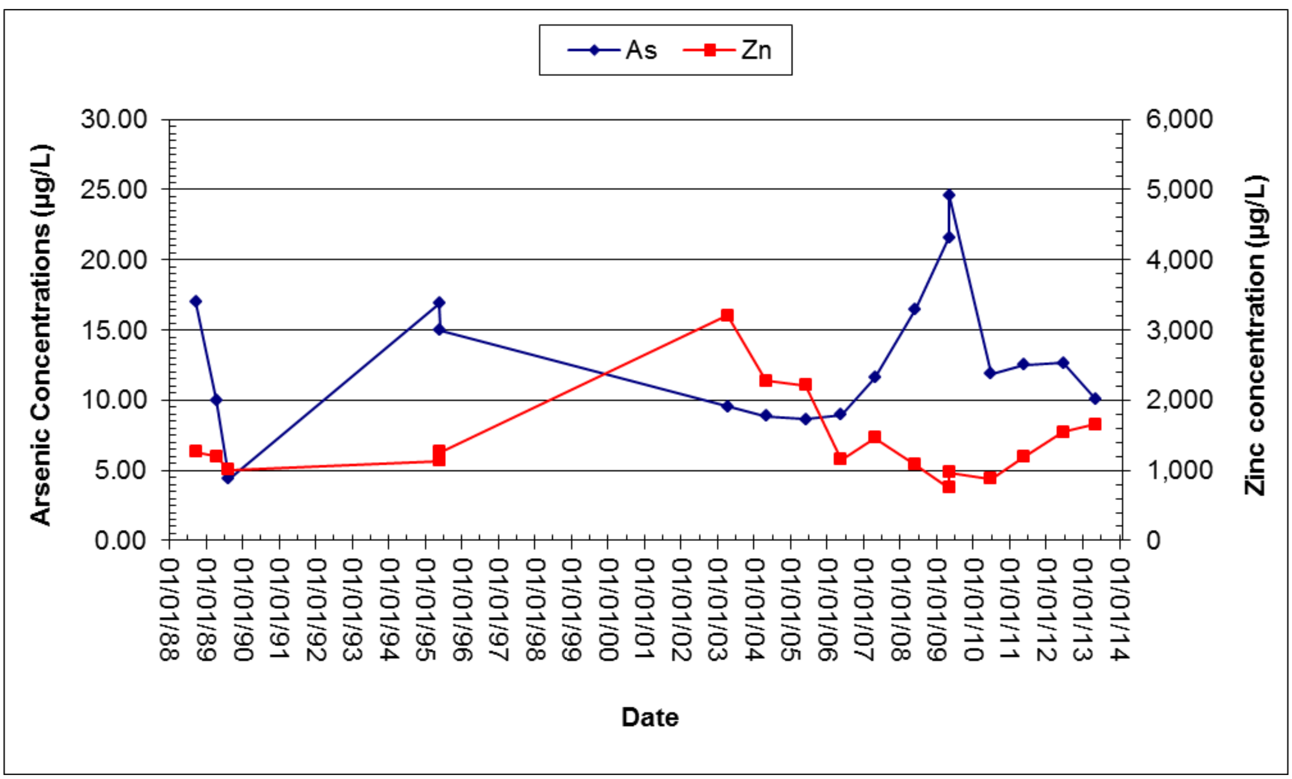

Figure 5-9. Arsenic and zinc concentrations for the Parrot Park well.

SECTION 6.0 Butte Alluvial and Bedrock Controlled Groundwater Area

The Butte Alluvial and Bedrock Controlled Groundwater Area (BABCGWA) was established by the Water Resources Division of the Montana Department of Natural Resources and Conservation (DNRC) in October, 2009. This area was designated as a controlled groundwater area because the alluvial and bedrock aquifers have been impacted by over a century of mining and associated activities. The restrictions in the BABCGWA were established to meet the requirements of the ROD or CD for the BMFOU, Butte Priority Soils Operable Unit (BPSOU), and Montana Pole and Treatment Plant NPL Site (MPTP), ensuring that contaminants associated with historic mining activities are not present in harmful concentrations in groundwater supplies.

The outer perimeter of the BABCGWA is shown in figure 6-1, with major historic mines and landmarks included for reference. The boundaries of the Old Butte Landfill and Clark Tailings areas are also shown near the southern edge of the map. The alluvial portion of the BABCGWA covers 8.11 square miles, with maximum vertical depths of over 300 ft in the northeast, thinning to less than 10 ft at the western edge. The bedrock portion of the area has a maximum vertical depth of approximately 1500 ft above MSL (all from Final Order, DNRC, 2009).

In the Final Order from the DNRC, the following conditions were placed on existing water wells and potential future usage:

- New groundwater wells will only be allowed within the BABCGWA after review and approval from the Butte–Silver Bow (BSB) Board of Health, the EPA and DEQ. Environmental monitoring/treatment wells are allowed within the BABCGWA, providing they are in compliance with applicable statutory criteria.
- An existing well for irrigation or industrial use may be replaced at the well owner's expense, but only if the replacement well has been shown not to be detrimental to the environment or to human health, and complies with applicable statutory requirements.
- All existing wells that are used as a drinking water supply for human consumption must meet the human health standards established by DEQ-7 for five contaminants of concern (COC): arsenic, lead, cadmium, copper, and zinc. If any of these health standards are exceeded during a sampling event, the well will be re-tested for verification. If this second sampling event yields results that exceed any of the COC standards, the well will cease being used for such purposes.

Section 6.1 Sampling Activities in 2013

Based upon site requests from the BSB Health Department, the MBMG collected groundwater samples from nine privately owned wells during 2013. General information about each well is found below, in table 6.1.1. The locations of these sites are shown in figure 6-2, and with the exception of one site, all of the wells are located within the BABCGWA. No sample was collected from the White-Shop Well this year due to access problems.

Table 6.1.1 General site information for the domestic wells sampled in 2013 for BABCGWA. The elevation, depth, and static water level (SWL) data are listed in feet (USGS datum).

GWIC ID	SITE NAME	LAT	LONG	ELEVATION	DEPTH	SWL
174040	BOWLER	45.99673	-112.55196	5450	32	11.67
269353	MILLER	45.99727	-112.55403	5450	25	16.86
50357	RAWLINS	46.00867	-112.55859	5660	250	N/A
4819	REYNOLDS	46.00623	-112.53776	5505	200	N/A
156158	WEST	45.98796	-112.53646	5480	44	N/A
171277	WHITE-EAST	45.98196	-112.54639	5500	300	N/A
171276	WHITE-HOUSE	45.98103	-112.54904	5520	160	N/A
171278	WHITE-SHOP	45.98103	-112.54639	5515	160	N/A
255690	WHITE-WEST	45.98206	-112.54939	5520	N/A	N/A

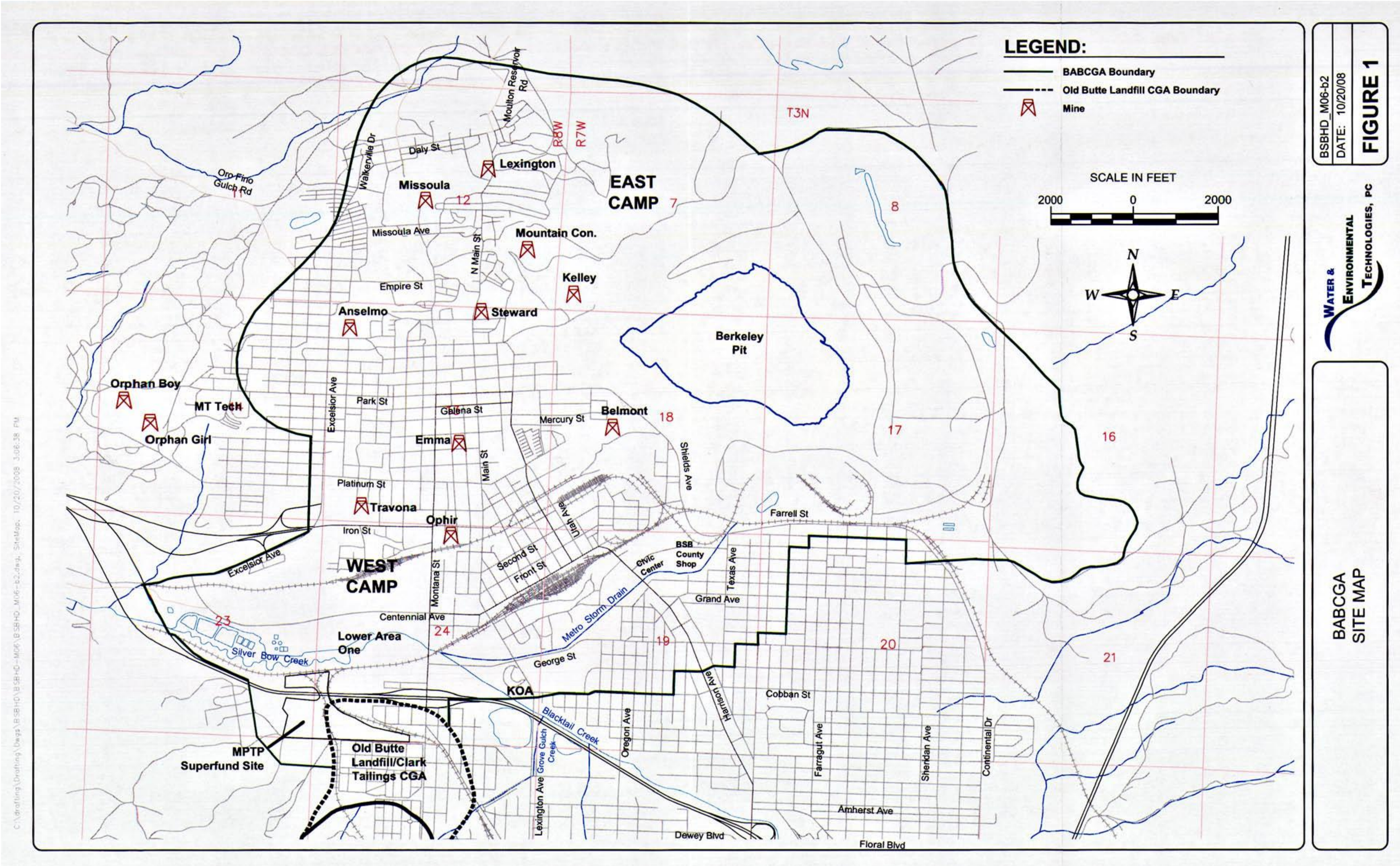

Figure 6-1. Site map for BABCGWA—prepared by Water & Environmental Technologies, included in the Final Order (DNRC).

Prior to purging water from each well, the SWL was measured with an electronic water-level probe, and if possible, the total depth was measured. At the majority of the sites, those measurements were not possible, due to sealed/buried wells with no downhole access. At least three well volumes were purged prior to sampling, with a "well volume" being the volume of standing water within the well prior to pumping.

During pumping, the water was measured for physical/chemical parameters [e.g., temperature, pH, oxidation-reduction potential (ORP), SC, and dissolved oxygen (DO)] in 5- to 10-minute intervals, using a calibrated Hach Hydrolab Minisonde-5. In the wells with unknown SWLs and well volumes, the wells were purged until the parameters stabilized, before collecting samples. After the parameters stabilized about the mean of three consecutive readings (i.e., temperature $<\pm0.5°C$; pH $<\pm0.1$; ORP $<\pm20$ mV SC $<\pm5\%$), a series of water samples were collected, in accordance with the following "dissolved analyte" suite:

- 500 mL unfiltered and unpreserved
- 500 mL filtered (0.45 µm pore-size) and preserved with 1% HNO_3
- 250 mL filtered (0.45 µm pore-size) and unpreserved

Although the Final Order for the BABCGWA identifies only five COCs, a complete analysis of these water samples was conducted in the MBMG laboratory, using methods approved by the EPA for the following species:

1. Cations and trace metals—Ca, Mg, Na, K, SiO_2, Al, As, Co, Cd, Cr, Cu, Fe, Mn, Mo, Ni, U, Zn, Ce, Cs, Ga, La, Nb, Nd, Pb, Pr, Rb, Tl, Th, Sn, Ti, and W (acidified below pH 2 with HNO_3);
2. Anions—SO_4, HCO_3, CO_3, Cl, and NO_3

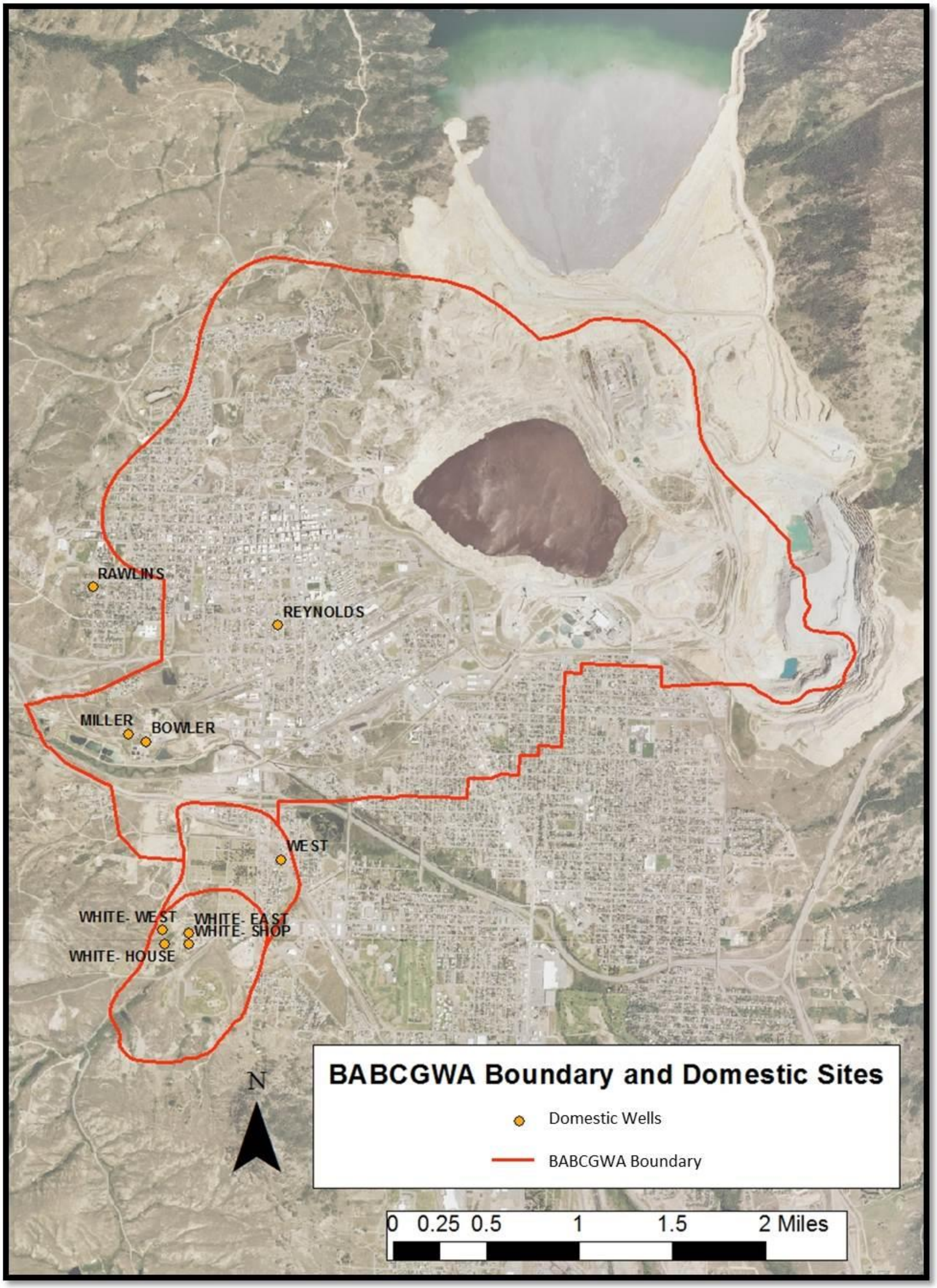

Figure 6-2. Site map for domestic well sampling locations; BABCGWA boundary is shown in red.

Section 6.2 Water-Quality Results

The laboratory results for the five COC (arsenic, cadmium, copper, lead, and zinc) are given for each well in table 6.2.1, with a comparison to the established drinking water MCLs (DEQ-7).

Table 6.2.1. Comparison of DEQ-7 MCLs for COC with 2013 domestic well results. J, estimated quantity above detection limit but below reporting limit. U, Undetected quantity below detection limit.

GWIC Id	Site Name	Sample Date	As (µg/l)	Cd (µg/l)	Cu (µg/l)	Pb (µg/l)	Zn (µg/l)
-	DEQ-7 STANDARD	-	10	5	1,000	15	2,000
174040	BOWLER	7/08/2013	<0.250 U	0.66 J	1.04 J	<0.150 U	64.99
269353	MILLER	7/15/2013	6.79	<0.250 U	5.96	<0.150 U	28.96
50357	RAWLINS	7/10/2013	3.49	<0.100 U	7.34	0.060 J	9.71
4819	REYNOLDS	7/10/2013	0.40 J	<0.250 U	29.44	0.150 J	12.37
156158	WEST	7/16/2013	0.49 J	0.150 J	9.38	<0.060 U	212.53
171277	WHITE-EAST	7/15/2013	3.12	<0.250 U	1.27 J	<0.150 U	29.98
171276	WHITE-HOUSE	7/15/2013	2.76	<0.100 U	0.49 J	<0.060 U	11.94
171278	WHITE-SHOP	Not sampled					
255690	WHITE-WEST	7/15/2013	1.40	<0.100 U	0.90 J	<0.060 U	46.23

Every domestic well sampled in 2013 had results below the established MCLs for the five COC, as required in the Final Order. These results are also consistent with the samples that were collected in previous years from the same wells (found in GWIC database). After the MBMG laboratory analyzed the samples and reported the 2013 results, each well owner was sent a letter that described the sampling objectives for the project and included a complete analytical report of their sample and comparison to the DEQ-7 standards. Although there were no exceedances for the five COC, there were some exceedances of the MCLs and SMCLs for other analytes. It should be noted that the SMCLs are based on the aesthetic quality of water, rather than a health standard. The MCL and SMCL exceedances for each well are given in table 6.0.2.2. There were no exceedances in the Rawlins (#50357) well.

Table 6.2.2. Comparison of DEQ-7 MCLs and SMCLs with 2013 exceedances.

GWIC Id	Site Name	Exceeded Analyte	2013 Result	MCL	SMCL
174040	BOWLER	Fe	6.38 mg/L	-	0.3 mg/L
174040	BOWLER	Mn	3.52 mg/L	-	0.05 mg/L
174040	BOWLER	SO_4	285.60 mg/L	-	250 mg/L
269353	MILLER	SO_4	350.20 mg/L	-	250 mg/L
4819	REYNOLDS	SO_4	367.00 mg/L	-	250 mg/L
4819	REYNOLDS	U	71.65 µg/L	30 µg/L	-
156158	WEST	Mn	0.103 mg/L	-	0.05 mg/L
171277	WHITE-EAST	U	105.47 µg/L	30 µg/L	-
171276	WHITE-HOUSE	U	60.39 µg/L	30 µg/L	-
255690	WHITE-WEST	U	66.26 µg/L	30 µg/L	-

A number of these wells are not used for drinking water, like the White-East and White-West wells (#171277 and 255690) and the Bowler well (#174040), which was previously used for drinking but is now only used for yard irrigation. The wells sampled during 2013 will continue to be sampled in the future, unless the site list changes after consultation with BSB, EPA, and DEQ.

SECTION 7.0 REVIEW OF THE BERKELEY PIT MODEL

The Berkeley Pit water-level model was updated based upon actual 2013 water-level measurements and HSB flows as measured at the weir upgradient of the water-treatment plant influent pond. The model incorporates monthly water-level rise information from July 1996 through December 2013.

Based upon the 2013 model update, it was projected that the CWL of 5,410 ft will be reached at the Anselmo Mine in **May 2023**, 1.3 months earlier than predicted in the 2012 model (July 2023). The model update includes the surface-water inputs from storm water diversions in the Kelley Mine area, the addition of sludge from the HSB water-treatment plant, and previous models infilling rates adjusted for the diversion of HSB water away from the pit. The update also included water-level increases from waste rock and alluvial material that entered the pit water from the February 2013 slump. The HSB drainage water that was flowing into the pit from June 2000 through November 17, 2003 continues to be diverted to the HSB water-treatment plant for treatment and is being used in MR's mining operations. No major changes in additions or withdrawals of water were made from the Berkeley Pit during 2013; the consistent filling rate and operational activities led to the minor adjustment in filling-rate projection. The pit contained 43.7 billion gallons of water at the end of 2013, while the projected volume of water in April 2023 is 53.4 billion gallons.

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, the submittal of a Technical Memorandum assessing the adequacy of the current treatment plant is due May 2019. Any necessary upgrades would have to be completed by May 2021 (fig. 7-1).

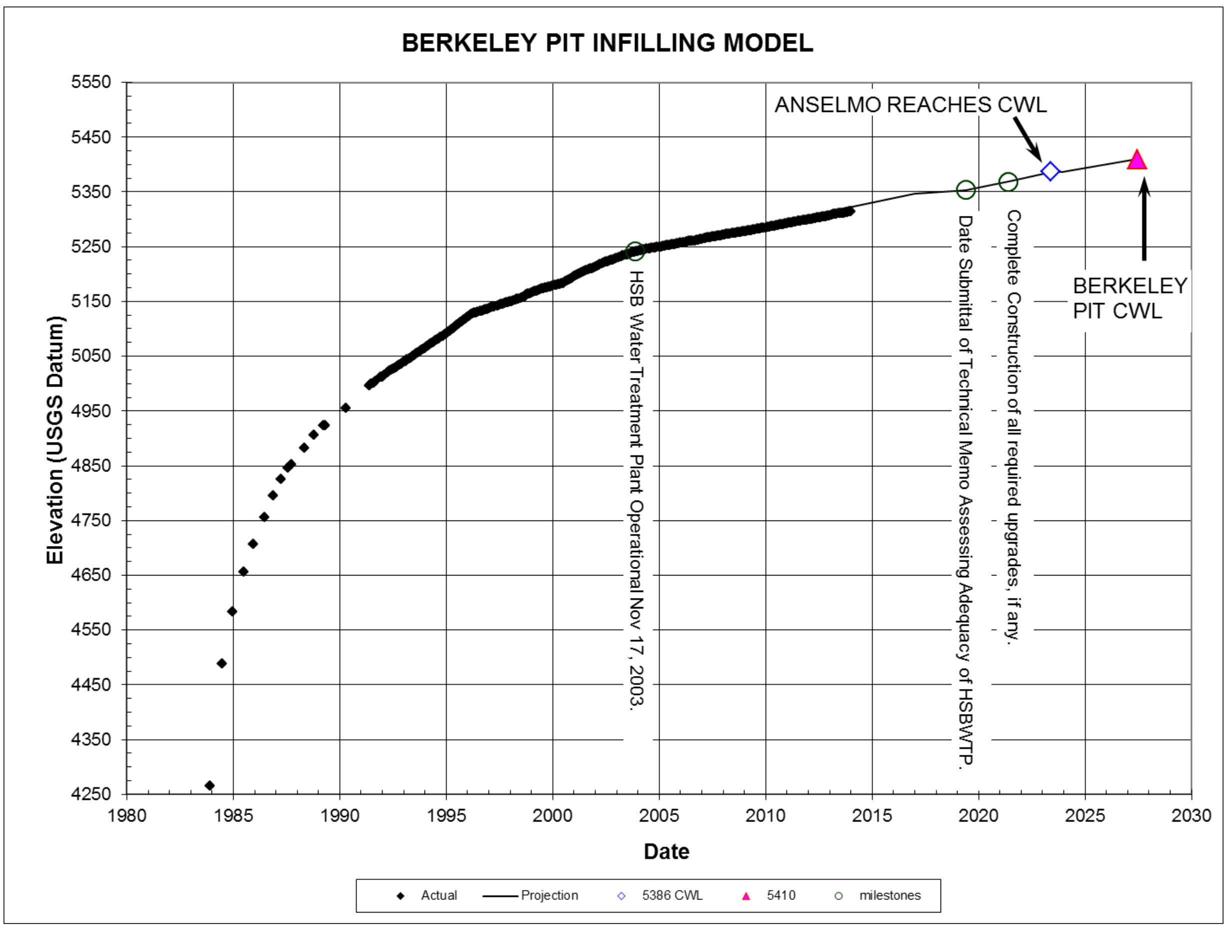

Figure 7-1. Projected Berkeley Pit filling rate & dates of treatment review & upgrades.

SECTION 8.0 CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system within the active mine area were similar to those of 2012, with water levels increasing in a majority of the wells north of the Pittsmont Dump; this is most likely the result of continued leaching operations. This reverses the trend observed from 2004 and earlier and from 2006 through 2009 of water levels decreasing in a majority of the wells in this area. Water levels decreased in a majority of the wells south of the Pittsmont Dump as a result of dewatering activities undertaken by MR.

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 have a greater response to mining and leaching operations than precipitation events.

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- to 3-month lag time. 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; however, water levels increased in all of these wells (AMC and GS series) in 2003 and a majority of them in 2004 before decreasing in 2005. The 2003 water-level 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. However, a relationship between filling of the MR concentrator Emergency (Dredge) pond and water-level increases in several AMC wells was apparent. A similar water-level rise (response) was seen in 2011 in several wells (AMC and BMF05 series) following MR's cleaning and deepening of the Ecology pond. MR drained this pond in 2012, resulting in a corresponding water-level decline; during 2013 the pond was capped with a clay liner and recontoured for use during extreme precipitation run-off events or mill upsets to temporary store water. Water levels continued to decline following the pond capping, adding additional support for the relationship between operational changes and water-level changes in the vicinity of the active mine area.

The increased water-level changes in the East Camp bedrock system are independent of precipitation, and are a result of the 1982 cessation of long-term mine dewatering activities. No notable precipitation influence was seen in any of the bedrock wells or underground mine water levels. However, the continued diversion of HSB drainage water away from the Berkeley Pit did have an influence on East Camp bedrock water levels. The water-level rise for 2013 (based upon wells A and G) was about 45 percent that of 2002–2003 when HSB water was flowing into the pit.

The date the East Camp system water level is predicted to reach the CWL elevation of 5,410 ft was changed from July 2023 to May 2023, or 1.3 months earlier than that predicted in 2012. The CWL date is assumed to be the date the 5,410-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 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 February 8, 2013 rotational slump that occurred in the southeast corner of the Berkeley Pit resulted in a 0.60 ft water-level rise in the Berkeley Pit and several nearby bedrock monitoring wells. This increased water-level rise was possibly responsible for the change in the Berkeley Pit filling rate. Safety concerns about additional slumps resulted in the cancellation of 2013 water-quality sampling and vertical profiling of the pit water column.

The pumping of groundwater in the West Camp System continues to control water levels in this system. The suspension of pumping from early July to mid-September allowed water levels to temporarily rise above the system's CWL; no negative impacts were seen from this suspension and water levels declined once pumping resumed. Water levels increased up to 12 ft throughout this system and were about 1 ft above the CWL at the end of the year.

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 historic trends, particularly with respect to iron concentrations. It now appears that instead of a sampling or analytical problem, the departure is 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 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.

Monitoring of domestic wells within the CGWA showed no water-quality exceedances for the five COCs; however, several sites were found to have elevated concentrations of such things as iron and uranium. These elevated concentrations are most likely due to local geologic conditions and not related to the rising water in the bedrock mine system.

Results of the 2013 monitoring program continue to show that the current monitoring program (water level and water quality) 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.

ACKNOWLEDGMENTS

The information contained in this report represents the work of many companies and agencies over the past 32 years. Numerous individuals have been responsible for actual data collection. Their dedication and creativity in monitoring and sampling of mine waters provided the information that all future work and evaluations relied upon.

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

The continued cooperation of Montana Resources and Atlantic Richfield Company is greatly appreciated, while representatives of New Butte Mining continue to allow access to their properties for monitoring purposes. Special appreciation is extended to the property owners who allowed access to their property for the monitoring of alluvial monitoring wells: Gilman Construction, Continental Public Land Trust, Butte School District #1, and Race Track Volunteer Fire Department. The cooperation of private landowners who allowed sampling of their domestic wells is recognized and appreciated.

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Errors and omissions remain the authors' responsibility.

REFERENCES

ARCO, 1992, Clark Fork River Superfund Site Investigations Standard Operating Procedures.

Burns, G., 1994, A Review of the Geology and Historic Production of the Butte District, Presented at the 100th Annual Northwest mining Association, Spokane, Washington, November 29–December 2, 1994.

Clark, I., and Fritz, P., 1997, Environmental Isotopes in Hydrogeology*,* Lewis Publishers, Boca Raton, FL.

Daly, W.B., and Berrien, C.L., 1923, Mining Methods and Installations of the Anaconda Copper Mining Co. at Butte, Montana, 1922 Meeting, Transactions of the American Institute of Mining and Metallurgical Engineers, Vol. LXVIII, 1923.

Duaime, T.E., Metesh, J.J., Kerschen, M.D., and Dunstan, C.B., 1998, The flooding of Butte's underground mines and Berkeley Pit: 15 Years of water-level monitoring (1982–1987): MBMG Open-File Report 376.

Duaime, T.E., and Metesh, J.J., 2000, The flooding of Butte's underground mines and Berkeley Pit, Butte mine flooding operable unit annual water-level update, 1998–1999: MBMG Open-File Report 410.

Duaime, T.E., and Metesh, J.J., 2001, The flooding of Butte's underground mines and Berkeley Pit, Butte mine flooding operable unit annual water-level update, 1999–2000: MBMG Open-File Report 435.

Duaime, T.E., and Metesh, J.J., 2003, Twenty Years of Water-Level and Water-Quality Sampling Butte's Underground Mines and Berkeley Pit, Butte, Montana 1982–2001: MBMG Open-File Report 473.

Duaime, T.E., and Metesh, J.J., 2004, 2002 Update of Water-Level Monitoring and Water-Quality Sampling Butte's Underground Mines and Berkeley Pit, Butte, Montana 1982–2002: MBMG Open-File Report 489.

Duaime, T.E., and Metesh, J.J., 2005, 2003 Update of Water-Level Monitoring and Water-Quality Sampling Butte's Underground Mines and Berkeley Pit, Butte, Montana 1982–2003: MBMG Open-File Report 518.

Duaime, T.E., and Metesh, J.J., 2005, 2004 Consent Decree Update Water-Level Monitoring and Water-Quality Sampling Butte's Underground Mines and Berkeley Pit, Butte, Montana: MBMG Open-File Report 527.

Duaime, T.E., and Metesh, J.J., 2006, 2005 Consent Decree Update Water-Level Monitoring and Water-Quality Sampling Butte's Underground Mines and Berkeley Pit, Butte, Montana: MBMG Open-File Report 549.

Duaime, T.E., and Tucci, N.J., 2007, History of Flooding of the Butte Underground Mines and Berkeley Pit, Water-Level Monitoring and Water-Quality Sampling, 2006 Consent Decree Update, Butte, Montana, 1982–2006: MBMG Open-File Report 566.

Duaime, T.E., and Tucci, N.J., 2008, Butte Underground Mines and Berkeley Pit, Water-Level Monitoring and Water-Quality Sampling, 2007 Consent Decree Update, Butte, Montana, 1982–2007: MBMG Open-File Report 577.

Duaime, T.E., and Tucci, N.J., 2009, Butte Underground Mines and Berkeley Pit, Water-Level Monitoring and Water-Quality Sampling, 2008 Consent Decree Update, Butte, Montana, 1982–2008: MBMG Open-File Report 589.

Duaime, T.E., and Tucci, N.J., 2011, Butte Underground Mines and Berkeley Pit, Water-Level Monitoring and Water-Quality Sampling, 2009 Consent Decree Update, Butte, Montana, 1982–2009: MBMG Open-File Report 599.

Duaime, T.E., and Tucci, N.J., 2011, Butte Underground Mines and Berkeley Pit, Water-Level Monitoring and Water-Quality Sampling, 2010 Consent Decree Update, Butte, Montana, 1982–2010: MBMG Open-File Report 609.

DNRC Final Order, 2009, Petition For Butte Alluvial and Bedrock Controlled Ground Water Area, No. 76G-30043832.

EPA Record of Decision, 1994, Butte mine flooding operable unit, Silver Bow Creek/Butte area NPL site, Butte, Montana, September 29, 1994, Three Volumes.

EPA Consent Decree, 2002, Butte Mine Flooding Operable Unit Consent Decree-02-35-BU-SEH.

Gammons, C.H., and Duaime, T.E., 2006, Long Term Changes in the Limnology and Geochemistry of the Berkeley Pit Lake, Butte, Montana, Mine Water and the Environment, Volume 25, Number 2, June 2006.

Gammons, C.H., Poulson S.R., Pellicori D.A., Roesler A., Reed P.J., and Petrescu E.M., 2006, The hydrogen and oxygen isotopic composition of precipitation, evaporated mine water, and river water in Montana, USA: Journal of Hydrology, 328, p. 319–330.

GWIC, 2007, Montana Bureau of Mines and Geology, Ground Water Information Center, On-Line Database, 2007.

Metesh, J.J., and Duaime, T.E., 2000, The flooding of Butte's underground mines and Berkeley Pit, 18 years of water-quality monitoring (1982–1999): MBMG Open-File Report 409.

Metesh, J.J., and Duaime, T.E., 2002, The flooding of Butte's underground mines and Berkeley Pit, water-quality monitoring through 2000: MBMG Open-File Report 456.

Miller, R.N., 1978, Production History of the Butte District and Geological Function, Past and Present; Guidebook for the Butte Field Meeting of Society Of Economic Geologists, August 18–21, 1973, 2nd printing.

Montana Bureau of Mines and Geology, 2002, Butte Mine Flooding Operable Unit, Sampling and Analysis Plan, EPA Dockett No. CERCLA—VIII-96-19, Butte, Mont., August 2002, Updated April 2011.

Montana Bureau of Mines and Geology, 2014, Draft West Camp Critical Water-Level Review, Data Summary Report, 2013–2014.

Pellicori, D.A., Gammons, C.H., and Poulson, S.R., 2005, Geochemistry and stable isotope composition of the Berkeley pit lake and surrounding mine waters, Butte, Montana: Applied Geochemistry, v. 20, p. 2116–2137.

Rozanski, K., Araguás-Araguás, L., and Gonfiantini, R., 1993, Isotopic patterns in modern global precipitation, *in* Continental Isotope Indicators of Climate, American Geophysical Union Monograph Series, v. 78.

Sales, R.H., 1914, Ore deposits at Butte, Montana, American Institute of Mining and Metallurgical Engineers: Transactions, v. 46, p. 3–106.

Spindler, J.C., 1977, The clean-up of Silver Bow Creek, Mining Congress Journal, June 1977.