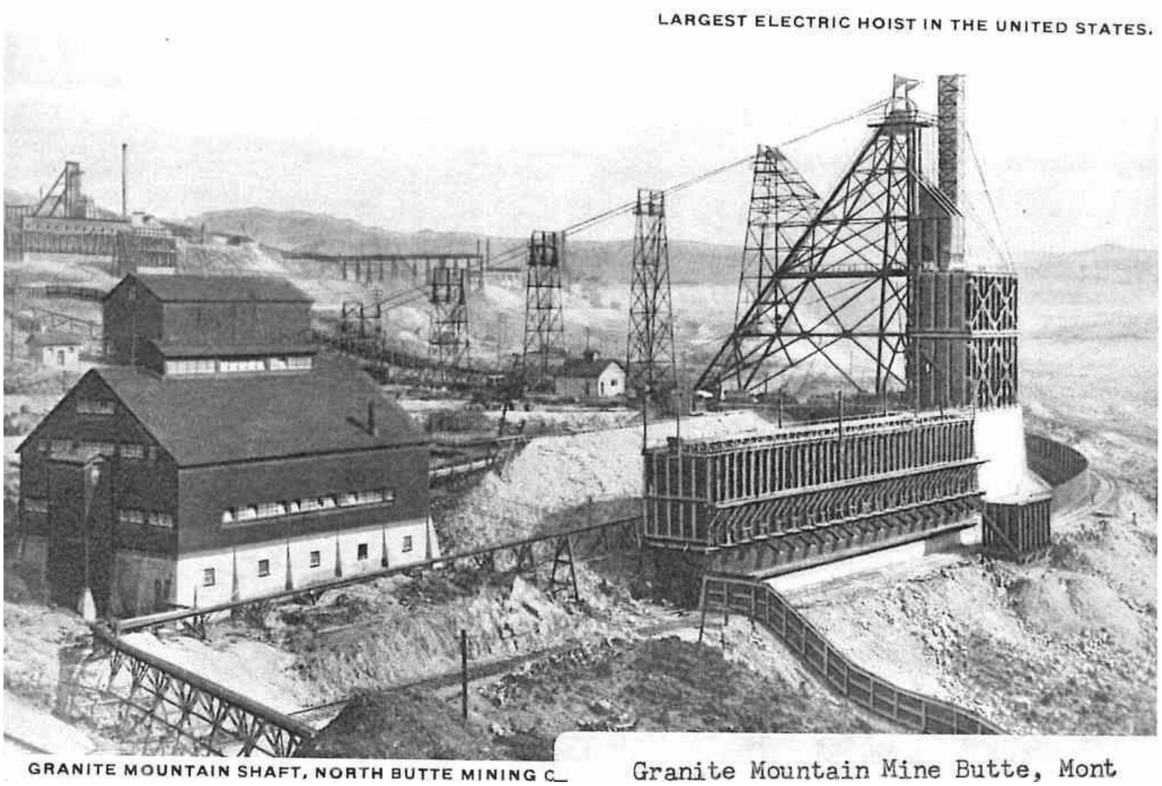
Butte Mine Flooding Operable Unit
Water-Level Monitoring and Water-Quality Sampling
2012 Consent Decree Update
Butte, Montana
1982-2012

prepared for

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



(Photo courtesy of the World Museum of Mining)

September 2013

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Contract No. 400022-TO-35

Montana Bureau of Mines and Geology Open File Report 641

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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 2012, 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. 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, and the addition of storm water flow from the Butte Hill. The projected date when the 5,410-foot water-level elevation would be reached at the Anselmo Mine was modified from April 2023 (2011 Report) to July 2023, a change of -0.25 years (-3 months);
2. West Camp pumping activities continue to maintain the groundwater level below the 5,435-foot elevation, stipulated in the 1994 Record of Decision. The volume of water pumped in 2012 was 88 percent of that in 2011 (223.6 vs. 252.9 acre-ft). Water levels increased between 6.25-ft and 7.22-ft throughout the West Camp underground system;
3. Water-quality variations in East Camp alluvial wells LP-16 and LP-17 were noted. Well LP-16 was sampled twice and LP-17 was sampled once during 2012. Moderate increases in sulfate, copper, and zinc were noted in LP-16. Metal concentrations remain very elevated in LP-17; however concentrations decreased from 2009-2011 levels. Nitrate concentrations decreased by 30 percent in 2012; however they are still 3 times the recommended standard;
4. Montana Resources began to use water from the Horseshoe Bend drainage to activate (recharge) idle leach pads. Flows from 1,200 to 2,500 gallons per minute are diverted; and
5. Two minor landslides occurred in the southeast corner of the Berkeley Pit, the first occurring on August 22nd and the last of November 3rd. No changes in water levels within the pit or adjacent bedrock aquifer were observed from these events. However, the MR pontoon boat

sustained minor damage. The boat was removed from the pit for repairs, resulting in a reduction in the fall pit sampling event.

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

Monitoring and sampling activities performed during 2012 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. There have been some minor organizational changes in this year's report in an effort to make it more readable.

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 Ground Water Area
BP/ARCO	British Petroleum/Atlantic Richfield Company
BMFOU	Butte 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
EPA	U.S. Environmental Protection Agency
GMWL	Global Meteoric Water Line
GPM	Gallons per Minute
GWIC	MBMG Ground Water Information Center
HSB	Horseshoe Bend Drainage
HSB Falls	Horseshoe Bend Falls
LMWL	Local Meteoric Water Line
MBMG	Montana Bureau of Mines and Geology
MBRGA	Moulton and Bull Run Gulch Area
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
NAVD88	North American Vertical Datum of 1988

ORP	Oxidation-Reduction Potential
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SC	Specific Conductance at 25^0C
SMCL	Secondary Maximum Contaminant Level
SWL	Static water level
YDTP	Yankee Doodle Tailings Pond

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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 (figure 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 it 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 1890's (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.)

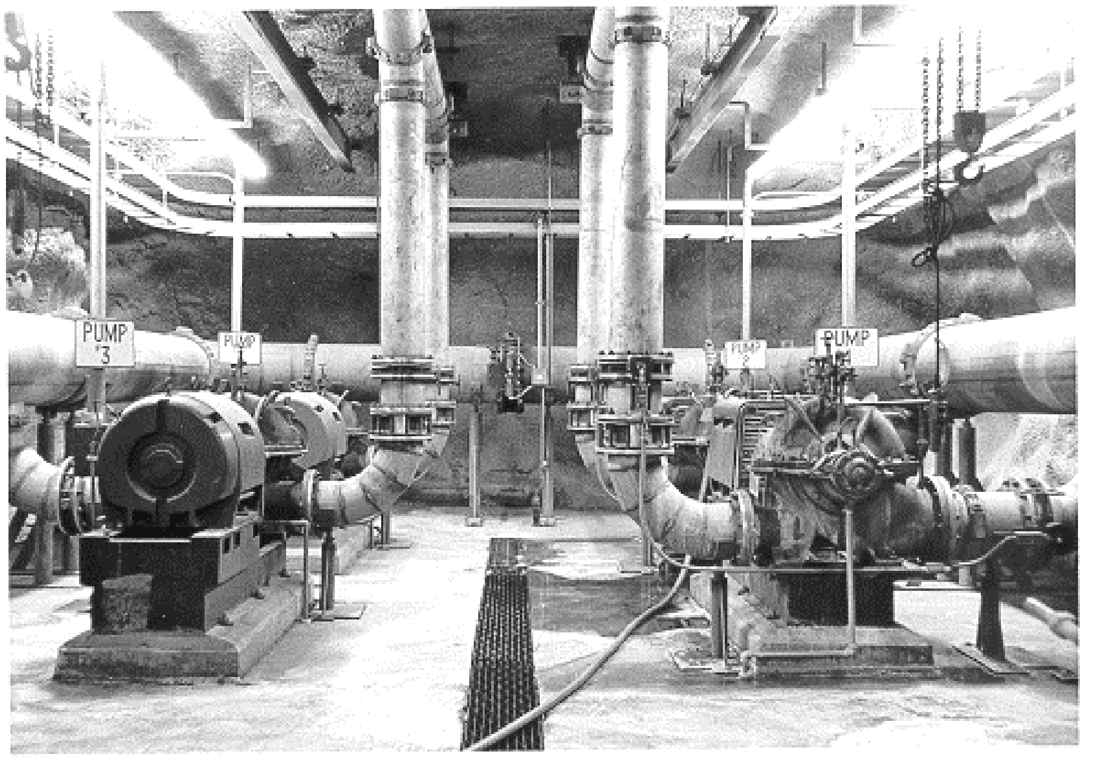


Figure 1-2. Kelley Mine pump station, 3900-ft level. (Photo courtesy World Museum of Mining, Butte, MT.)

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. Map showing location of selected underground mines engulfed by development and expansion of the Berkeley Pit.

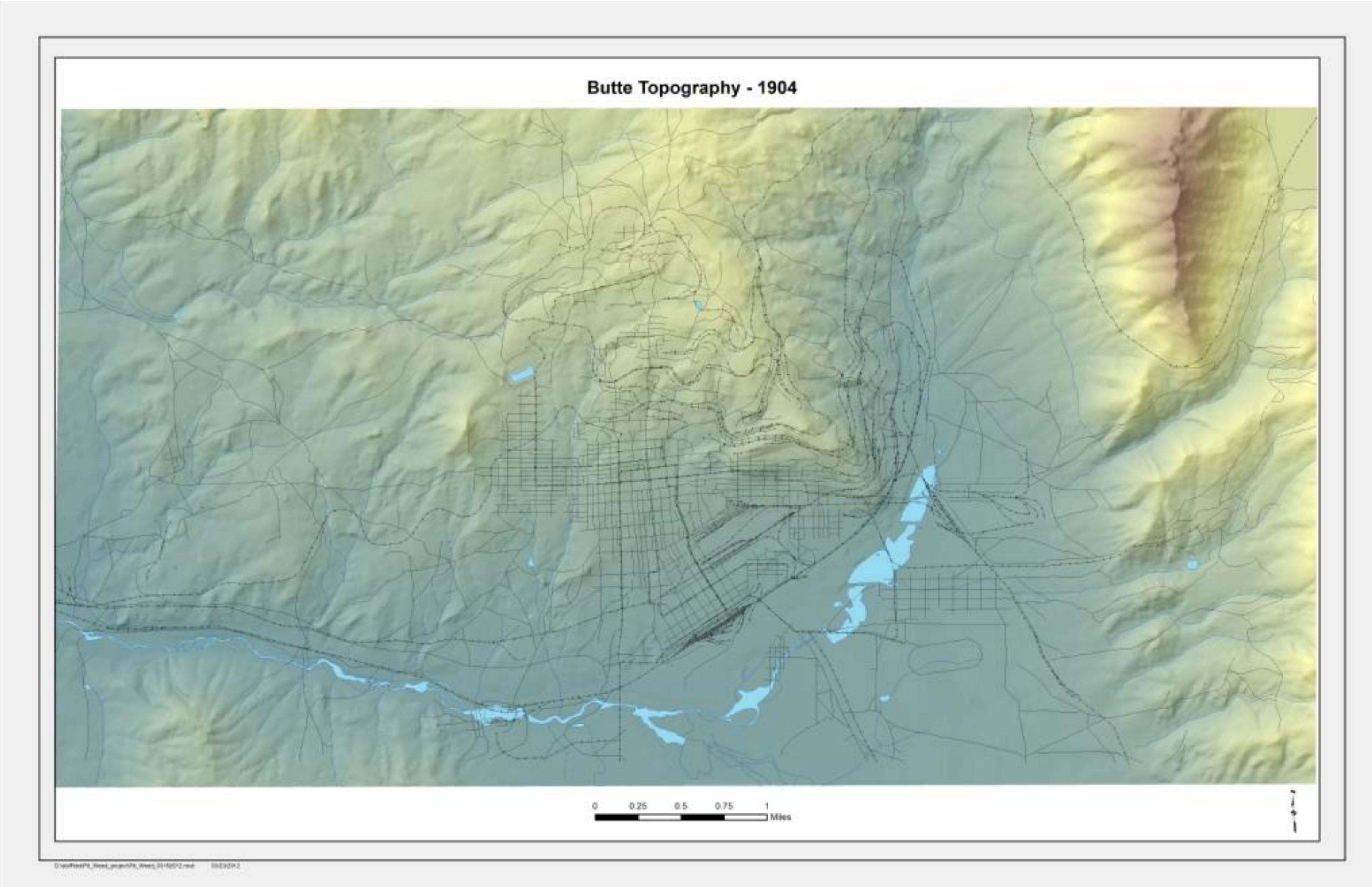


Figure 1-5. Digital elevation model showing Butte topography, 1904.

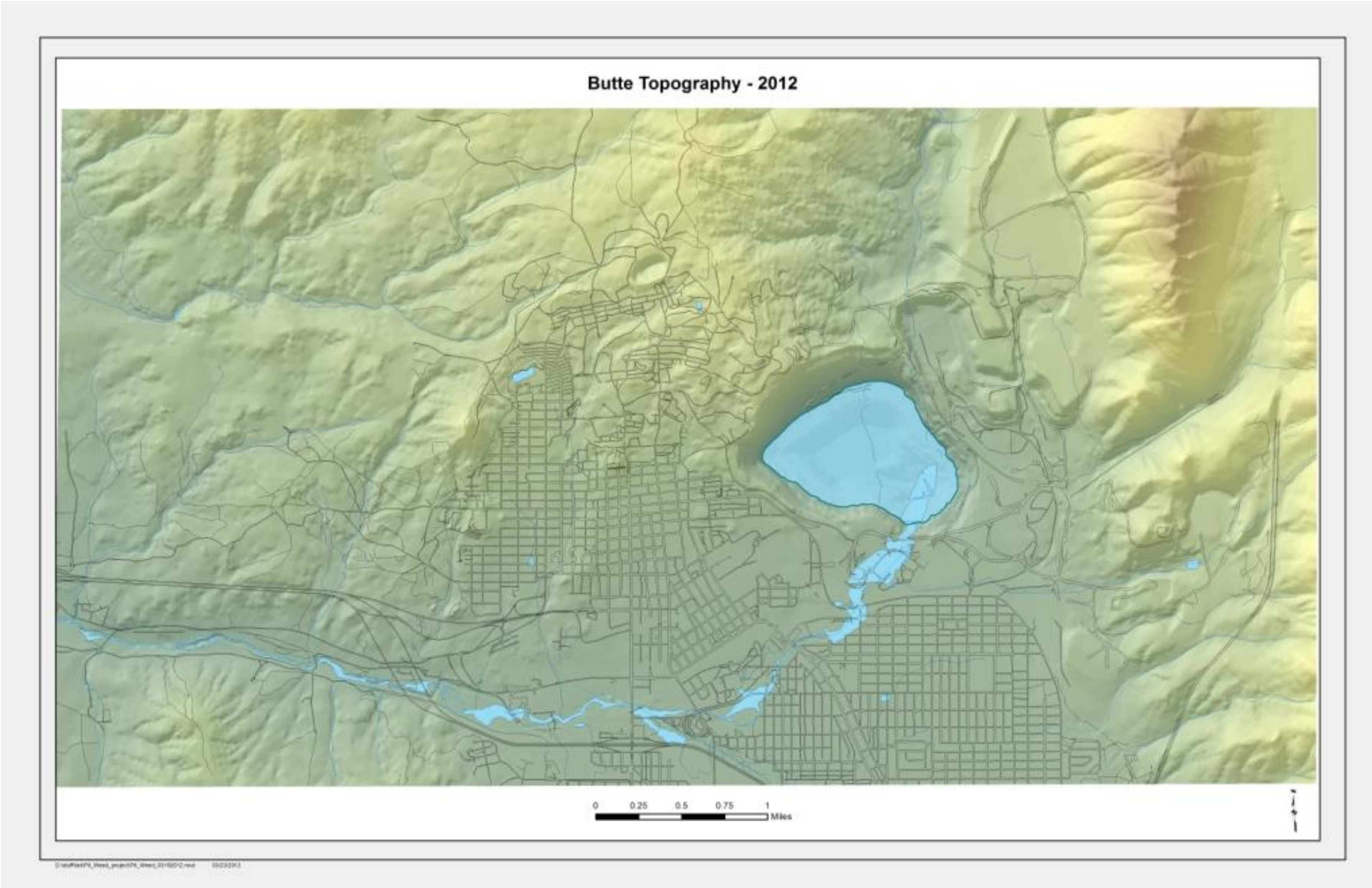


Figure 1-6. Digital elevation model showing Butte topography, 2012.

Mines located in the areas described by Sales (1914) as the Intermediate and Peripheral Zones, were shut down and eventually sealed off from the remainder of the operating mines. These areas were isolated from the working mines to reduce the amount of water pumped from the underground workings and to lessen the required amount of fresh air brought into the mines for worker safety.

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 gallons per minute (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 time line of selected activities relating to Butte mining operations, including the Berkeley Pit, Continental Pit, concentrator, underground mining and ancillary activities from 1995 through 2012.

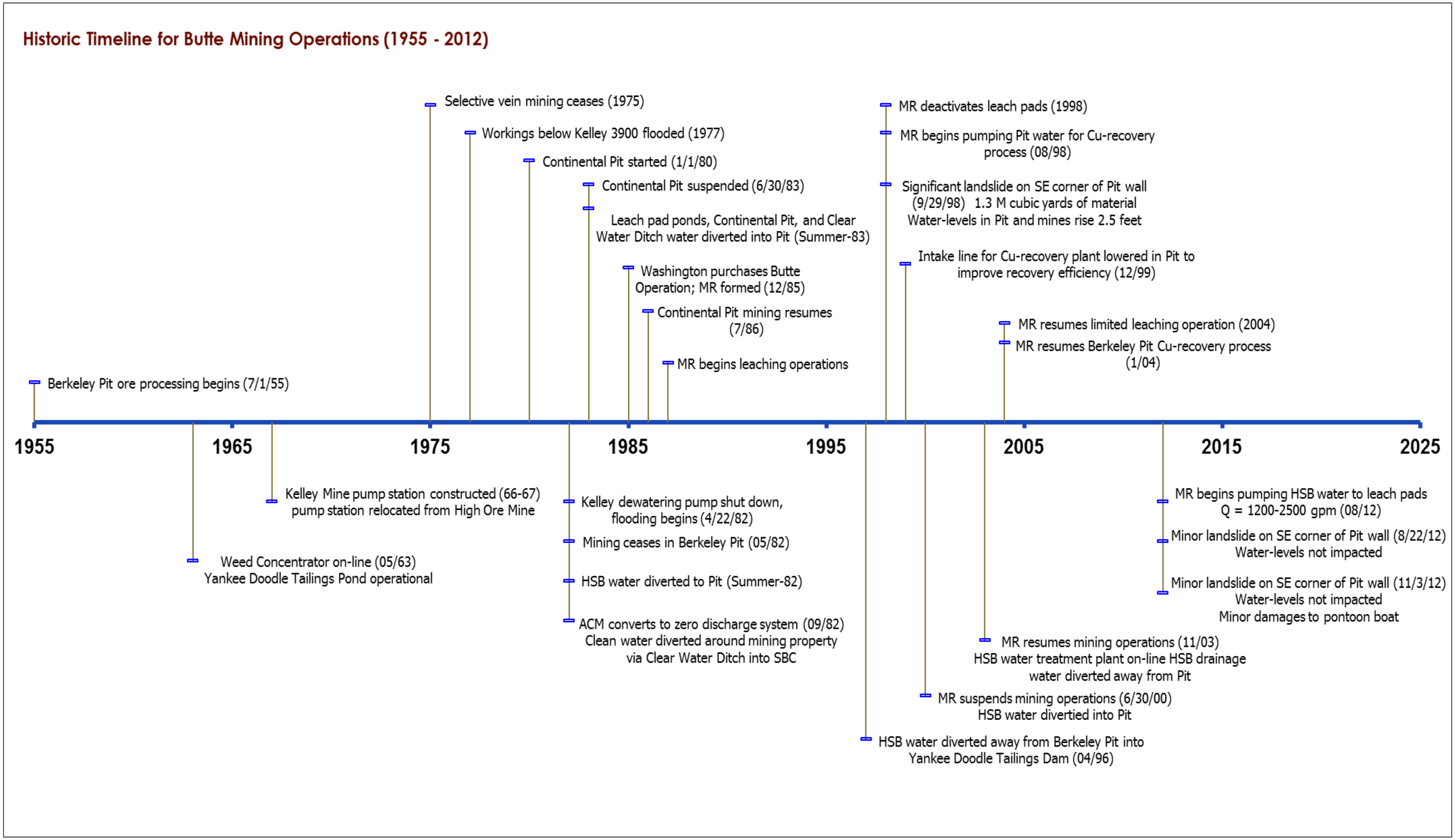


Table 1.0.1 Time line for Butte Operations, 1955-2012.

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 three 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 this monitoring network. The current monitoring program includes 63 monitoring wells, 11 mine shafts, and four surface-water sites. The Berkeley Pit and Continental Pit, as appropriate, are also part of the monitoring network. The monitoring network can be broken down into the following categories:

1) East Camp bedrock wells – 13;
2) East Camp mines – 6;
3) East Camp alluvial wells within the active mine area – 22;
4) East Camp alluvial wells outside the active mine area – 16;
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 (Horseshoe bend, Blacktail Creek, Silver Bow Creek, and Outer Camp seep)-4.

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 NGVD 1929 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 NGVD 1929 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 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. British Petroleum/Atlantic Richfield Company (BP/ARCO) and the Montana Resources Group agreed in the CD to be responsible for all costs associated with the design, construction, operation, and maintenance of a water-treatment plant for treating HSB, Berkeley Pit, and other contaminated waters associated with the site.

The present study is the seventeenth such report, summarizing 31 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 No. 376 for greater detail and information about the site.

Monitoring activities continued in 2012 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 Montana Bureau of Mines and Geology developed a Sampling and Analysis Plan based upon the requirements of the 2002 CD which 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 2012. 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.

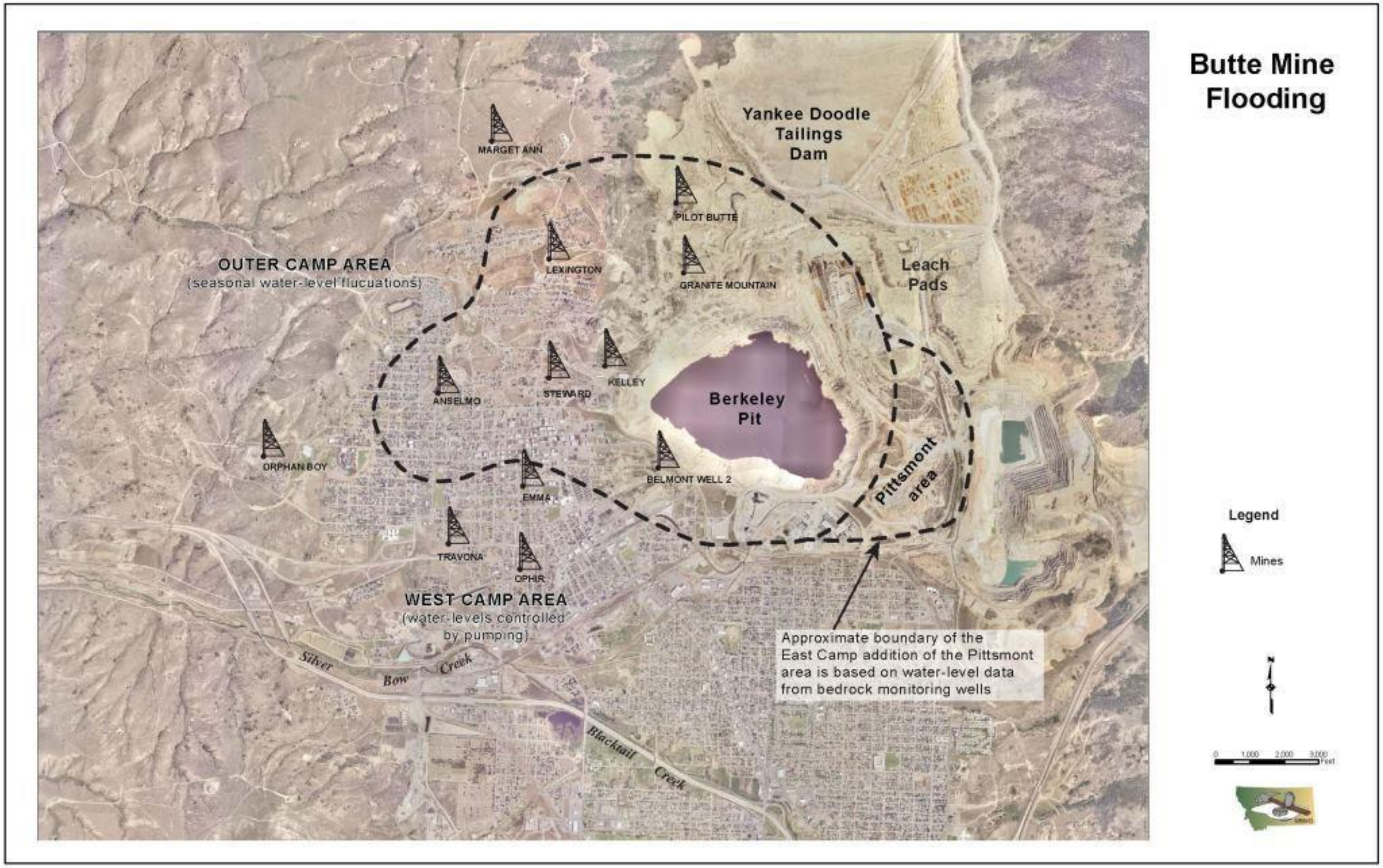


Figure 1-7. The mines of the Butte hill are presently considered in three groups: the East Camp, which includes the Berkeley Pit and the area east; the West Camp in the southwest part of the hill; and the Outer Camp which includes the outlying mines.

Section 1.2 Notable 2012 Activities and Water-Level and Water-Quality Observations

For the fourth consecutive year nothing significant occurred, i.e. earthquake, landslide or mine exploration, that had a dramatic impact on water levels or water-quality conditions throughout the monitoring network. Two minor landslides did occur within the Berkeley Pit; however, they did not have an influence of water levels in the pit or surrounding bedrock aquifer. The main activities and observations for 2012 are listed below:

(1) Montana Resources (MR) continued mining and milling operations throughout 2012 following their November 2003 resumption of mining.

(2) Montana Resources began to use water from the Horseshoe Bend (HSB) drainage to activate (recharge) idle leach pads. Flows from 1,200 to 2,500 gallons per minute were diverted. Water-levels increased in several LP wells downgradient of the re-activated leach pads and water quality changes were observed in several of the constituents analyzed as part of monthly monitoring of the HSB water.

(3) East Camp alluvial well LP-16 had a modest increase in sulfate, copper and zinc from prior years.

(4) East Camp alluvial well LP-17 had a decrease in nitrate and metal concentrations from 2009-2011 concentrations; however, they are considerably higher than previous levels (pre-2003).

(5) MR installs three pumping wells to lower alluvial groundwater levels adjacent to the August and November Berkeley Pit landslides. Monitoring well LP-15 used for dewatering purposes also.

(6) Fall Berkeley Pit sampling was reduced due to access limitations following November landslide.

(7) Groundwater dewatering associated with Butte Priority Solis activities showed short-term influences in the adjacent shallow East Camp alluvial aquifer.

Section 1.3 Precipitation Trends

Total precipitation for 2012 was 9.05 inches, compared to 12.46 inches in 2011 (27% decrease). The 2012 amount is 3.64 inches below the long-term (1895-2012) average. Precipitation totals have been below average for seven of the past ten years and eighteen of the last thirty-one years. The 2012 precipitation total was a decrease of 29 percent below the long-term average of 12.69 inches. Table 1.3.1 contains monthly precipitation statistics from 1982 through 2012, 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 2012.

Table 1.3.1 Butte Precipitation Statistics, 1982-2012.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Mean	0.45	0.42	0.75	1.10	1.96	2.29	1.38	1.31	0.96	0.76	0.60	0.50	12.47
Std. Dev.	0.33	0.28	0.40	0.67	0.78	1.20	1.04	0.89	0.69	0.55	0.38	0.37	2.90
Maximum	1.40	1.26	1.84	3.20	3.88	4.62	4.18	3.10	2.56	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													18

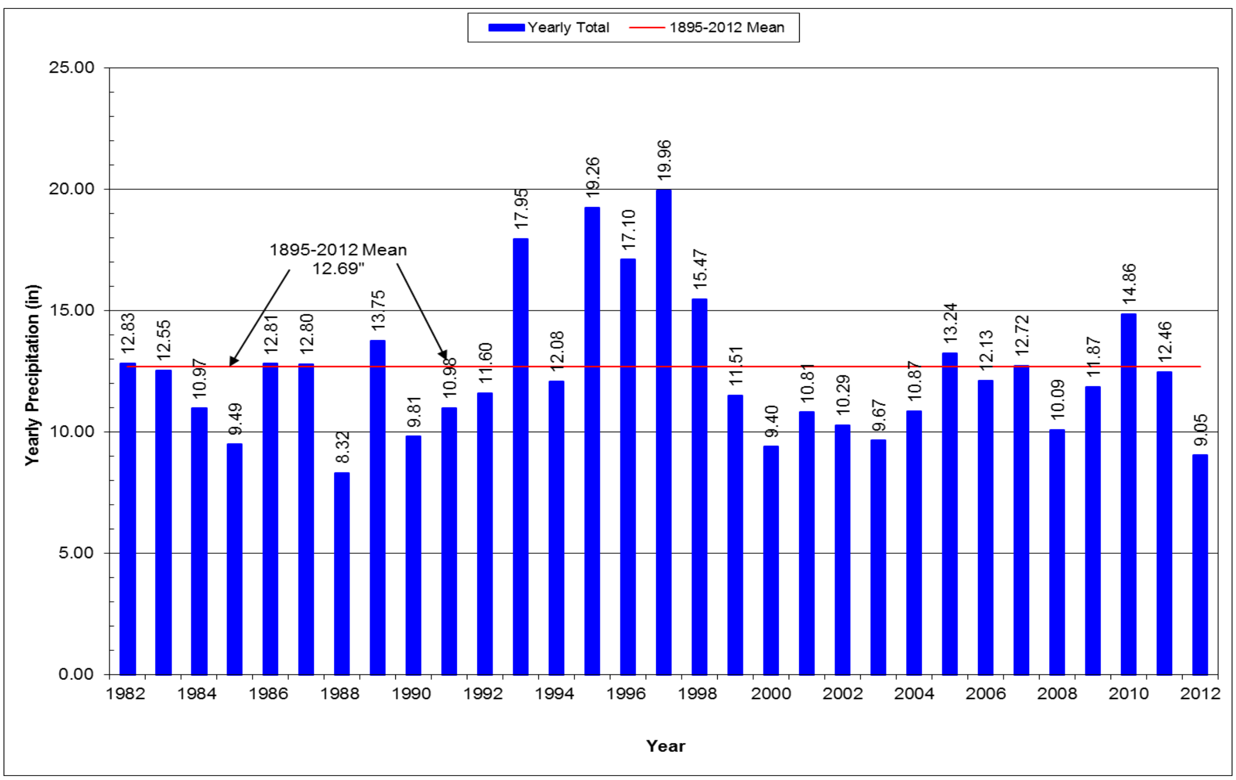


Figure 1-8. Yearly precipitation totals 1982-2012, showing 1895-2012 mean.

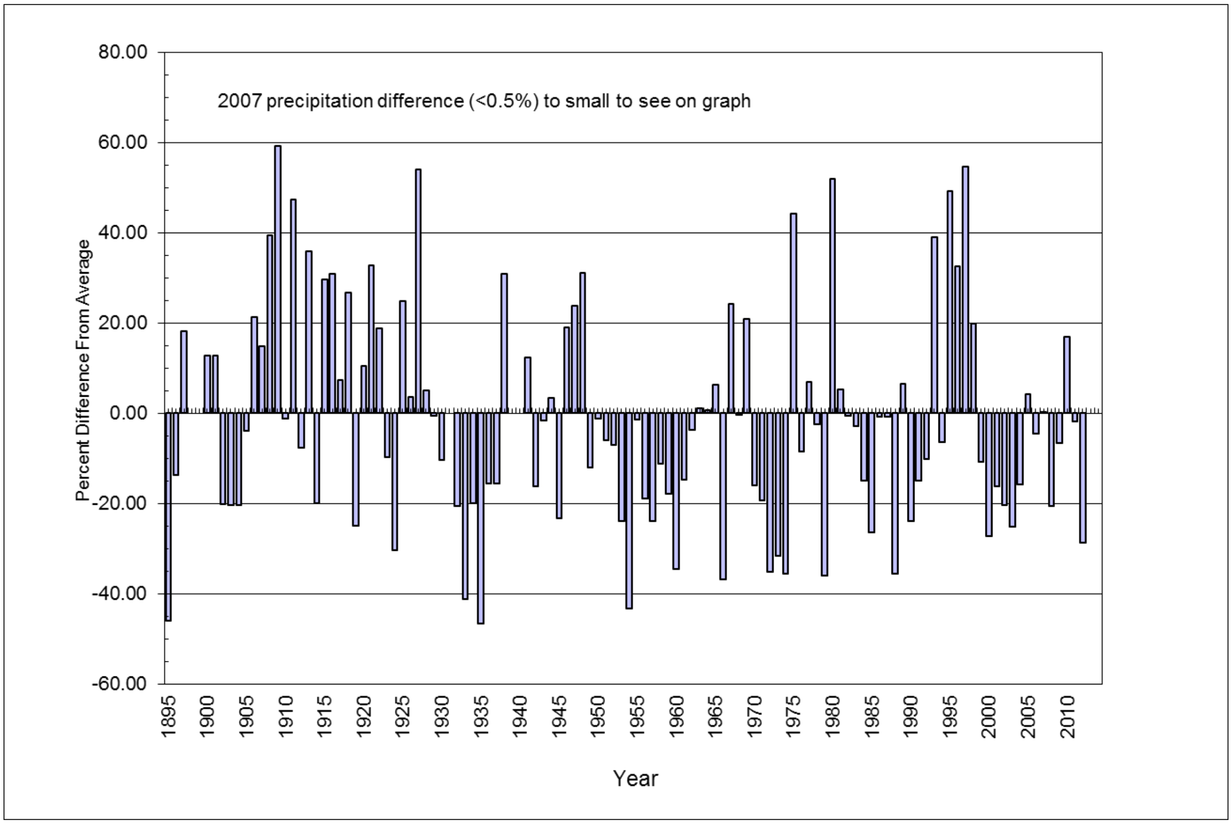


Figure 1-9. Percent precipitation variation from normal, 1895-2012.

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.

Section 2.1 East Camp Alluvial System

The East Camp alluvial groundwater monitoring system consists of the LP- and MR97-series wells located within the active mine area, plus selected AMC, GS, AMW, and BMF05 series wells. All wells in the latter four groups are located south of the active mine area, with the exception of wells

AMC-5 and AMC-15, located within the mine area. Each group of wells represents sites installed or monitored during different studies now incorporated into the BMFOU-CD monitoring program.

Four new alluvial monitoring wells were installed within the East Camp system in 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 new wells were situated in areas of limited data and were equipped with transducers for increased water-level data collection. The new series was named "BMF05-wells" and is discussed with the GS-series wells. Water-quality samples were collected three times annually throughout 2007 (to help establish baseline conditions) and semi-annually thereafter.

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 occurred only once or twice annually.

Water-level conditions and water-quality characteristics vary throughout the alluvial system. Data from wells within or adjacent to historic mining activities show the influence of those activities, i.e., elevated metal concentrations. Data from sites outside historic mining areas reflect conditions typical of the regional hydrogeology.

In late September 1998, a significant landslide occurred in the southeast corner of the Berkeley Pit. The landslide caused an almost immediate 3 ft water level rise in the Berkeley Pit, East Camp mines, and bedrock groundwater system. However, the landslide influenced water levels in parts of the East Camp alluvial system by causing water-levels to fall through mid-2003. Seasonal precipitation responses are noticeable on many well hydrographs (GS series wells), although the overall water-level trend during those years was downward; little seasonal response is noticeable in other well hydrographs (i.e. AMC-series wells). Labels on hydrographs here and in subsequent sections indicate the date of the landslide and water-level in wells just prior to the landslide for the readers benefit.

Figure 2-1. East Camp alluvial monitoring wells.

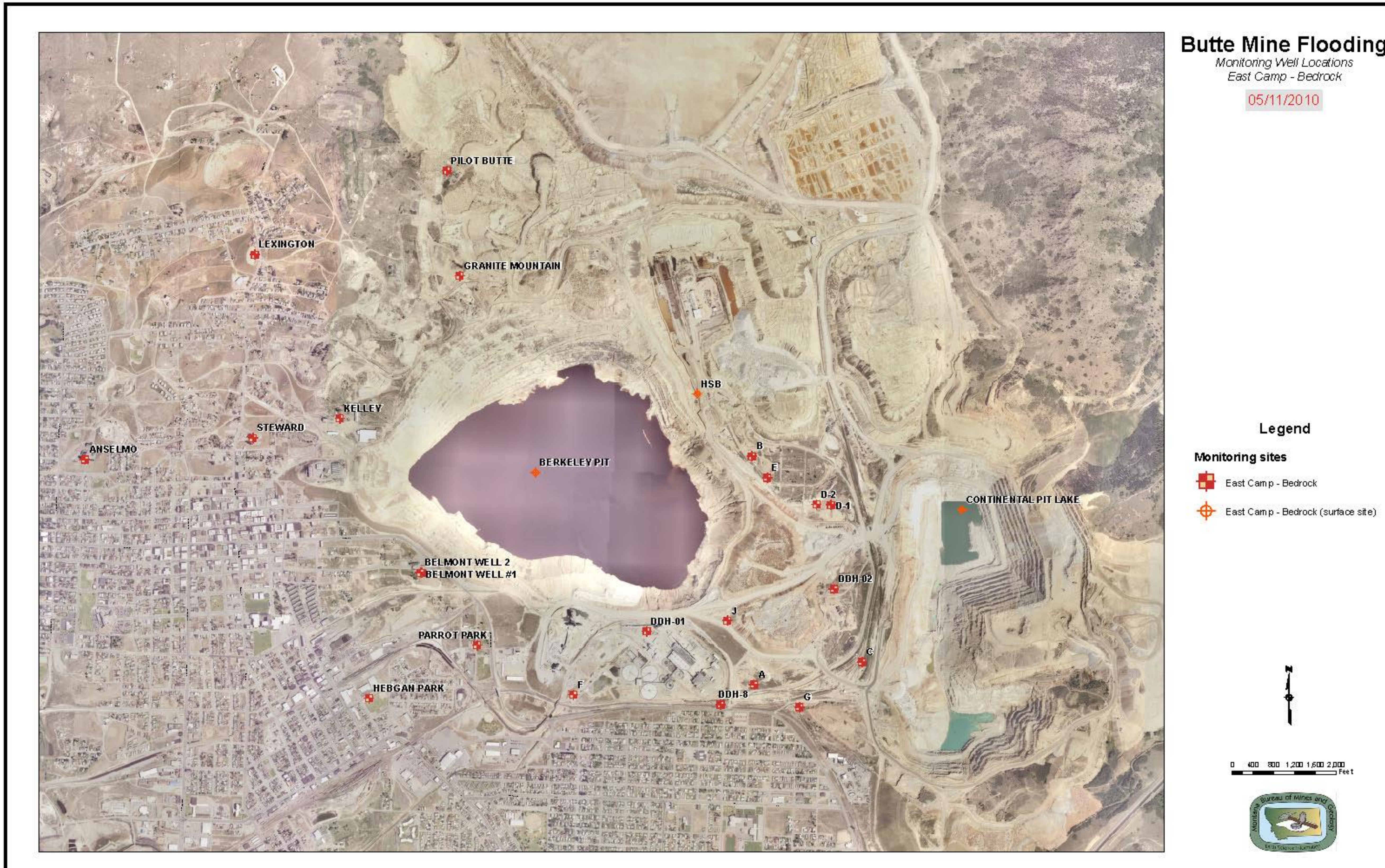


Figure 2-2. East Camp bedrock monitoring wells.

Section 2.1.1 AMC-Series Wells

The locations of the Anaconda Mining Company (AMC) wells are shown on 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 2012, with one well (AMC-10) remaining dry. This well has been dry since its installation in 1983. The decrease in water levels for 2012 is a change from 2011. Water levels had a net decline during the first 20 years of monitoring; however a majority of the wells had a net rise during seven of the past ten years. The overall water-level change is a net decline in six wells, with one well dry. Net declines vary from 2.9 ft to more than 26 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, 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 two 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 shown on figure 2-4 for this well 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 2012 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.

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
Net Change	**-26.13**	**-6.05**	**-5.71**	**0.00**	**-3.11**	**-2.96**	**-10.49**

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

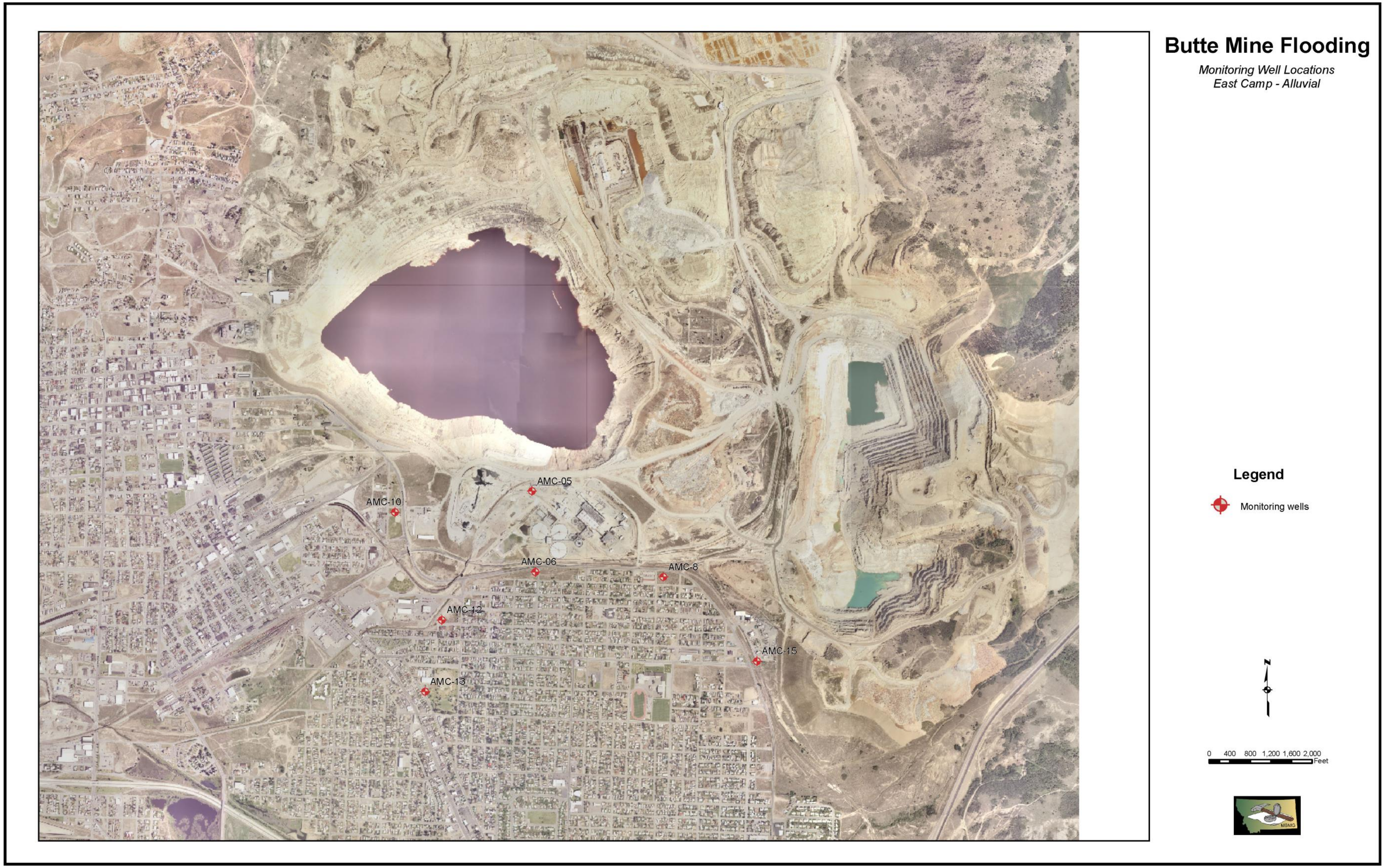


Figure 2-3. AMC well location map.

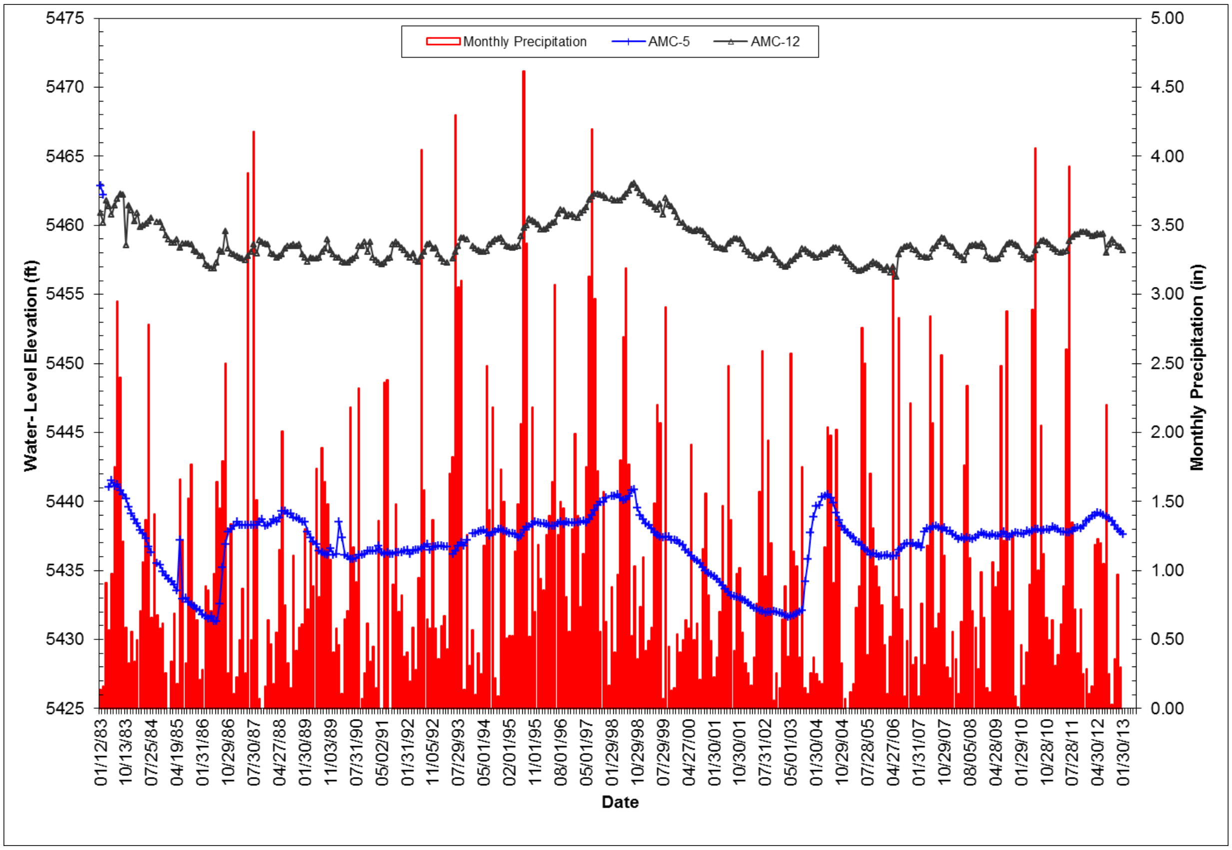


Figure 2-4. Water-level hydrographs for wells AMC-5 and AMC-12.

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 summer of 2005. Beginning late spring 2005, minor water-level increases (one foot or less) occurred which 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; following excavation of sediment, MR re-filled the pond, resulting in an increased water-level rise in October(fig. 2-5), continuing throughout the remainder of the year. 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. The decrease continued throughout the remainder of 2012. The water-level response in this well had been strongly influenced by seasonal precipitation conditions; 2011 and 2012 water-level responses were influenced by MR operational changes (filling and draining).

The water-level trend from 2003 through 2005 in well AMC-8 (fig. 2-5) was very similar to the 1986-1988 time period, with water levels declining following a period of increase 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 seen the past several years. Water levels followed a similar upward trend as seen in AMC-6 throughout 2012 with no seasonal variation.

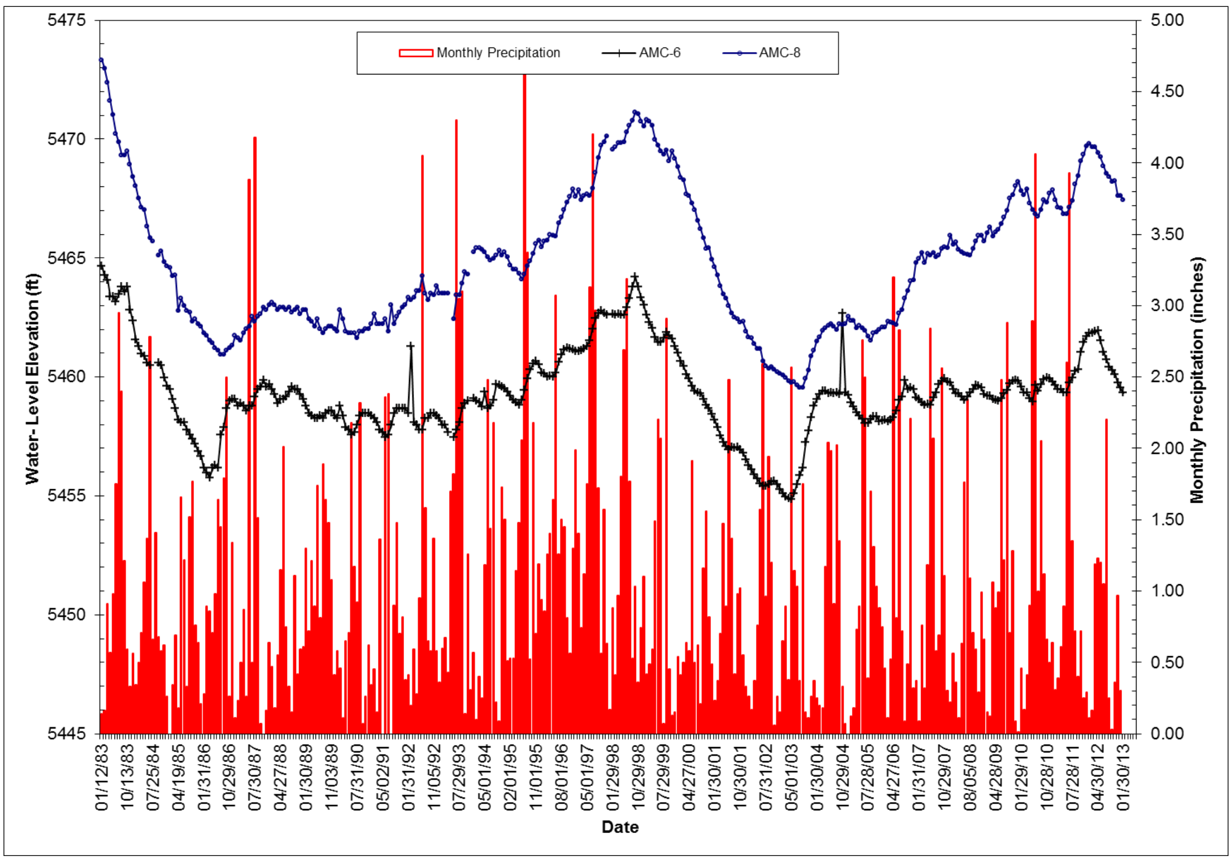
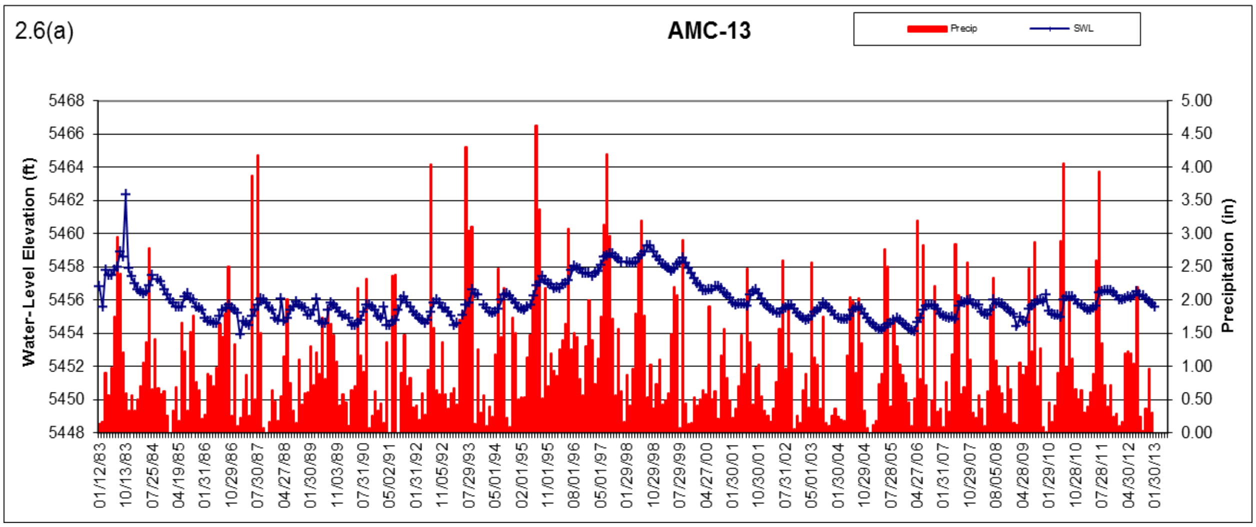


Figure 2-5. Water-level hydrographs for wells AMC-6 and AMC-8.

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 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 were the largest (1.13-ft) since 2006, which may be related to MR's cleaning of the Ecology Pond. The 2012 water-level decline may be in response once again to the draining and discontinued use of the Ecology Pond in 2012. The minor water-level decline in July was related to dewatering activities associated with nearby Butte Priority Soils activities and was short lived. Seasonal trends are noticeable on the well hydrograph.



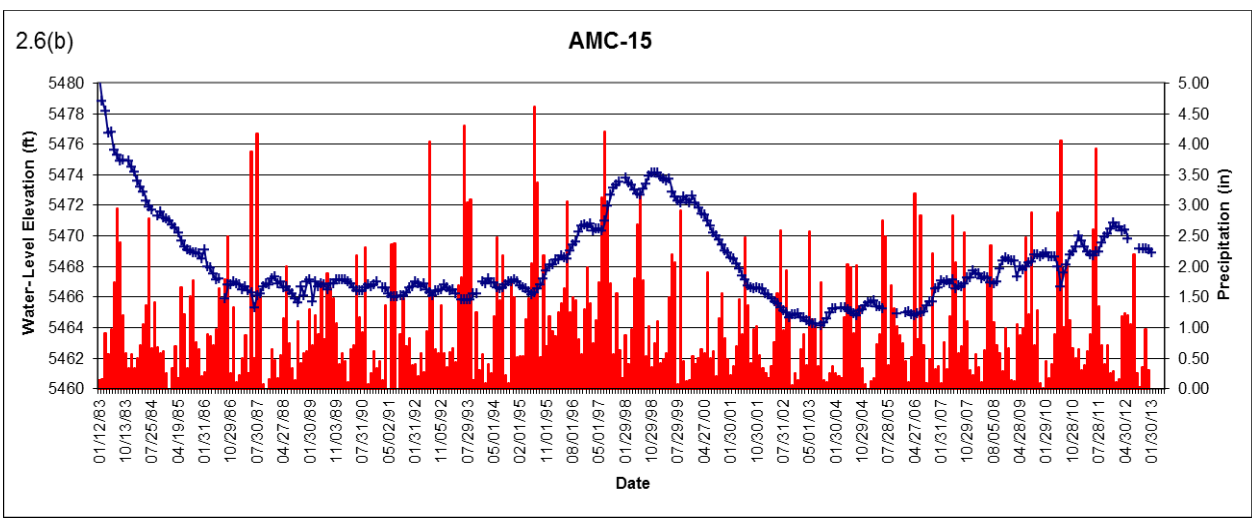


Figure 2-6. Water-level hydrographs for wells AMC-13 (a) and AMC-15 (b).

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 began to rise in late spring and continued throughout the summer, before starting to decline in the fall. This trend is similar to that of prior years showing typical seasonal changes.

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) compared to 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 one-half 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 other alluvial well sites. The water-level has net rise during eight of the past ten years. Access issues limited 2012 monitoring activities.

Section 2.1.1.1 AMC Series Water Quality

Trends of concentrations for chemical constituents in the 2012 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 containment levels (MCLs) and secondary maximum containment levels (SMCLs) throughout the period of record. The concentrations of most of the dissolved metals have shown a slight downward trend.

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 has 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 2012 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 October 2012. Cadmium concentrations have increased the past several years and are currently above the MCL.

Table 2.1.1.2 Exceedances and trends for AMC series wells, 2012

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 and cadmium
AMC-12	Y	Variable	Very high iron, manganese, cadmium, copper, and zinc
AMC-15	N	Variable	Unchanged in recent years, currently only sampled every two years

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 (Metro Storm Drain) 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 2012 showed very little change from previous years, the exception being sulfate and cadmium concentrations in well AMC-8 that continues to increase. Wells closest to historic and current mining operations have the highest levels of contamination; well AMC-5 has very high levels of iron, manganese, cadmium, copper, and zinc.

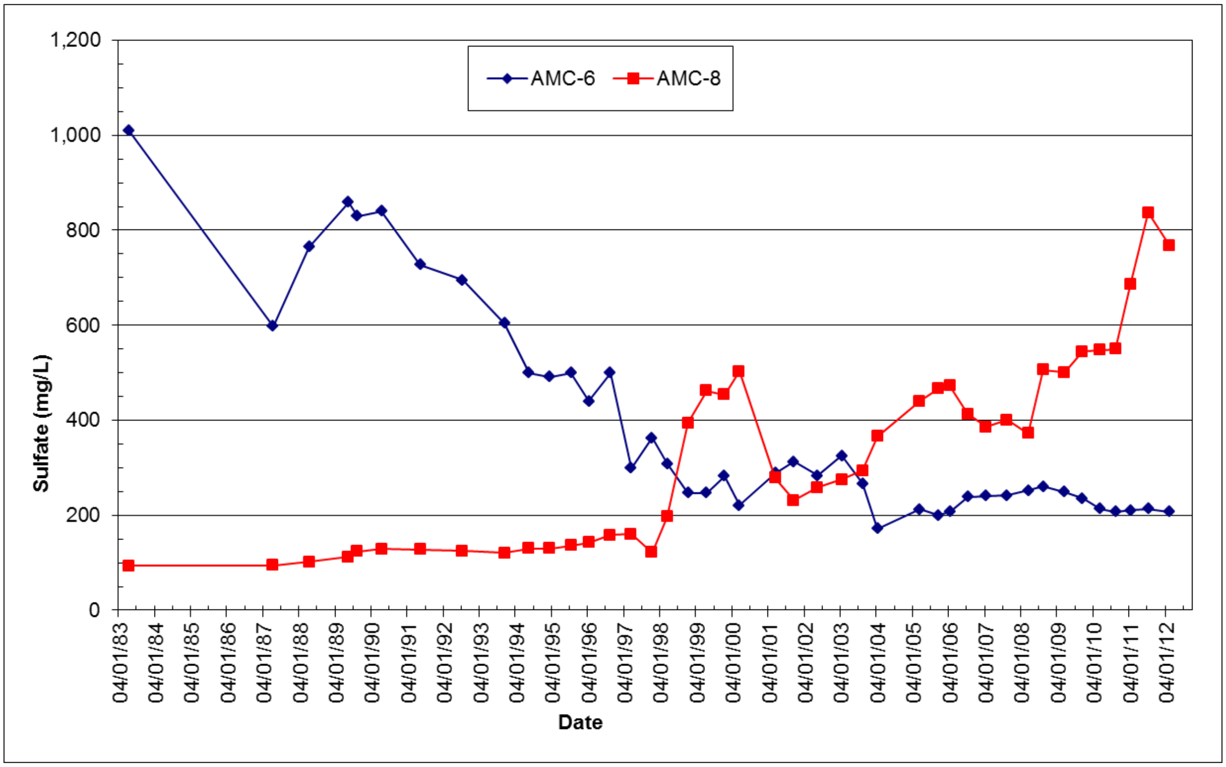


Figure 2-7. Graph showing sulfate concentration changes over time for wells AMC-6 and AMC-8.

Section 2.1.2 LP-Series Wells

The locations of the LP-series monitoring wells are shown on figure 2-8. 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 2012. Table 2.1.2.1 presents a summary of annual water-level changes for these 17 sites. Well LP-11 was plugged and abandoned in 2001; well LP-03 was plugged and abandoned in 2002 to make room for the HSB water-treatment plant. Wells LP-06 and LP-7, had been dry for over three years, before having a water-level rise during 2004; however, they had a corresponding decline in 2005 and have been dry ever since. Well LP-6 was plugged and abandoned in 2010 to allow for mine expansion. Well LP-8 has been dry since May 2010. Water levels declined in eight of the remaining 12 wells, not already pugged or dry, during 2012. Wells near MR dewatering activities had the largest water-level decline during 2012, varying from 3.19 ft to 65.32 ft. Since monitoring began, water levels have experienced a net decline in 13 of the LP series wells, ranging from 5.32 ft in LP-10 to 64 ft in well LP-15. Net water-level increases vary between 0.38 ft and 4.61 ft in four wells (LP-12, 13, 14, and 17) located to the south of the Pittsmont Dump.

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
Change Years 21-30	**1.37**	**-0.03**	P&A*	**-0.08**	**0.10**	**Dry**	**Dry**	**Dry**	**4.56**
Net Change	**-25.93**	**-24.41**	**-31.45**	**-30.68**	**-32.02**	**-4.17**	**-17.43**	**-43.01**	**-29.14**

(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
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
Change Years 21-30	**-4.15**	**P&A***	**-4.81**	**-3.52**	**-1.58**	**-64.45**	**-3.00**	**-3.89**
Net Change	**-5.32**	**-5.38**	**1.69**	**0.38**	**4.61**	**-64.98**	**-6.69**	**1.54**

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

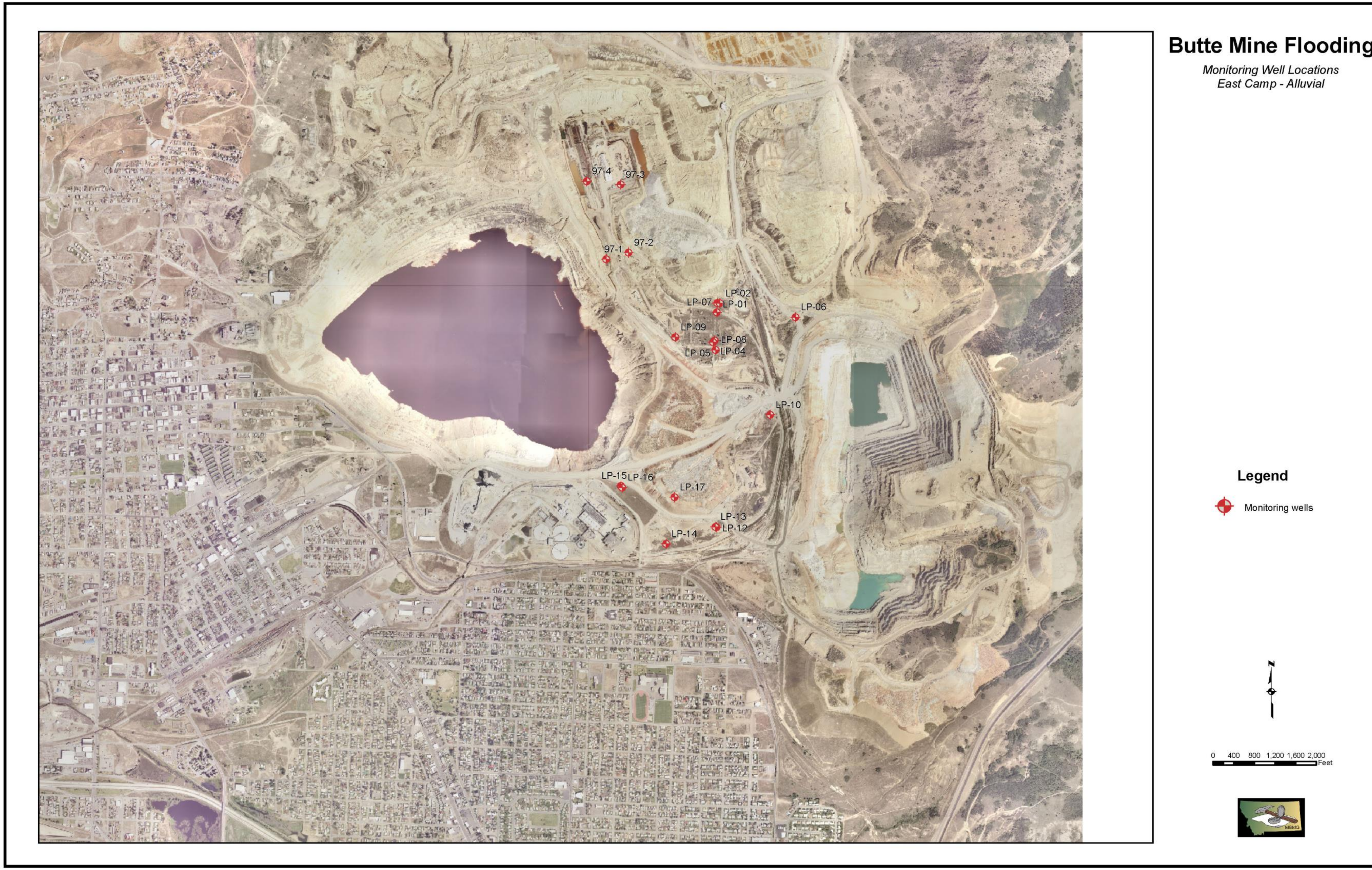


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Figure 2-8. LP series and MR97 wells location map.

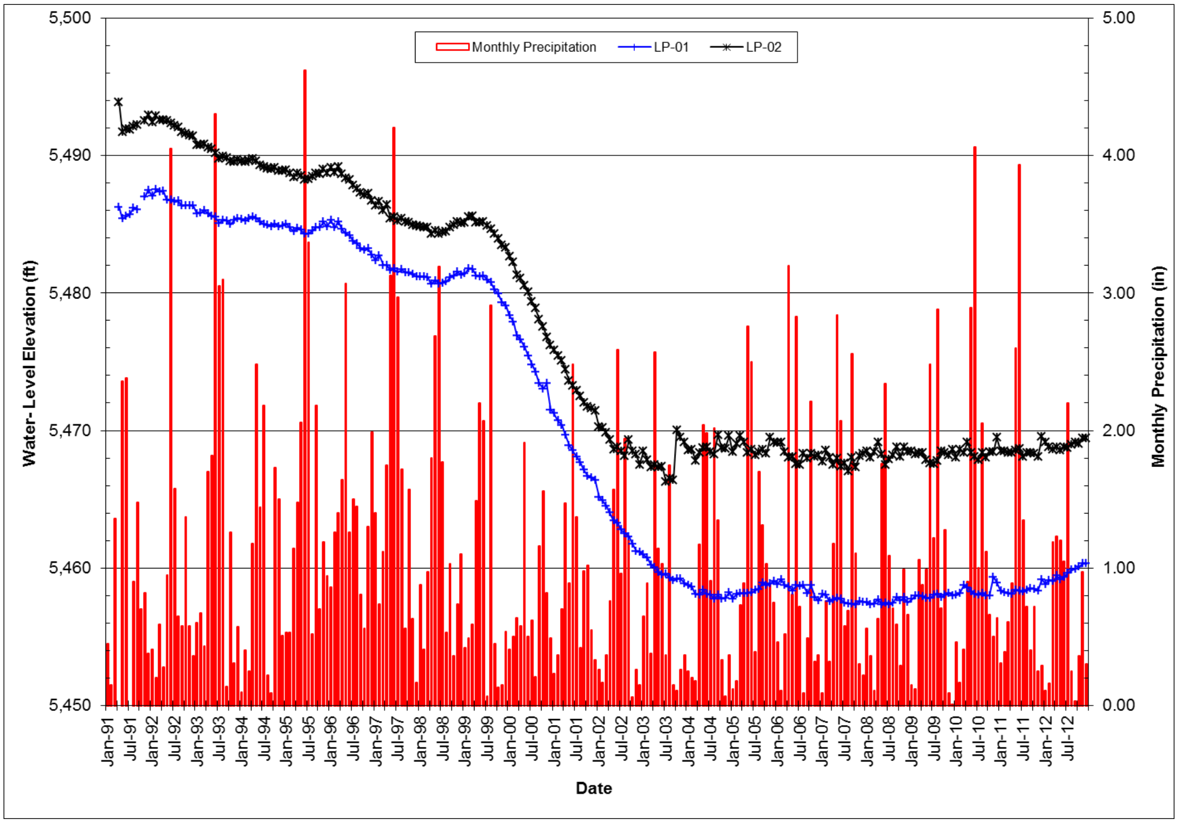


Figure 2-9. Water-level hydrographs for wells LP-01 and LP-02.

The increases in water levels to the north of the Pittsmont Waste Dump is a substantial change from trends seen in water-level trends (decline) observed between 1992 and 2003. The 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 down gradient of the leach pads where the leaching took place. Limited leaching operations were undertaken during 2010-2012 by MR as part of their active mining operations, which might be reflected in 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 on figure 2-9, water levels steadily declined for the most part since its installation through 2004. Since then water levels have varied slightly with periodic increases followed by declines. 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 from 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.

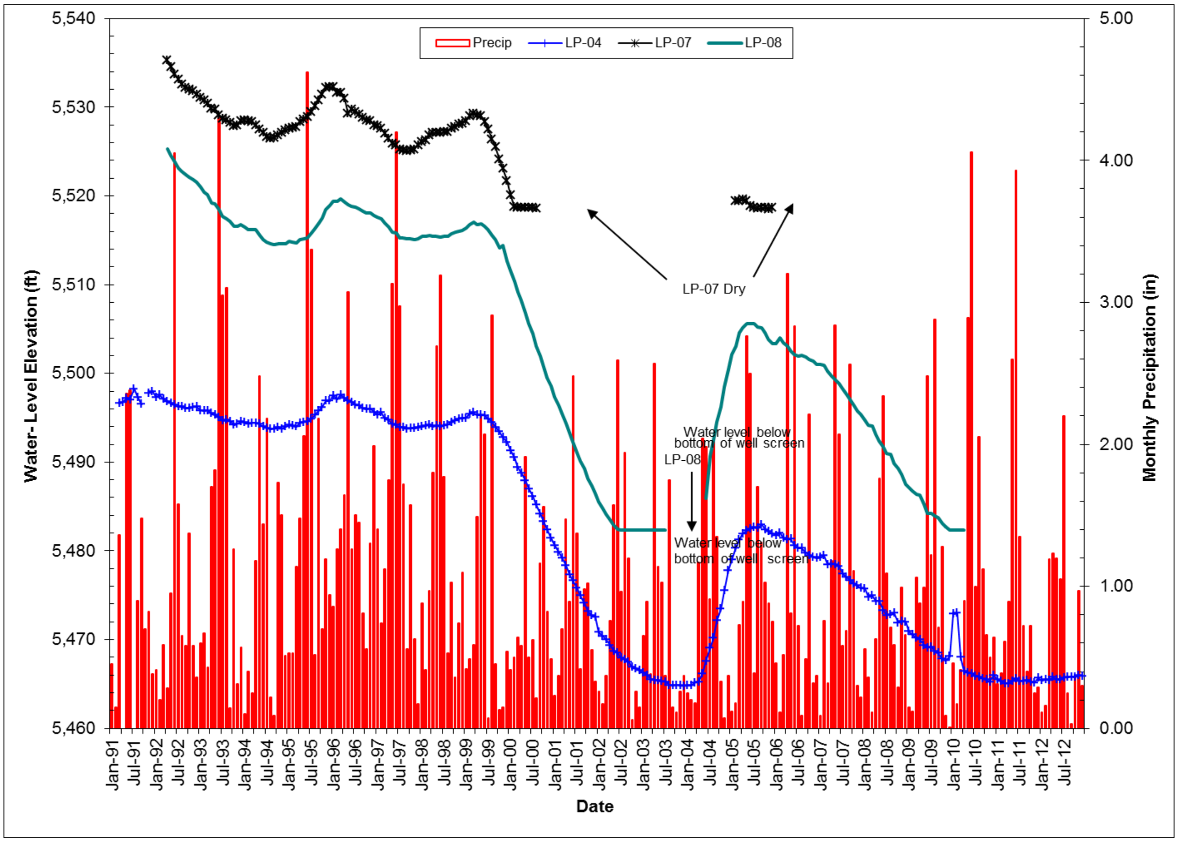


Figure 2-10. Water-level hydrographs for wells LP-04, LP-07, and LP-08.

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 are similar for wells LP-04, LP-07, and LP-08. 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 on figure 2-10. Well LP-07 has remained dry since the later part of 2000, except for a short period of time in early 2005. LP-8 has been dry since mid-2010.

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 of 2004.

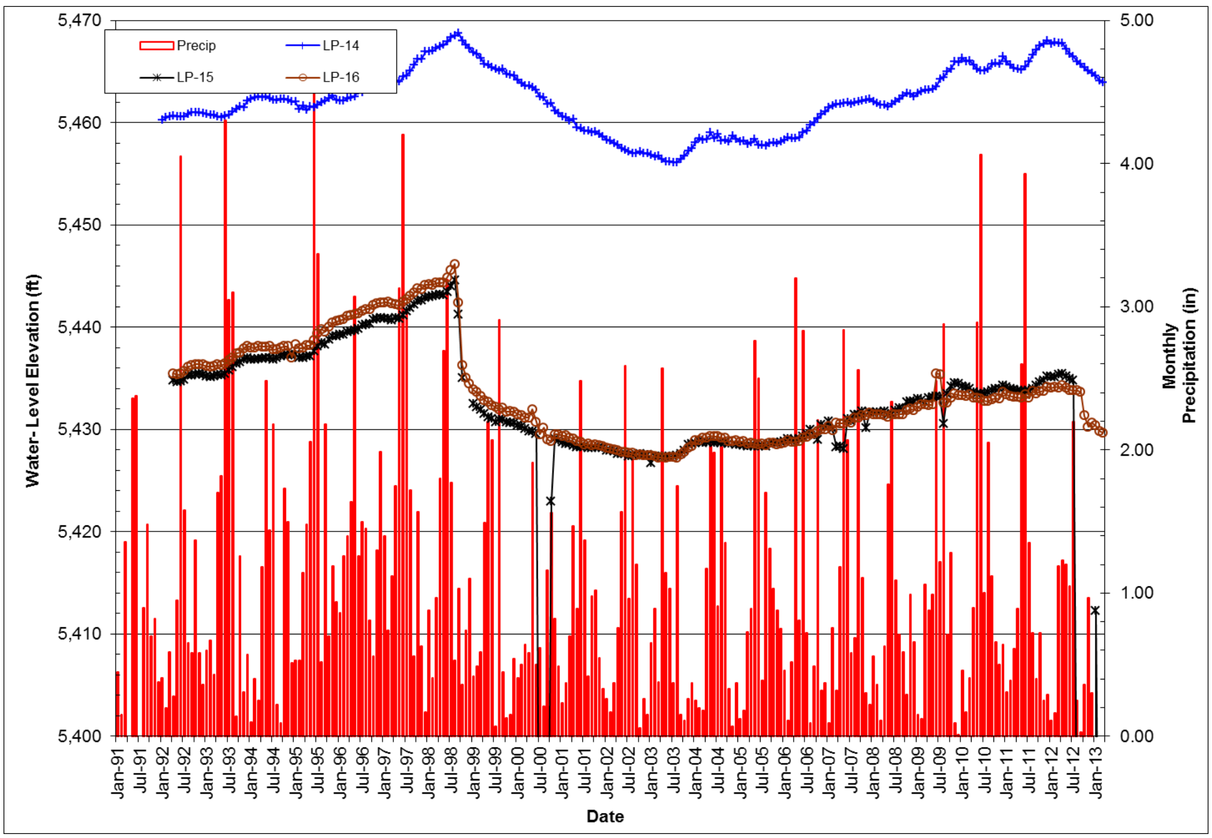


Figure 2-11. Water level changes for wells LP-14, LP-15, and LP-16 before and after 1998 Berkeley Pit landslide.

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 landslides. This is in contrast to observations made following the 1998 landslide when water-levels decreased dramatically. 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 throughout the remainder of the year. Pumping resulted in significant drawdown of water levels near the well, figure 2-12. MR also installed three additional dewatering wells in the area which have operated almost continuously since their installation.

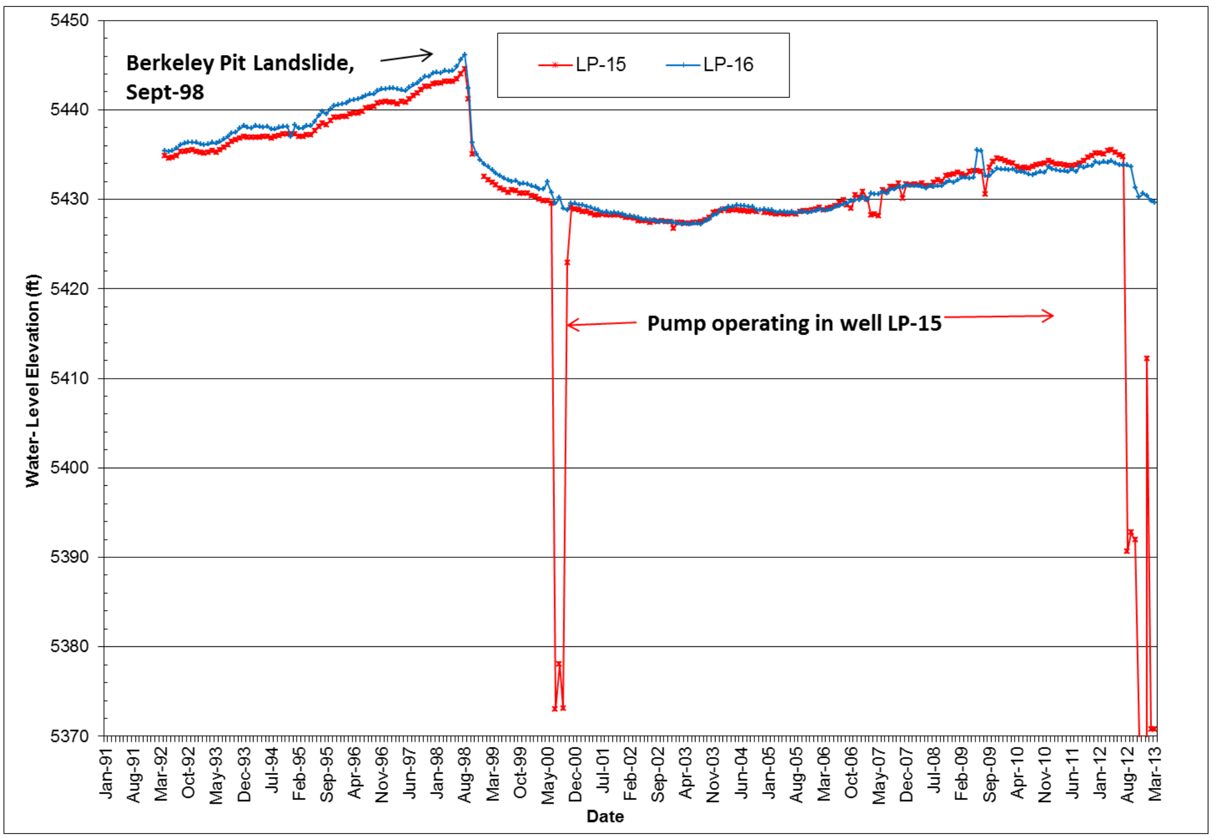


Figure 2-12. Water-level hydrographs showing influence of dewatering on water-levels in wells LP-15 and LP-16.

The net result of these pumping activities was the decrease in water-levels in the alluvial aquifer in the general area of dewatering. Transducers were installed in monitoring wells LP-12, LP-13, and LP-16 to better track water-level changes, following the November landslide.

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 either controlled by the operation and subsequent dewatering of the leach pads, operation of the Yankee Doodle Tailings Dam, by depressed water levels in the Berkeley Pit, or a combination of all three. The water-level response seen in wells adjacent and down-gradient of limited leaching operations during 2004-2005 and 2009-2012 clearly demonstrates the relationship of water-level changes and the leach pads operations. The influence of climatic changes is minimal, at best, on these wells.

An alluvial aquifer potentiometric map (fig. 2-13), constructed using December 2012 water levels (BMF monitoring well network sites only) show 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.

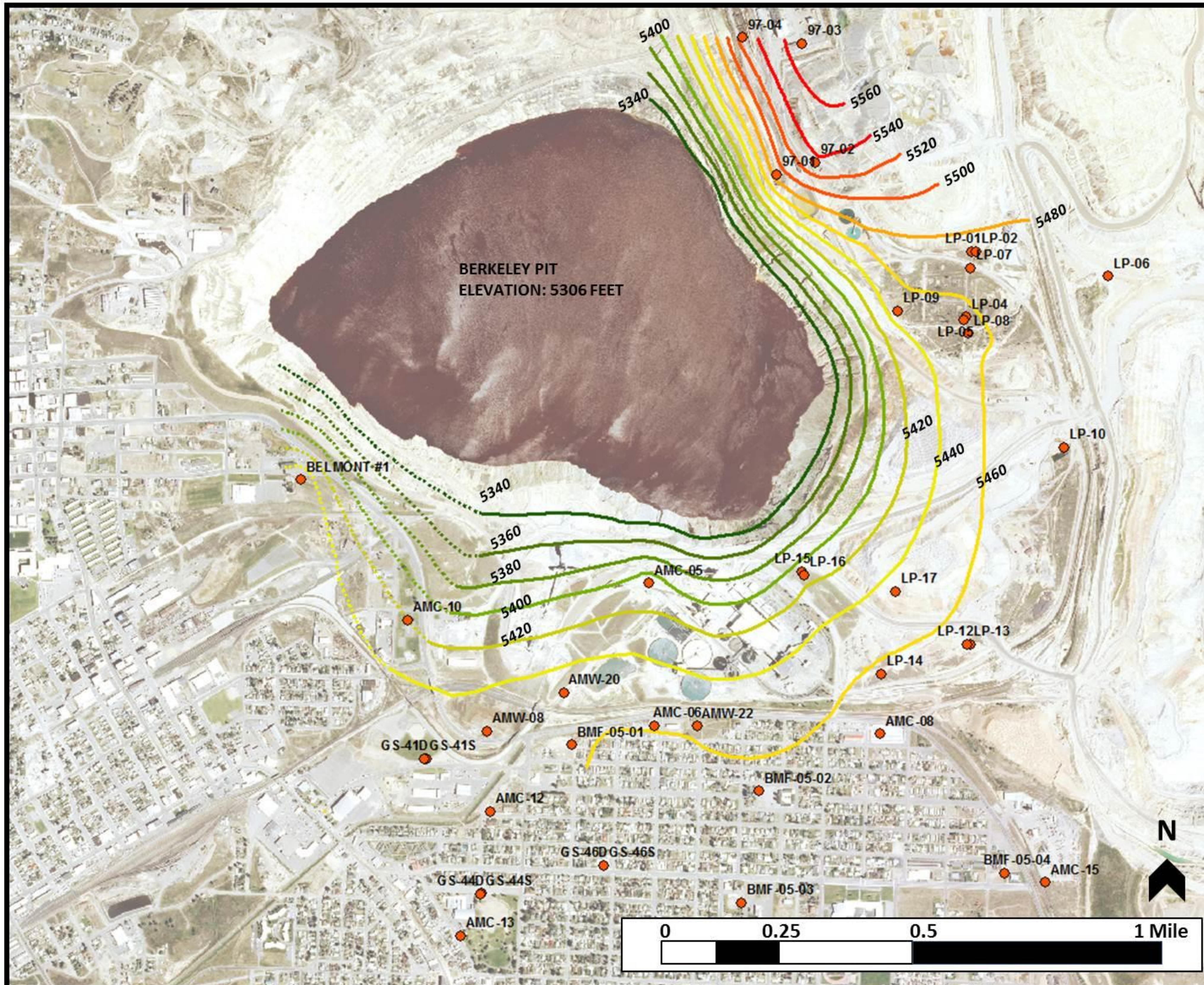


Figure 2-13. Alluvial aquifer potentiometric map for December, 2012 (contour interval is 20 feet).

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, LP-09, and LP-10), which are south of the leach pad area and north of the Pittsmont dump. Water-quality trends in 2012 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 of 2003; it has been sampled yearly until 2011 when there was too little water in the well to collect a sample. Water-levels increased enough in 2012 to allow sampling to occur. A comparison of the data indicates large increases in the concentration of most dissolved constituents starting in 1994. Data collected in 2010 and 2012 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 in 2012; and zinc increased from 172,000 µg/L in 1992 to levels greater than 1,600,000 µg/L in 2012. (Zinc concentrations declined somewhat below those seen the past few years, 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 six to ten years and approach those values seen in the pregnant solution of the up-gradient leach pads.

Well LP-16 exhibited moderate increases for sulfate, copper and zinc in 2010-2012 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, current concentrations are still three times the MCL.

The water-quality trend in other LP-series wells generally remained the same in 2012 as in recent years. A summary of exceedances and trends is presented in table 2.1.2.2.

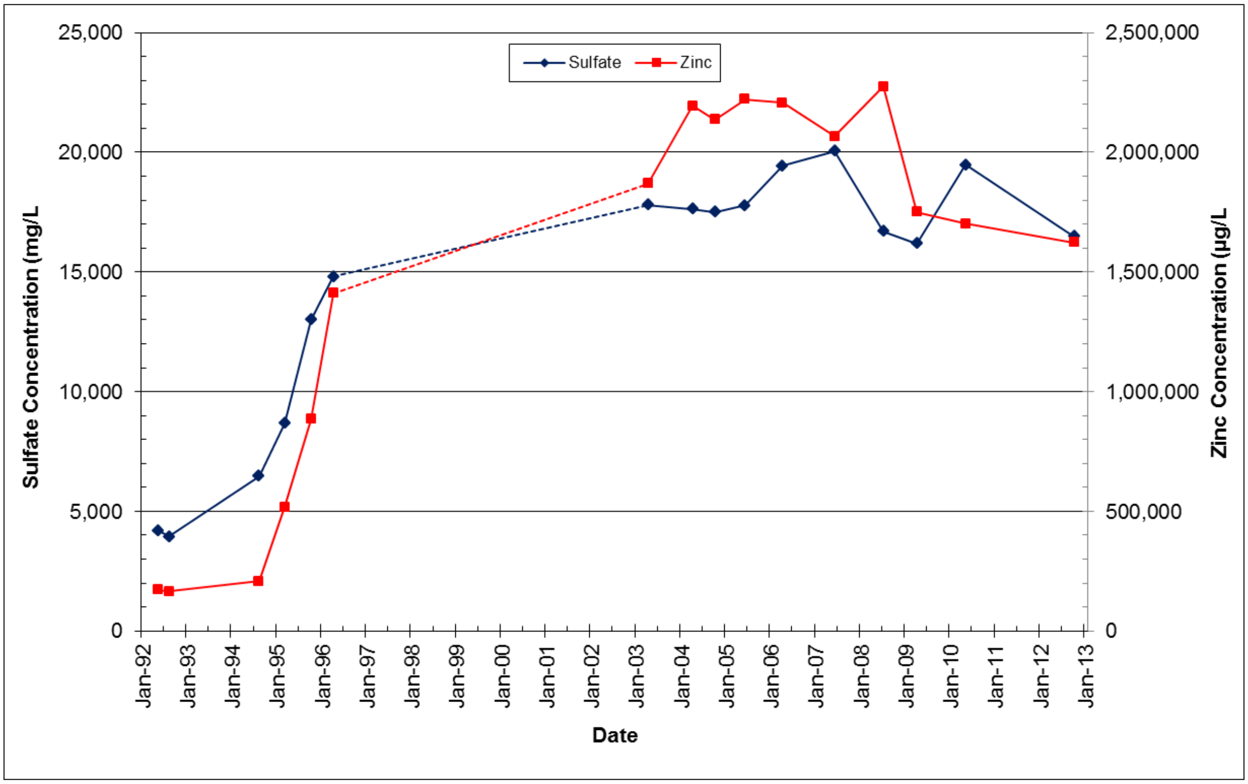


Figure 2-14. Sulfate and zinc concentrations in well LP-09.

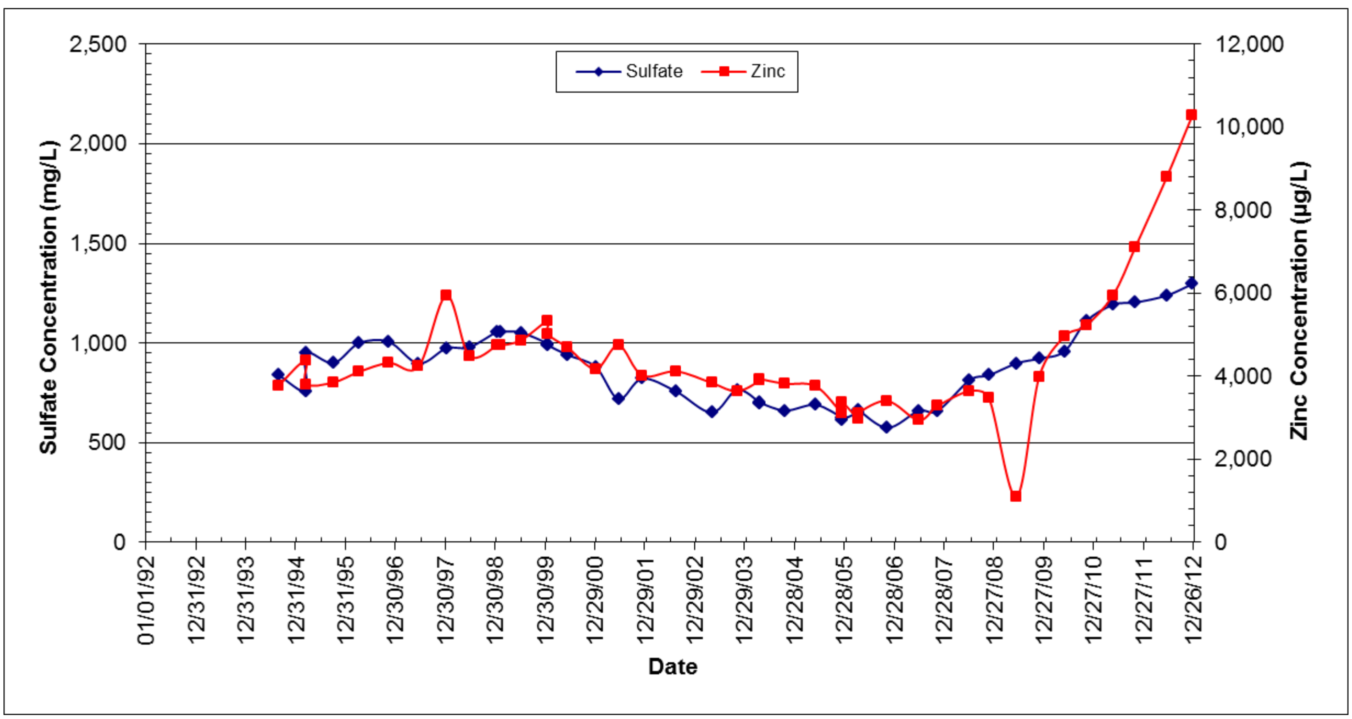


Figure 2-15. Sulfate and zinc concentrations in well LP-16.

Table 2.1.2.2 Exceedances and trends for LP series wells, 2012

Well Name	Exceedances (1 or more)	Concentration Trend	Remarks
LP-08	Y	Downward	Very elevated concentrations. No 2012 sample.
LP-09	Y	Upward	Large increases since 1992. No 2011 sample.
LP-10	N	None	No significant changes in 2009, not sampled in 2006-2007, 2010 due to access problems.
LP-12	Y	None	No significant changes in 2012.
LP-13	Y	None	No significant changes in 2012.
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	Variable	Sulfate trend continues increase seen in 2008, copper and zinc increased 2010-2012.
LP-17	Y	Downward	Nitrate declining; however, still 3 times MCL.

Section 2.1.3 Precipitation Plant Area Wells

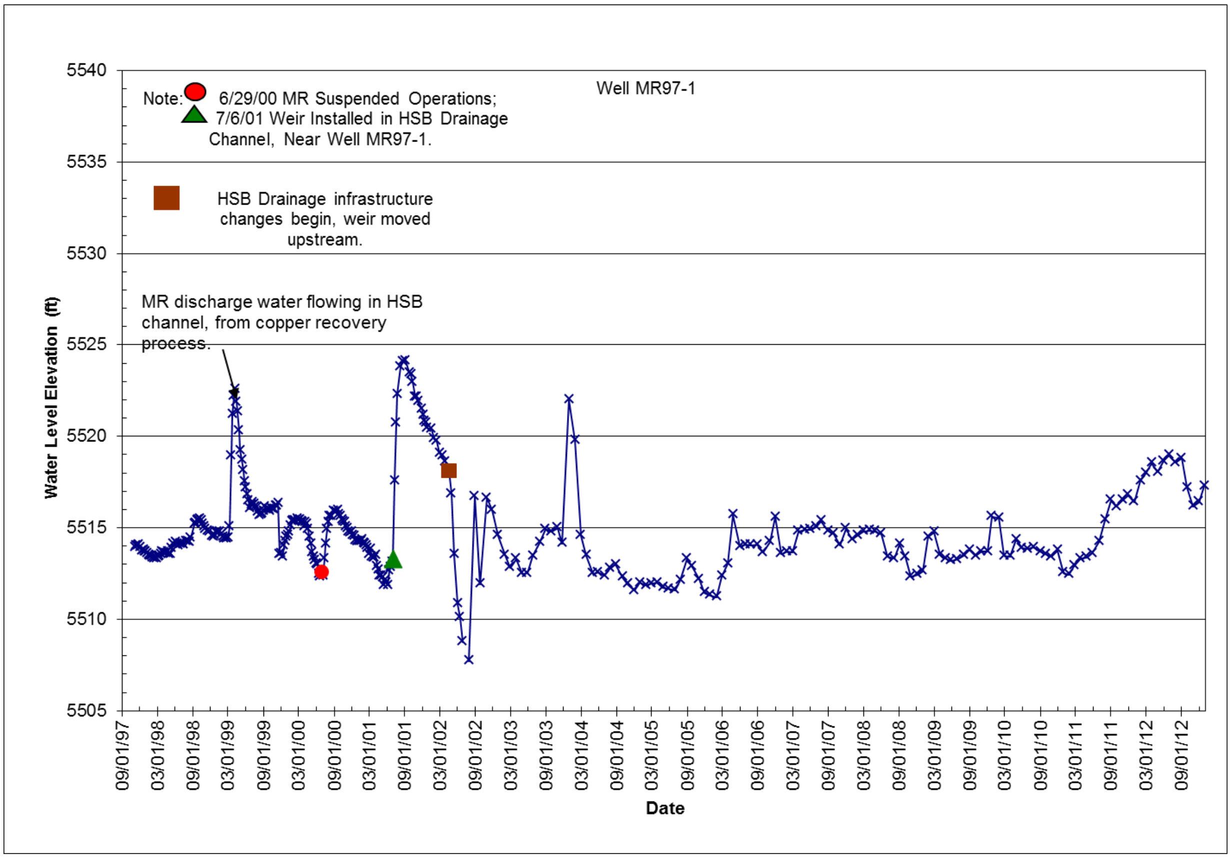
Wells MR97-1, MR97-2, MR97-3, and MR97-4 (fig. 2-8) are adjacent to various structures (drainage ditches, holding ponds) associated with the leach pads and precipitation plant. Table 2.1.3.1 lists annual and net water-level changes for these wells. Water-level changes appear to correspond to flow in 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
Change Years 11-15	**3.70**	**9.10**	**6.73**	**-3.02**
Net Change	**3.36**	**0.95**	**-5.04**	**-0.12**

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

Water levels in well MR97-1 have shown the greatest degree of variations (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 are 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 shut-down. 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.



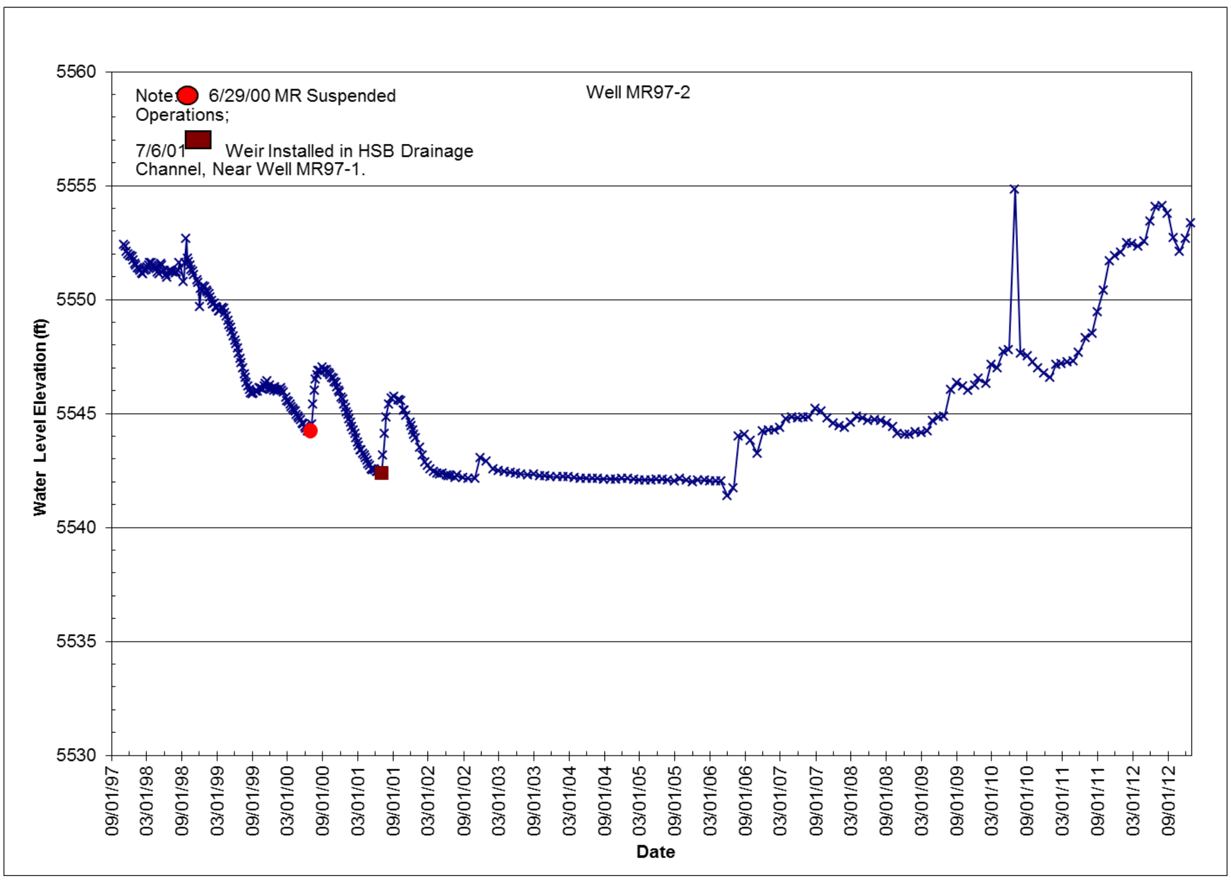


Figure 2-16. Water-level hydrograph for well MR97-1 (top) and MR-97-2 (bottom).

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 up gradient 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 2012 but with a slight downward 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 became less 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 2009-2012 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, figure 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 2009-2012.

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 2008-2012. 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.

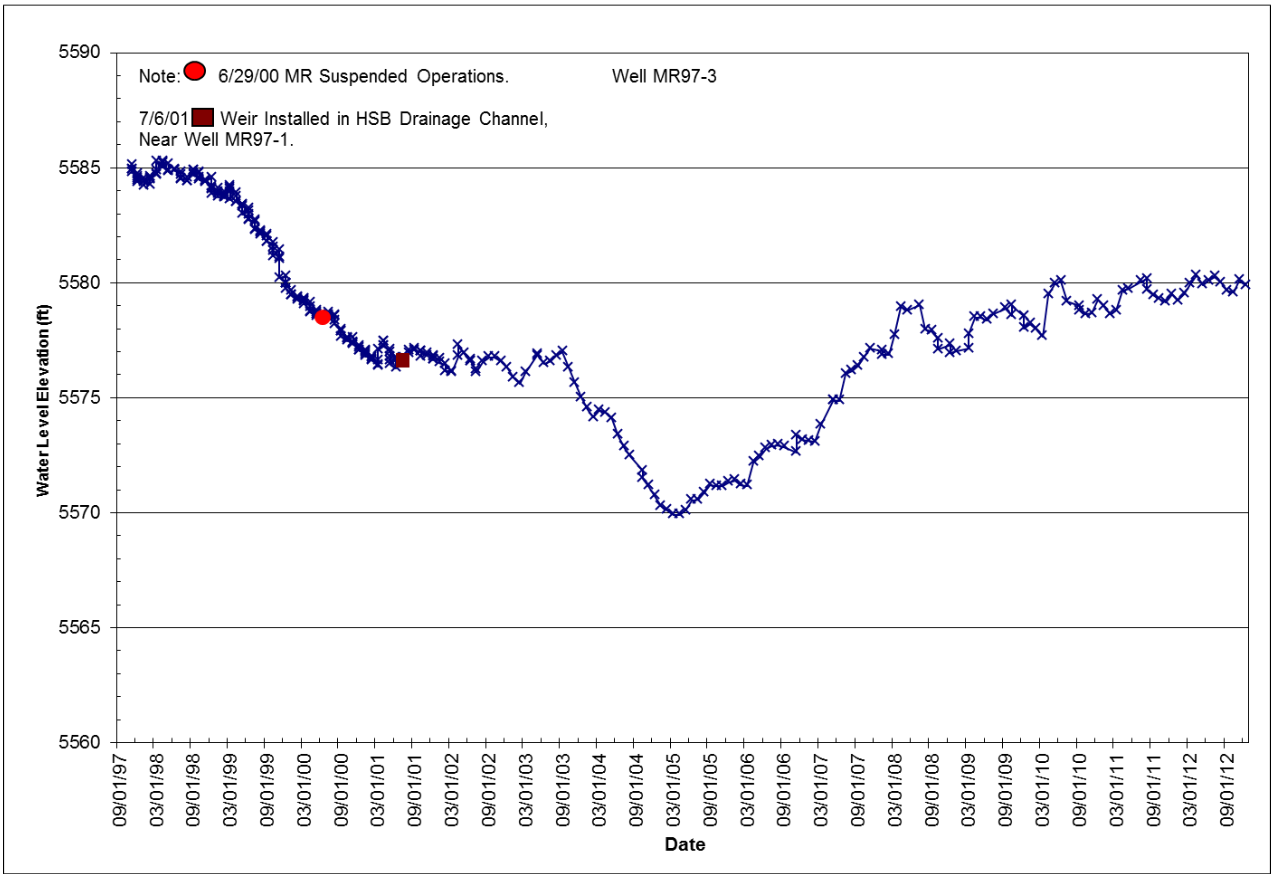


Figure 2-17. Water-level hydrograph for well MR97-3.

Water-level changes in well MR97-4, figure 2-18, have shown the least amount of variability over time. Water levels declined during most of 2011, with a net decline of all most 2 ft. The net water-level change in this well is less than 0.10 ft over time.

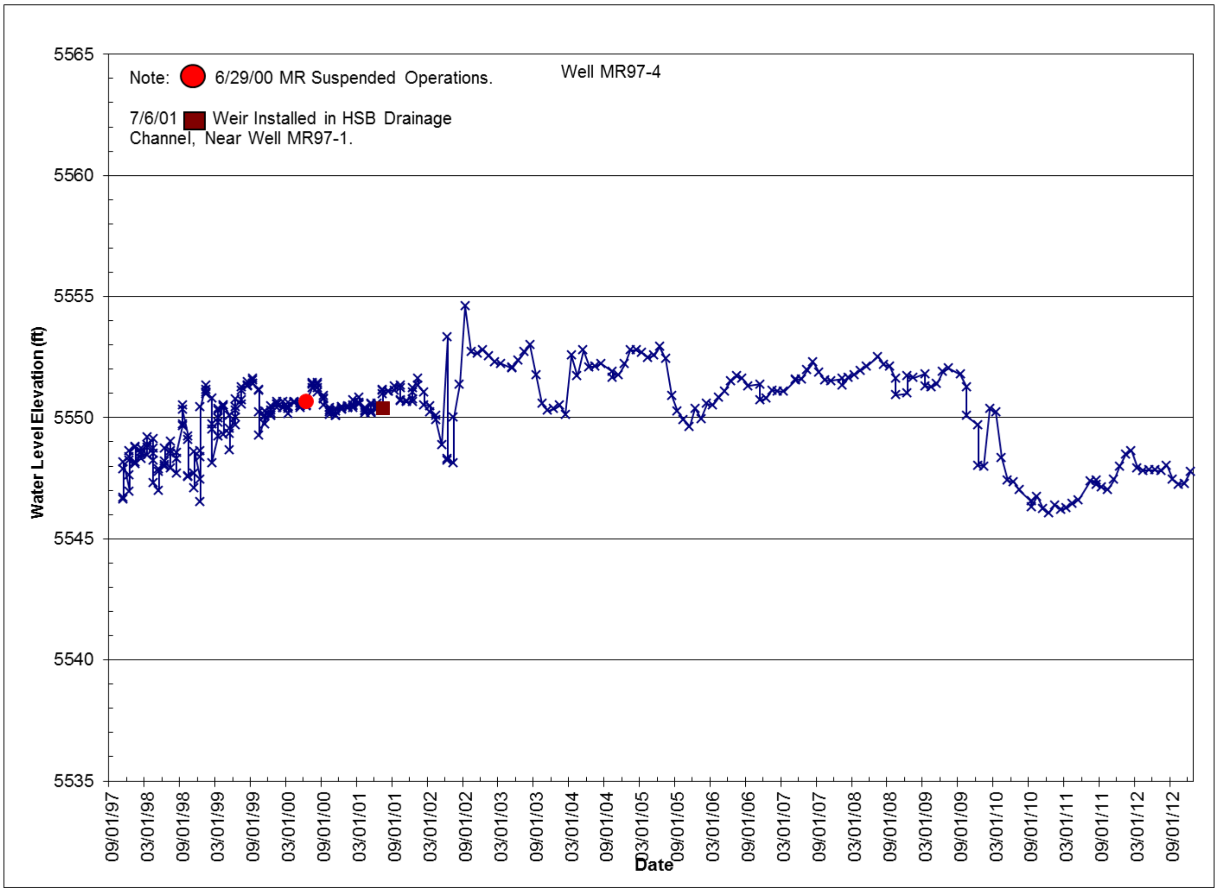


Figure 2-18. Water-level hydrograph for well MR97-4.

Water levels have declined 5ft 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 0.95 and 3.36 ft in wells MR97-1and MR97-2, respectively. It appears there is a direct influence on the shallow alluvial aquifer in this area by mining 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 2012. Previous sampling documented the presence of elevated metals 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 2012. The locations of these wells are shown on 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 all six GS-series wells, with net increases ranging from 0.2 ft to 2.3 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 2012 (fig. 2-20) and the influence of precipitation was very noticeable. Water levels decreased about 1 ft in these two wells during 2012.

Net water-level changes in the GS-44 series wells during 2012 were similar to those seen in the past and in those seen in 2012 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 2012 (fig. 2-21. The water levels in wells GS-44S and GS-44D decreased 0.56 ft and 0.60 ft, respectively, during 2012.

Overall, water-level trends were similar during 2012 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 0.75 ft during 2012, while having a net water-level rise since monitoring began.

The influence of BPSOU dewatering activities near Texas Ave. and Civic Center Road were noticeable in July through September 2012 water-levels. These changes were characterized by a larger-than-usual water level decline followed by a similar water-level rise once pumping (dewatering) stopped. Water-level changes were more pronounced in the GS-41 series wells which were closer to the dewatering; however, the influence in dewatering on the local groundwater system was noticeable at all three well locations. Figure 2-23 shows dewatering influences on water-levels in wells GS-41S and GS-41D that were observed in transducer data.

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**
Net Change	**0.20**	**0.30**	**0.97**	**0.88**	**2.30**	**1.87**	**1.78**	**1.63**	**2.98**	**3.39**

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

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

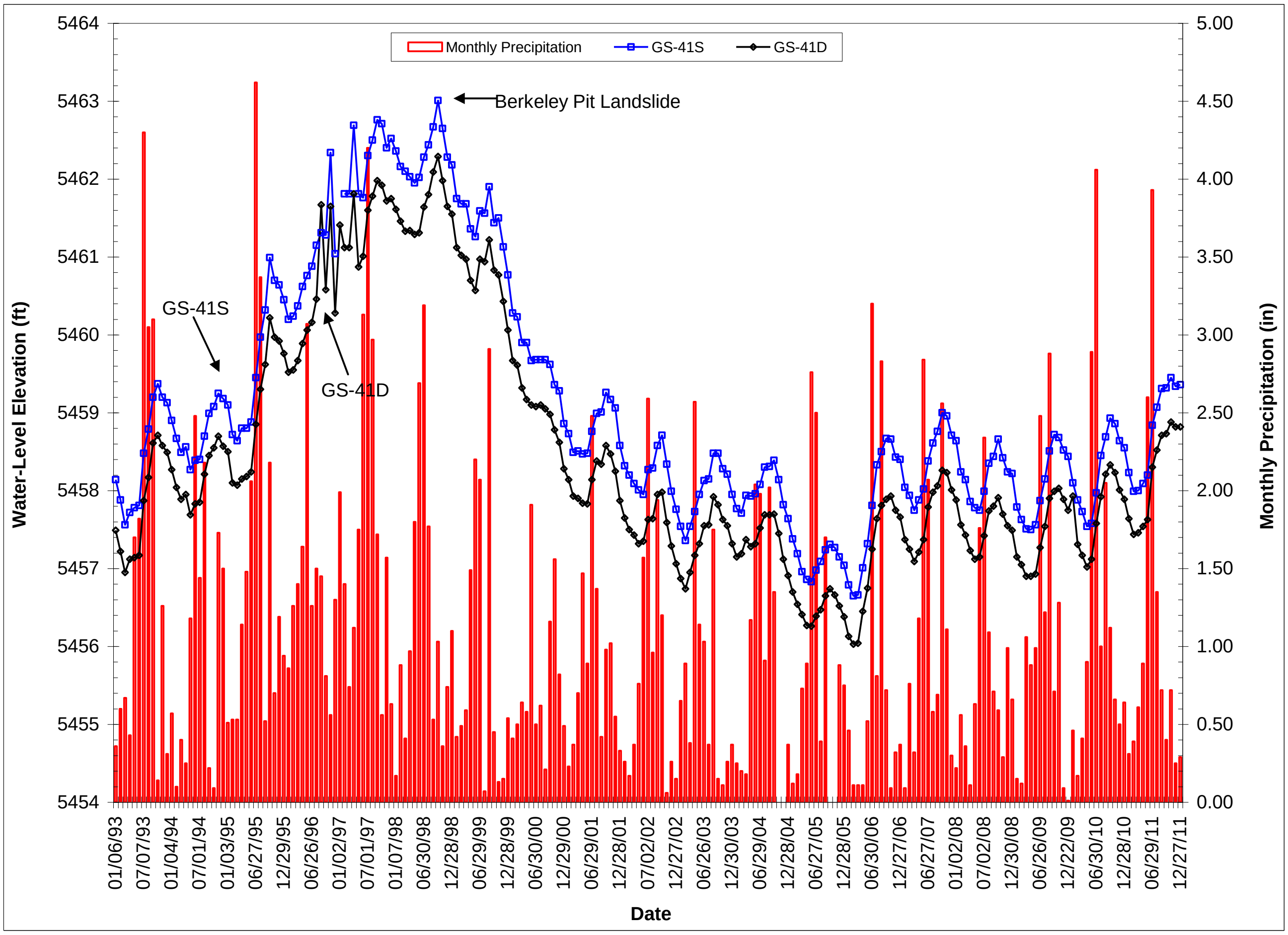


Figure 2-20. Water-level hydrographs for wells GS-41S and GS-41D.

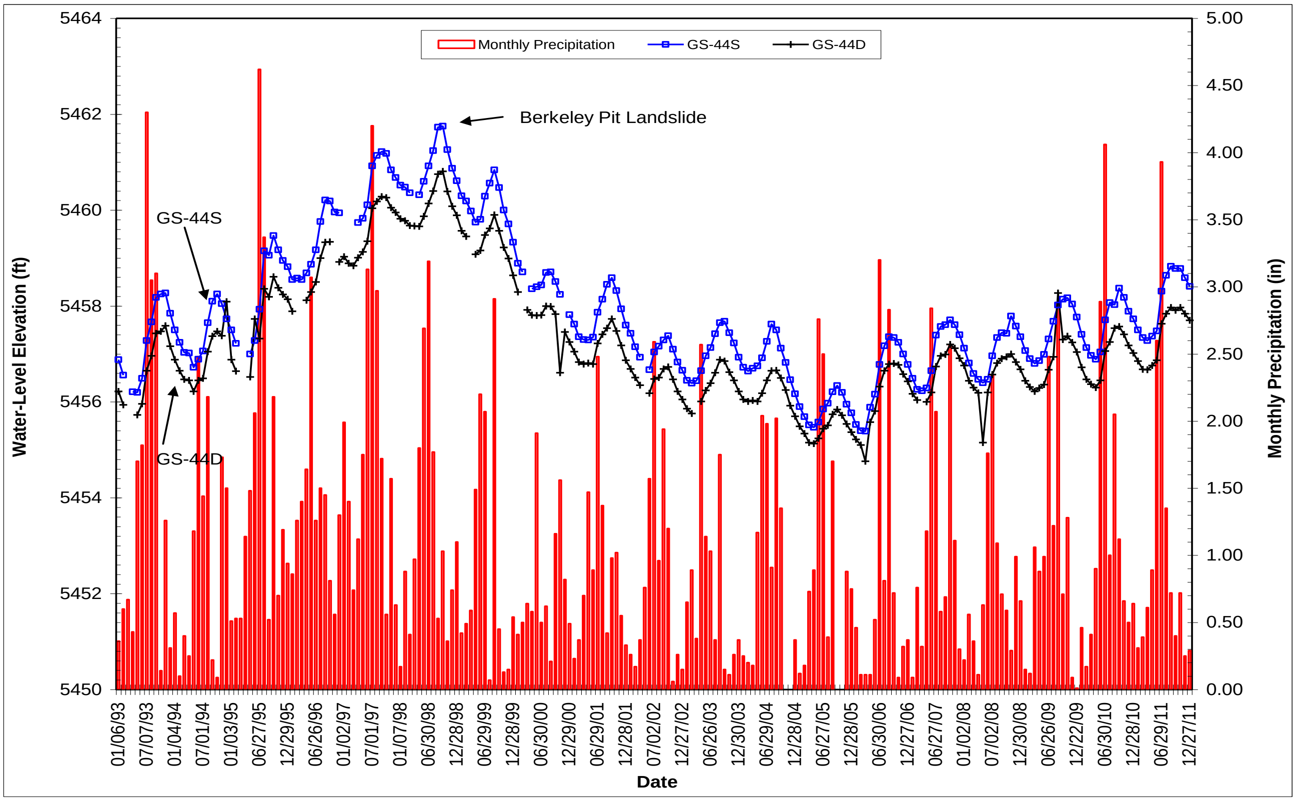


Figure 2-21. Water-level hydrographs for wells GS-44S and GS-44D.

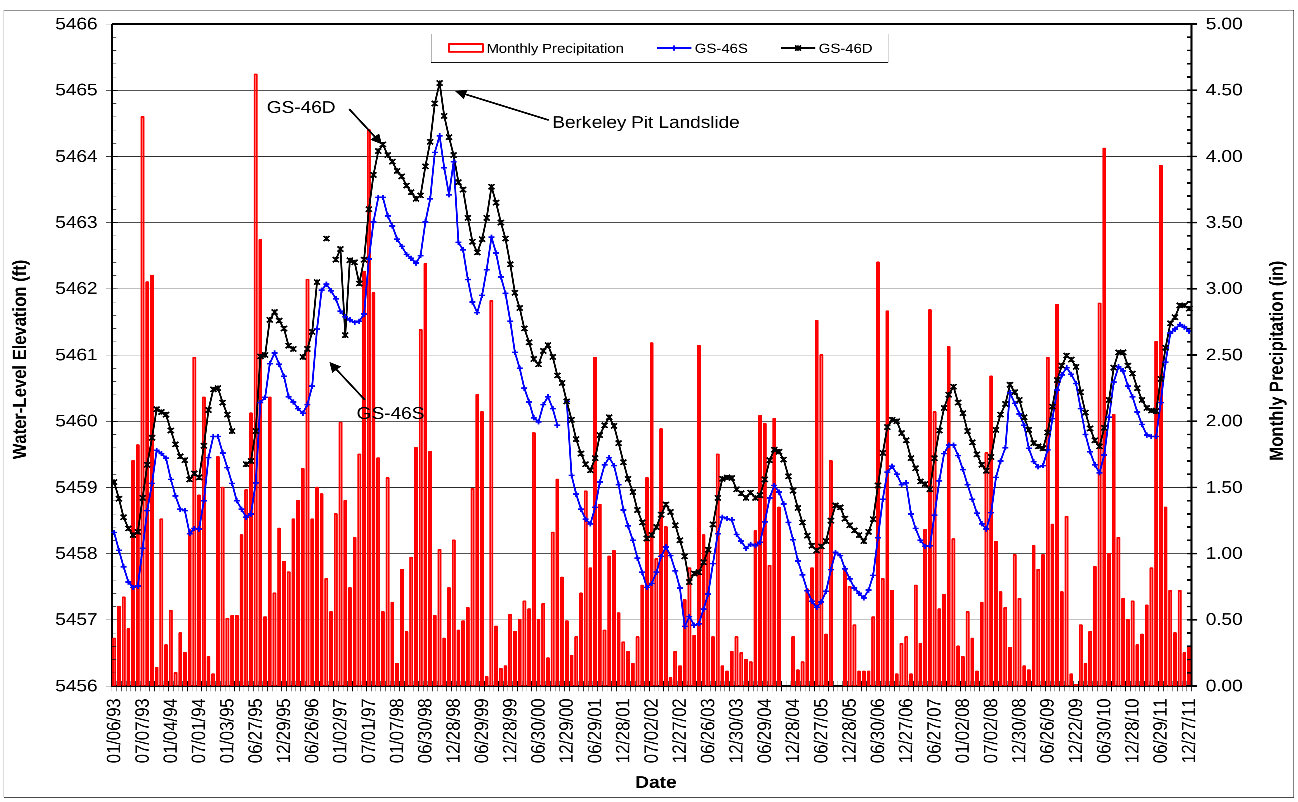


Figure 2-22. Water-level hydrographs for wells GS-46S and GS-46D.

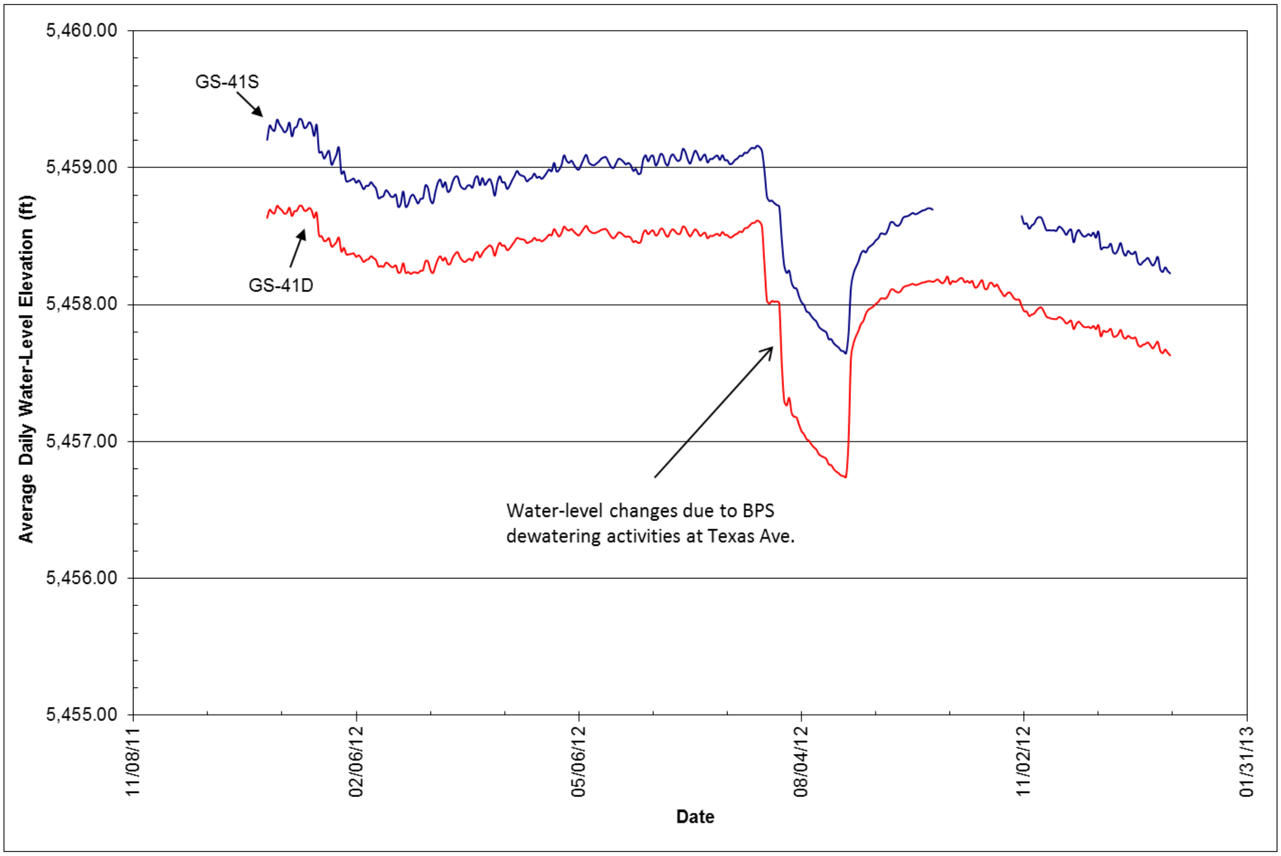


Figure 2-23. Water-level hydrographs for wells GS-41S and GD-41D showing influence of Butte Priority Soils dewatering activities at Texas Ave.

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 location of these wells is shown on 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 2-24 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 data set. Each well has an overall upward water-level trend that levels off in the fall and early winter with the exception of well BMF05-4. The water level continued to rise throughout the fall and winter in this well. 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 the last quarter of 2011; this increase corresponds to the re-filling of MR's Ecology Pond following maintenance activities during the summer. A water-level decline occurred in this well, corresponding to the timing of MR's draining of the pond. Water level trends were similar to those noted in well AMC-6, located nearby. Figure 2-25 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 snow-melt 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.

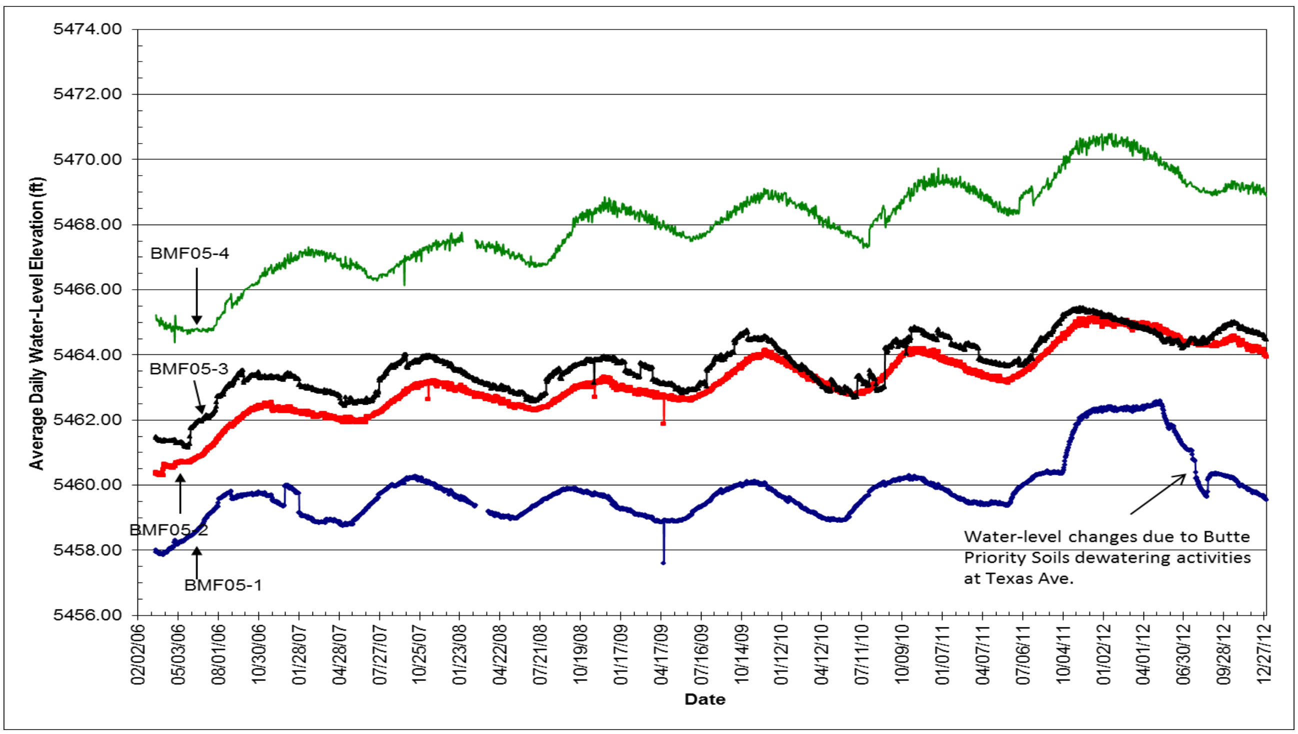


Figure 2-24. Average daily water-levels for BMF05 series wells.

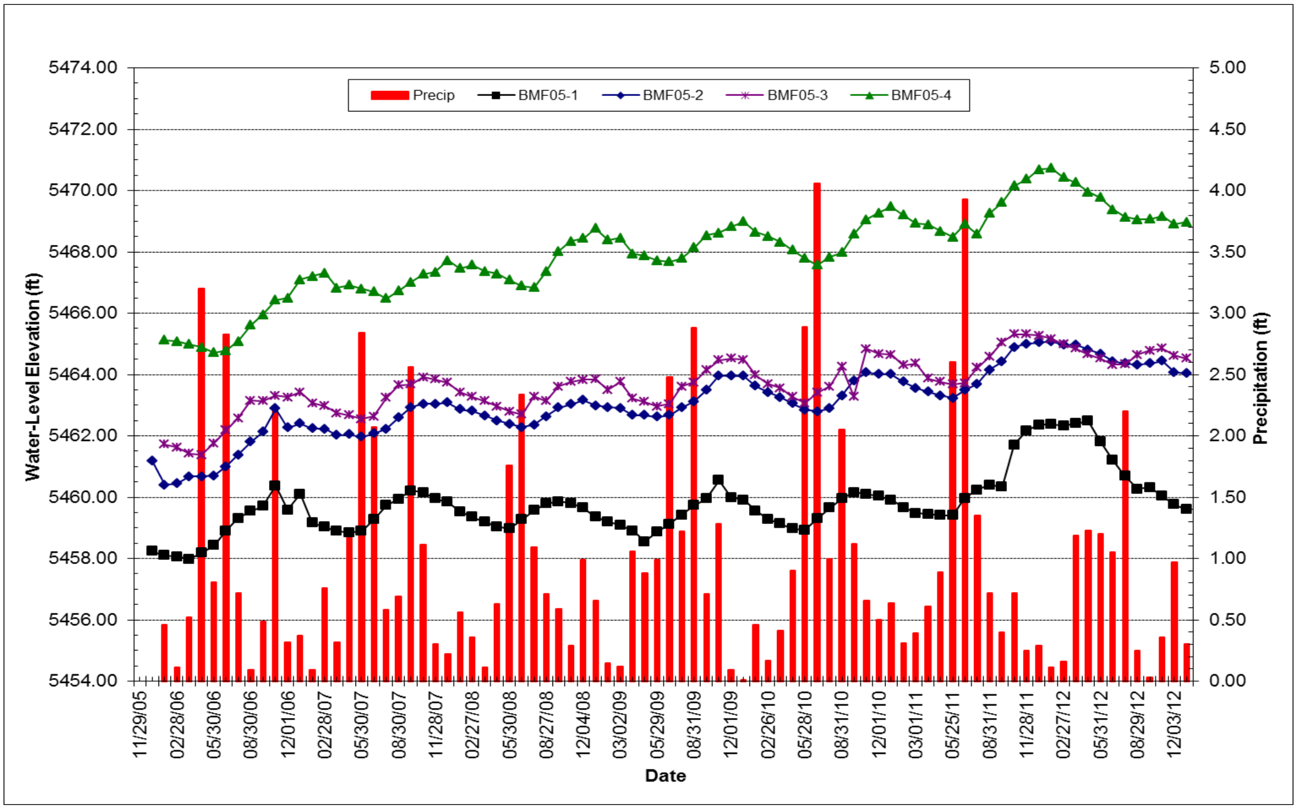


Figure 2-25. Monthly water-levels versus precipitation, BMF05 series wells.

Section 2.1.4.1 GS and BMF05-Series Wells Water Quality

Water-quality samples were collected during the spring (May) sample event from GS-series wells as part of the 2012 BMFOU monitoring; additional samples were collected during fall sampling to determine if BPS dewatering activities had an impact on water quality since these wells showed water-level changes in response to dewatering. 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 2012 confirms the large increases noted in many of the dissolved constituents since 2004; concentrations were similar to those seen in 2010-2011 data. Fall sample results showed minor to modest changes (increases) in concentrations in well GS-41S from the spring samples, while very little change in concentrations in well GS-41D was noted. The water quality changes in the shallow well (GS-41S) may be seasonal in nature and not related to the above mentioned dewatering activities.

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 to levels above the MCL in 2005-2012 samples, after being below the MCL for the previous three years. While well GS-44D continues to exhibit concentrations greater than MCLs for cadmium, overall concentrations have decreased by as much as 50 percent over the period of record. Wells GS-46S and D, northeast of Clark

Park continued to exhibit good water quality in 2012 and show 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. No notable changes in water quality were seen in the fall sampling event for these four wells.

Quarterly water-quality samples were collected from the BMF05 wells during 2006-2007 to establish baseline conditions for these four 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	5.14		6.5-8.5
Iron	9.08		0.30
Manganese	122.		0.05
Aluminum	0.568		0.05-0.2
Cadmium	0.204	0.005	
Copper	3.48		1.0
Zinc	47.3		2.0
Sulfate	1,575		250

Based upon the location of this well (fig. 2-19), adjacent to the historic Silver Bow Creek channel and down gradient 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 on figure 2-26. During the year 2012, water levels rose between 5.96 and 7.08 ft in the mines, which were less than 1 ft to 3 ft less than last year's totals. The Berkeley Pit water level rose 6.32 ft, which is 0.88 ft less than last year (Table 2.2.1). Figure 2-25 shows the annual water-level changes graphically for these sites. The net 2012 water-level changes between the mine shafts and Berkeley Pit were very comparable. 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, in feet.

Year	Berkeley Pit	Anselmo	Kelley	Belmont (1)	Steward	Granite Mountain	Lexington(2)	Pilot Butte
1982			1,304.00	117.00	85.00			
1983			877.00	1,054.00	1,070.00			
1984			262.00	269.00	274.00			
1985			122.00	121.00	123.00			
1986		56.00	96.00	102.00	101.00			
1987		77.00	84.00	77.00	79.00	67.00		
1988		53.00	56.00	53.00	52.00	57.00	8.10	
1989		29.00	31.00	31.00	29.00	31.00		
1990		32.00	33.00	34.00	33.00	34.00		
1991	12.00	29.00	33.00	30.00	29.00	31.00		
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	**6.32**	**6.54**	**6.42**	**6.67**	**6.43**	**6.42**	**7.08**	**5.96**
Change Years 31-40	**6.32**	**6.54**	**6.42**	**6.67**	**6.43**	**6.42**	**7.08**	**5.96**
Net Change*	***306.32***	***545.98***	***3,179.81***	***2,150.65***	***2,155.98***	***510.61***	***166.04***	***165.29***

(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 2-26. East Camp mines and bedrock wells location map.

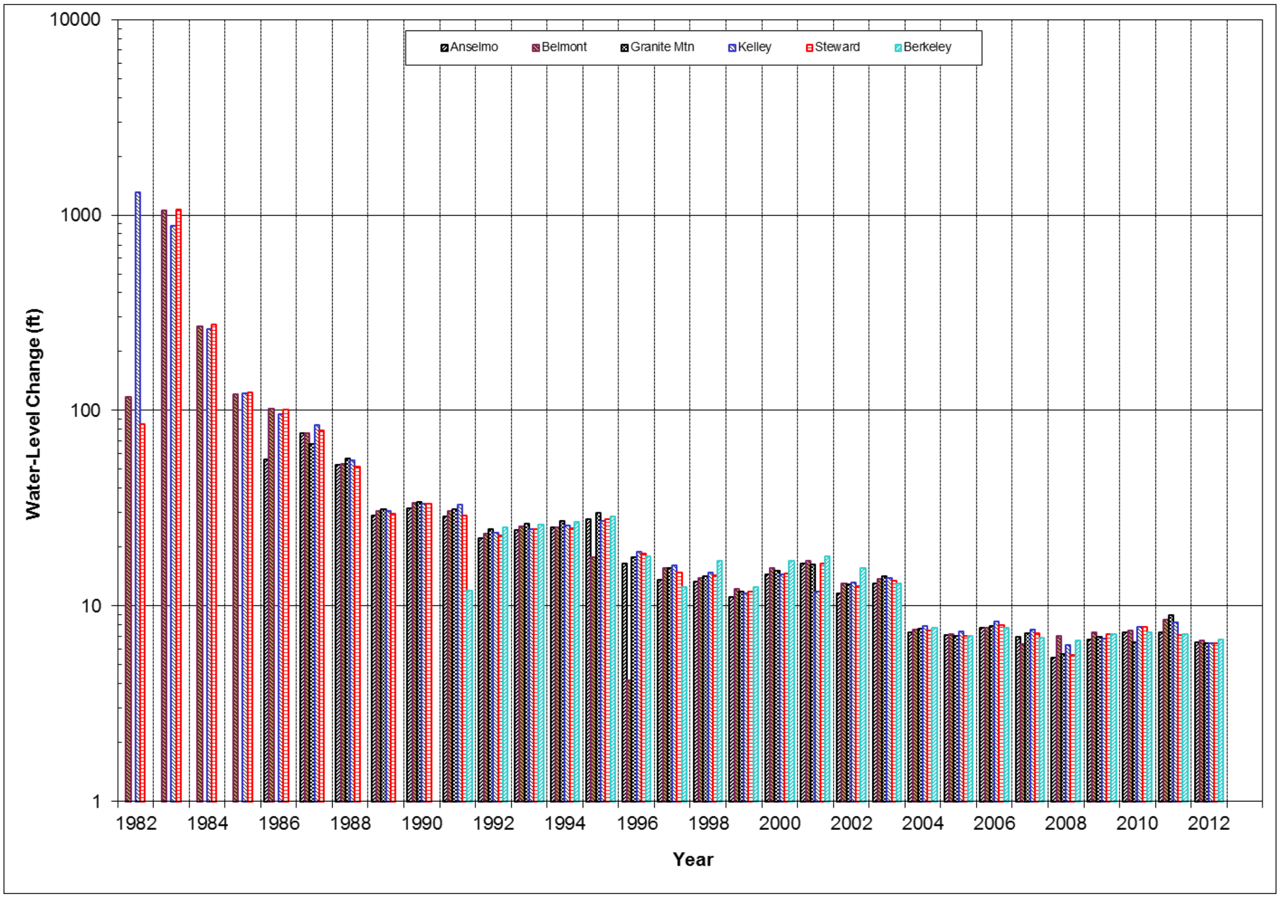


Figure 2-27. East Camp mines annual water-level changes.

The hydrograph (fig. 2-28) 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 2012, several changes are noticeable (fig. 2-29). 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 on fig. 2-30 remained the same throughout 2012, 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 2-28). 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 2012 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 5410 ft, only 3 percent of the underground workings remain to be flooded.

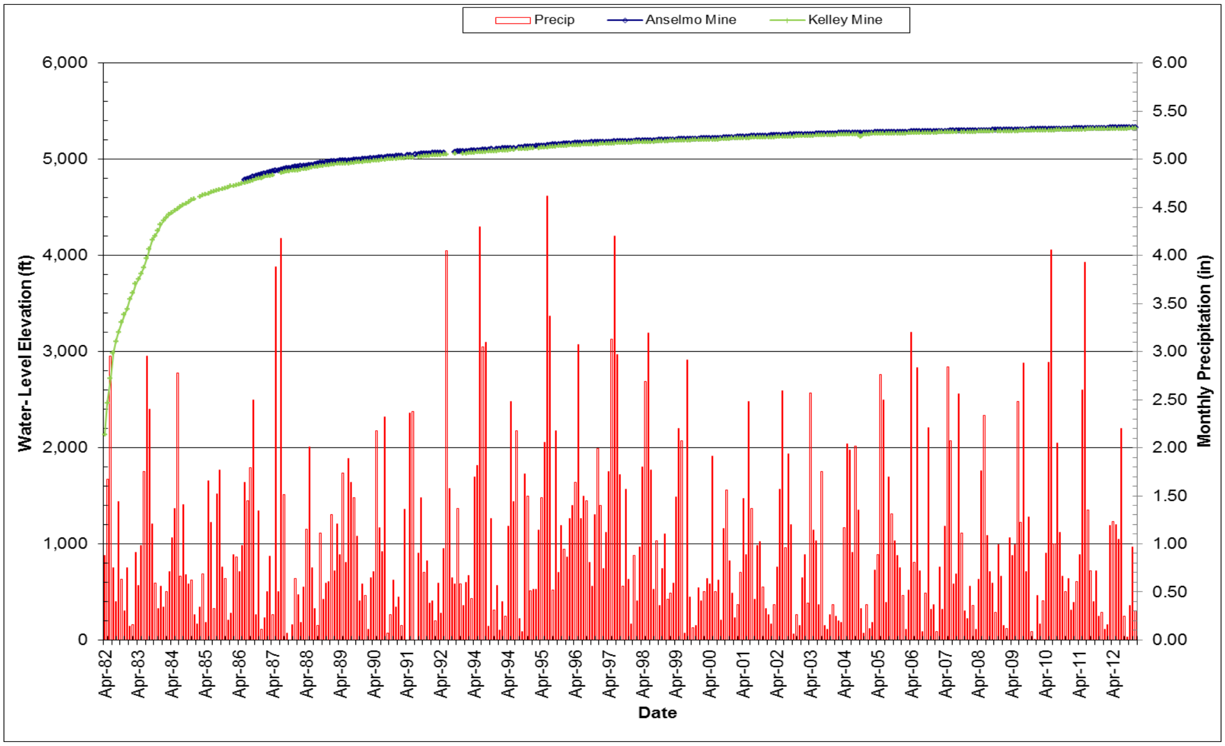


Figure 2-28. Anselmo Mine and Kelley Mine hydrograph versus precipitation, 1983-2012.

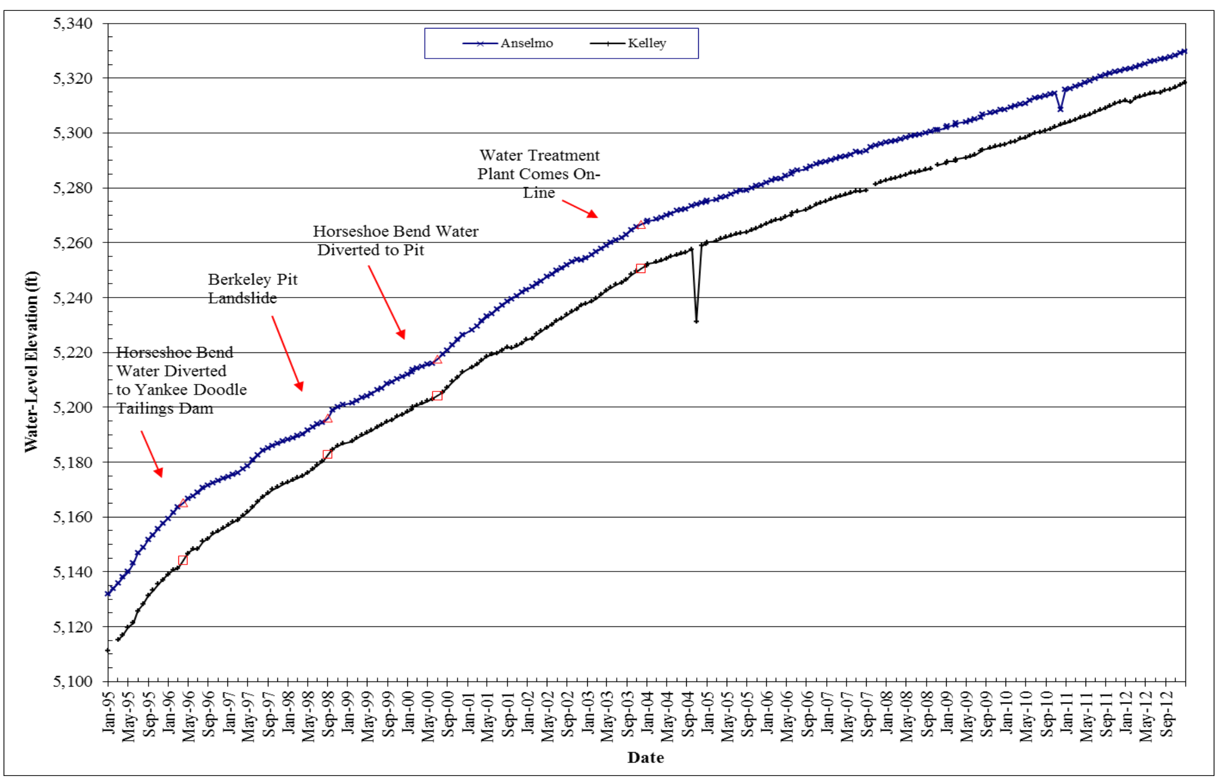


Figure 2-29. Anselmo Mine and Kelley Mine hydrograph, 1995-2012.

Figure 2-30 shows monthly water-level changes in the Berkeley Pit from 1991 through 2012. Water-level changes (increases) seen over the last 6 months of 2000, following the addition of HSB drainage water, continued through 2003. However, water-level increases were much less from 2004-2012 as a result of the decreased inflow of water into the pit.

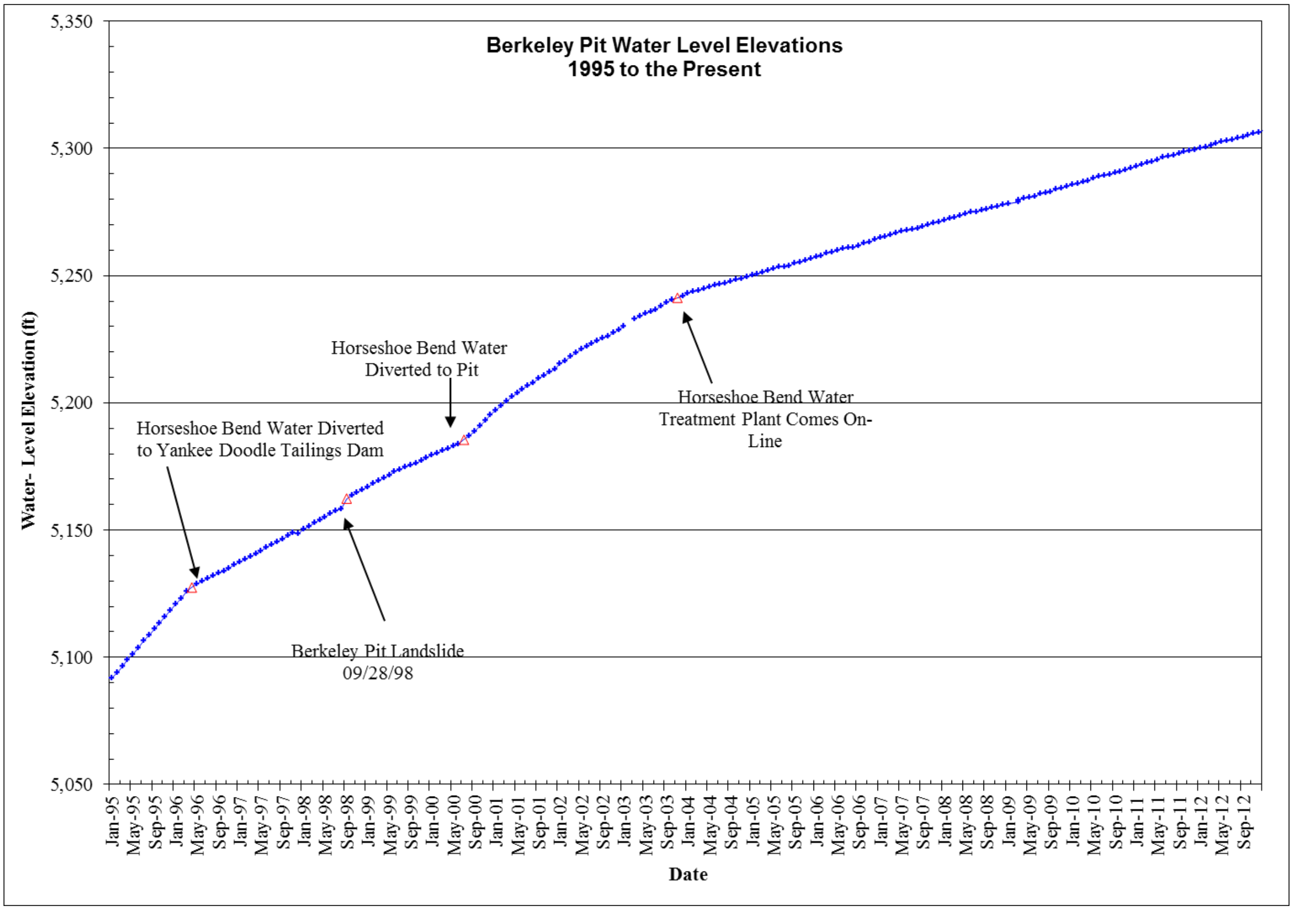


Figure 2-30. Water-level hydrograph for the Berkeley Pit, 1991-2012.

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 insure contaminated water was contained within the underground mine system and Berkeley Pit. The POC elevation was established at an elevation of 5,410 above sea level. Under the terms specified in the ROD and CD the water level cannot exceed the 5,410 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 2012 was the Pilot Butte Mine, which was at an elevation of 5,332 ft, or 78 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 2012 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 Kelley and Steward mines were sampled during the spring 2012 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 the past several years. (Data shown in figures are from samples collected 100 ft below the water surface.)

Kelley: iron, sulfate, arsenic, and aluminum increased to near historic concentrations in 2003-2004, decreasing gradually during 2005-2012 (fig. 2-31). Copper concentrations increased in the 2010-2012 samples; however, they remain very low.

Anselmo: 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. 2-32). Copper concentrations remain very low (<20 µg/L).

Steward: 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. 2-33); however zinc concentrations remain well above standards.

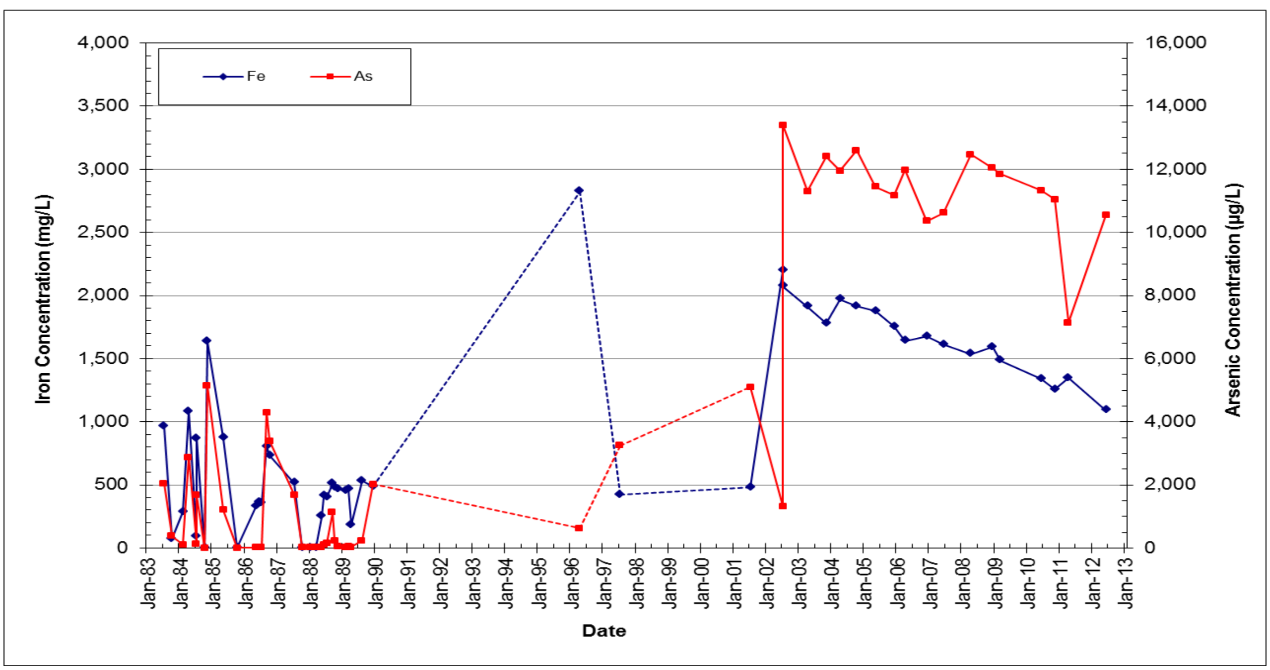
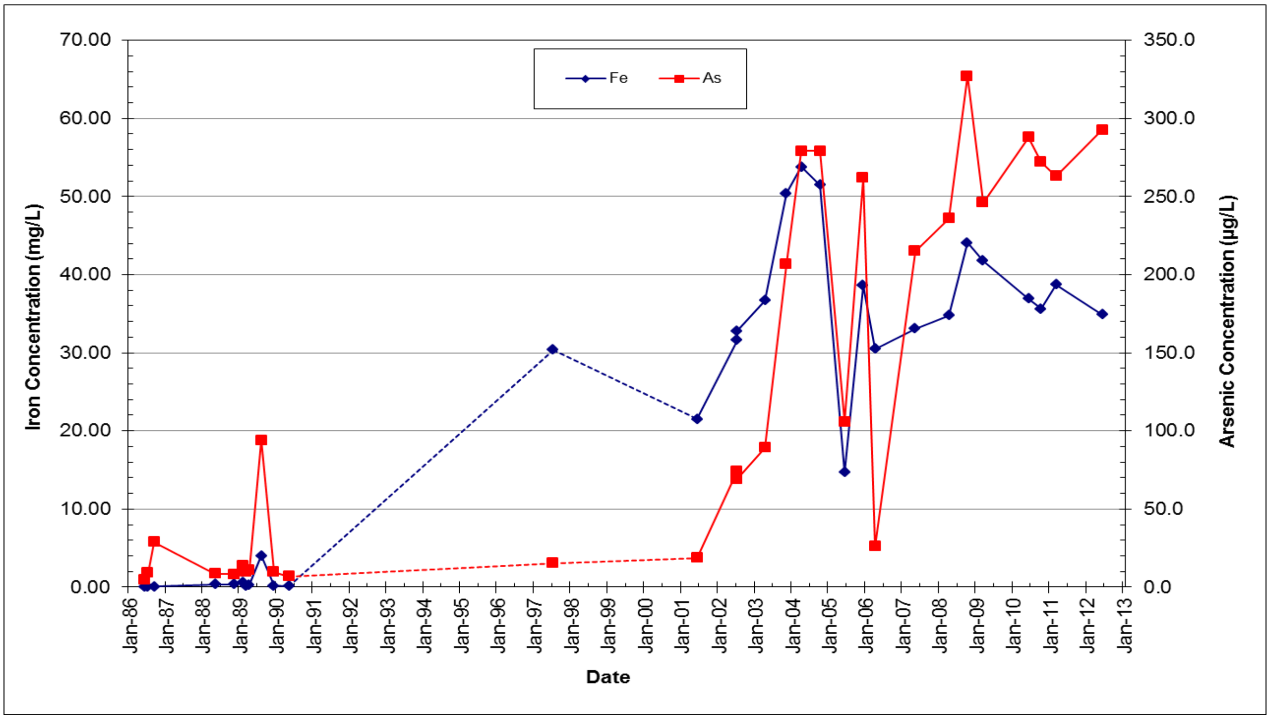


Figure 2-31. Iron and arsenic concentrations over time in the Kelley Mine.



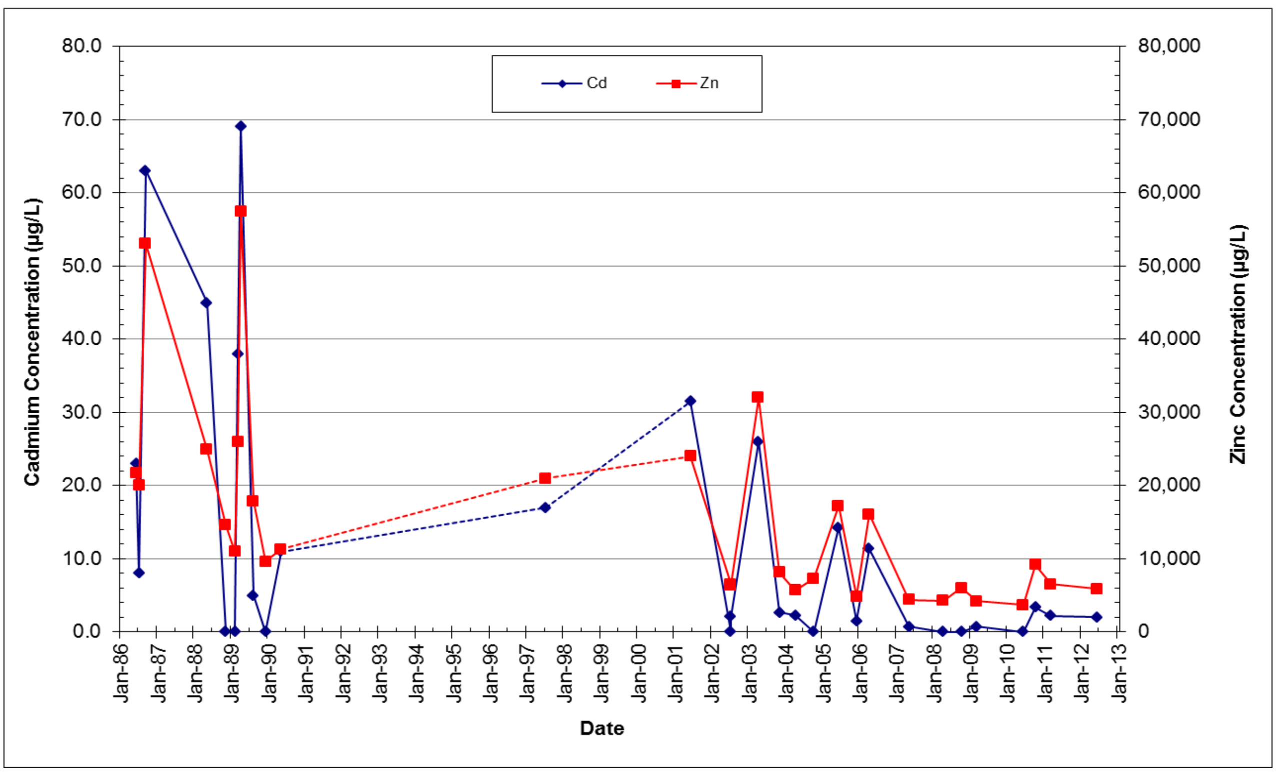
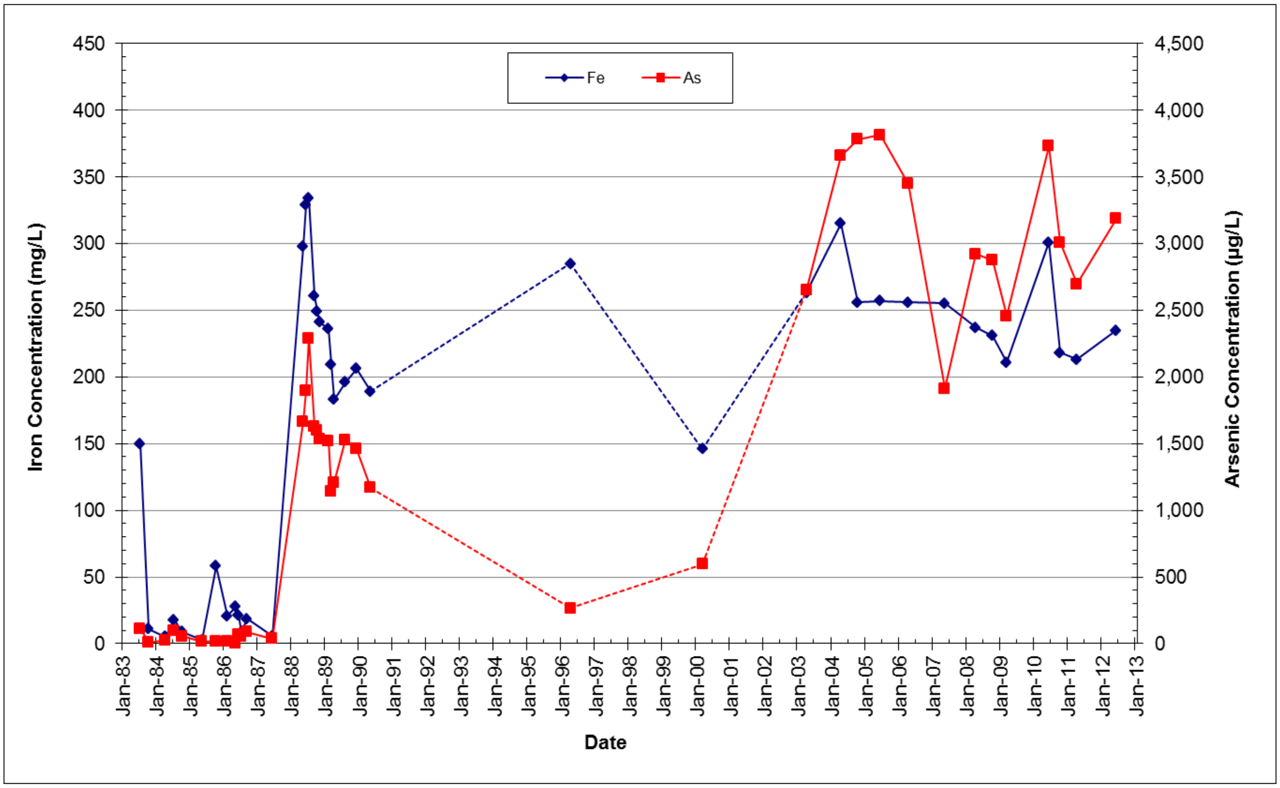


Figure 2-32. Iron and arsenic concentrations (top) and cadmium and zinc concentrations (bottom) over time in the Anselmo Mine.



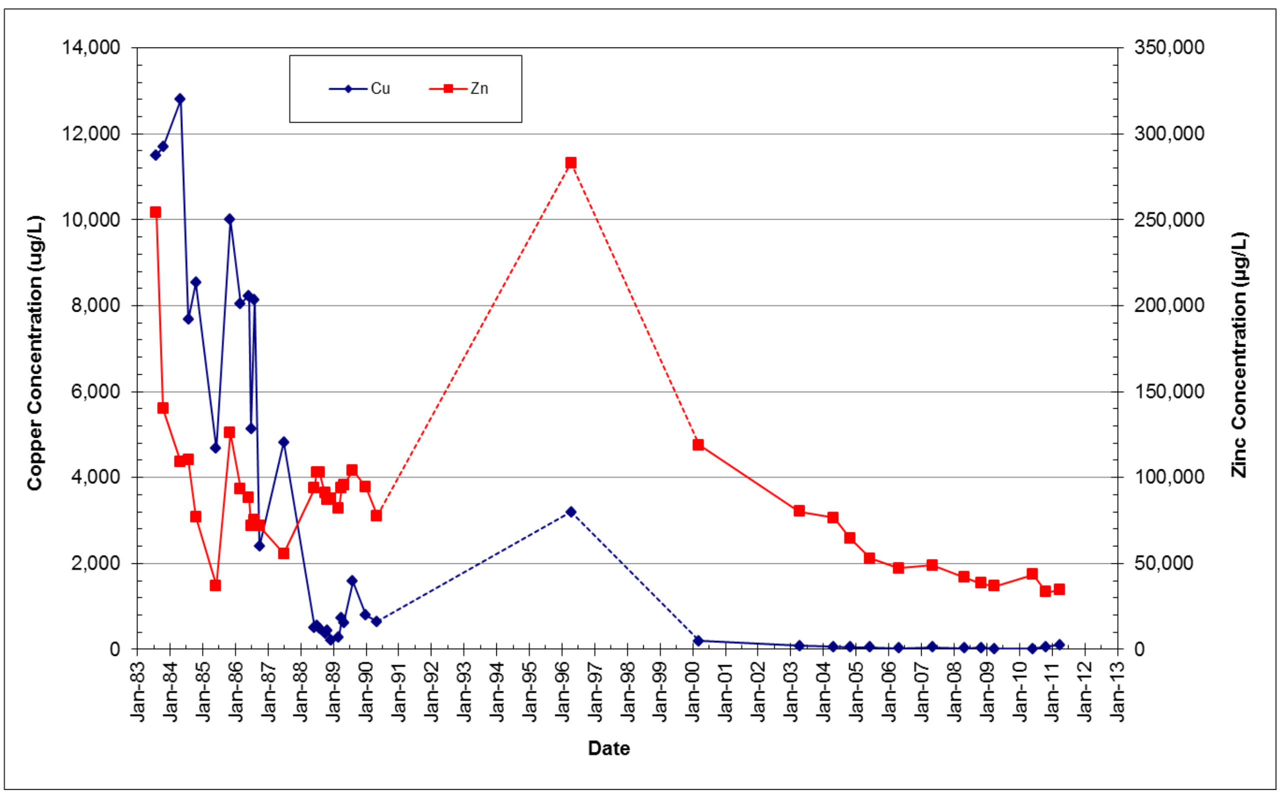


Figure 2-33. Iron and arsenic concentrations (top) and cadmium and zinc concentrations (bottom) over time in the Steward Mine.

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 on figure 2-26. 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 2-34 shows these changes graphically.

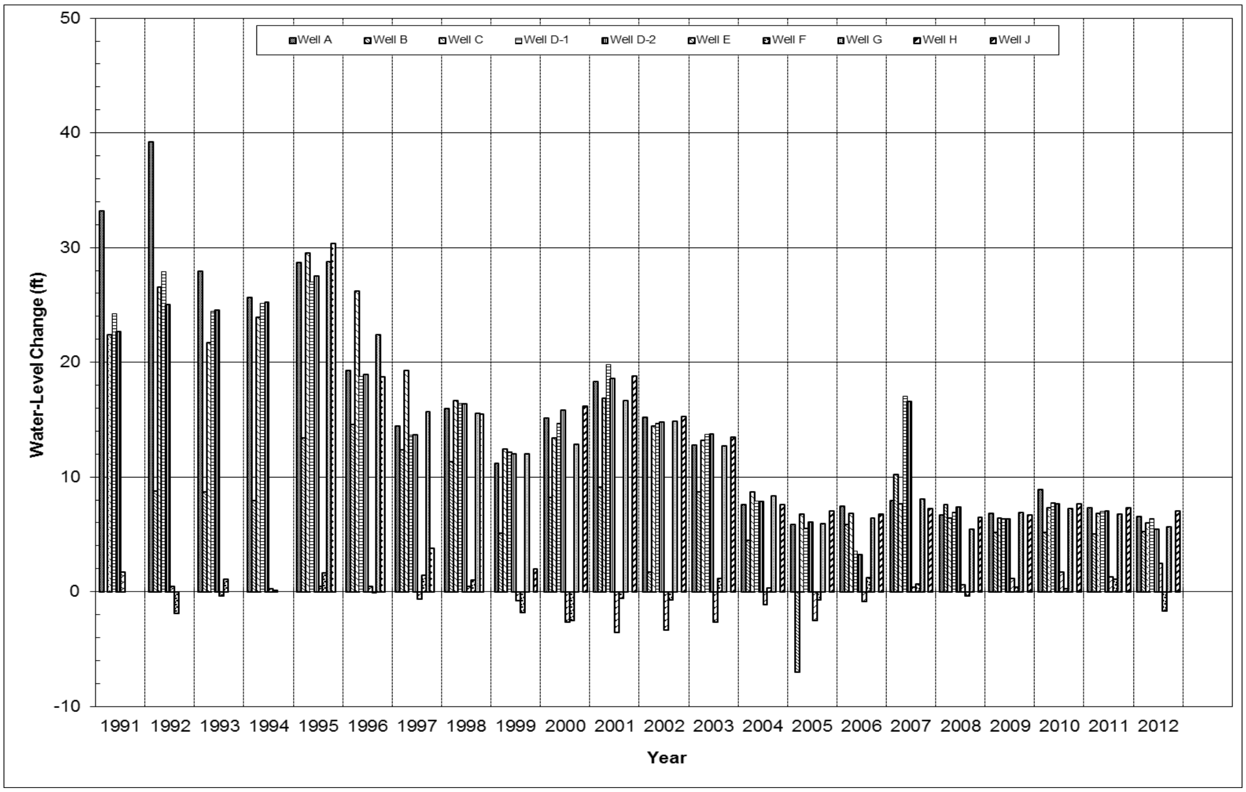


Figure 2-34. RI/FS bedrock wells annual water-level change.

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 2012. 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 2-35 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, in feet.

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)
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, in feet. (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**
Change Years 31-40	**6.55**	**5.24**	**6.02**	**6.37**	**5.44**	**2.46**	**-1.72**	**5.67**	**0.00**	**7.03**
Net Change	**341.99**	**151.55**	**319.37**	**320.89**	**316.27**	**-7.18**	**-0.17**	**212.15**	**68.29**	**129.47**

(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, in feet. (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, in feet. (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**
Change Years 31-40	**0.00**	**7.10**	**0.00**	**0.00**	**2.51**
Net Change	**338.38**	**353.55**	**276.05**	**240.42**	**419.69**

(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

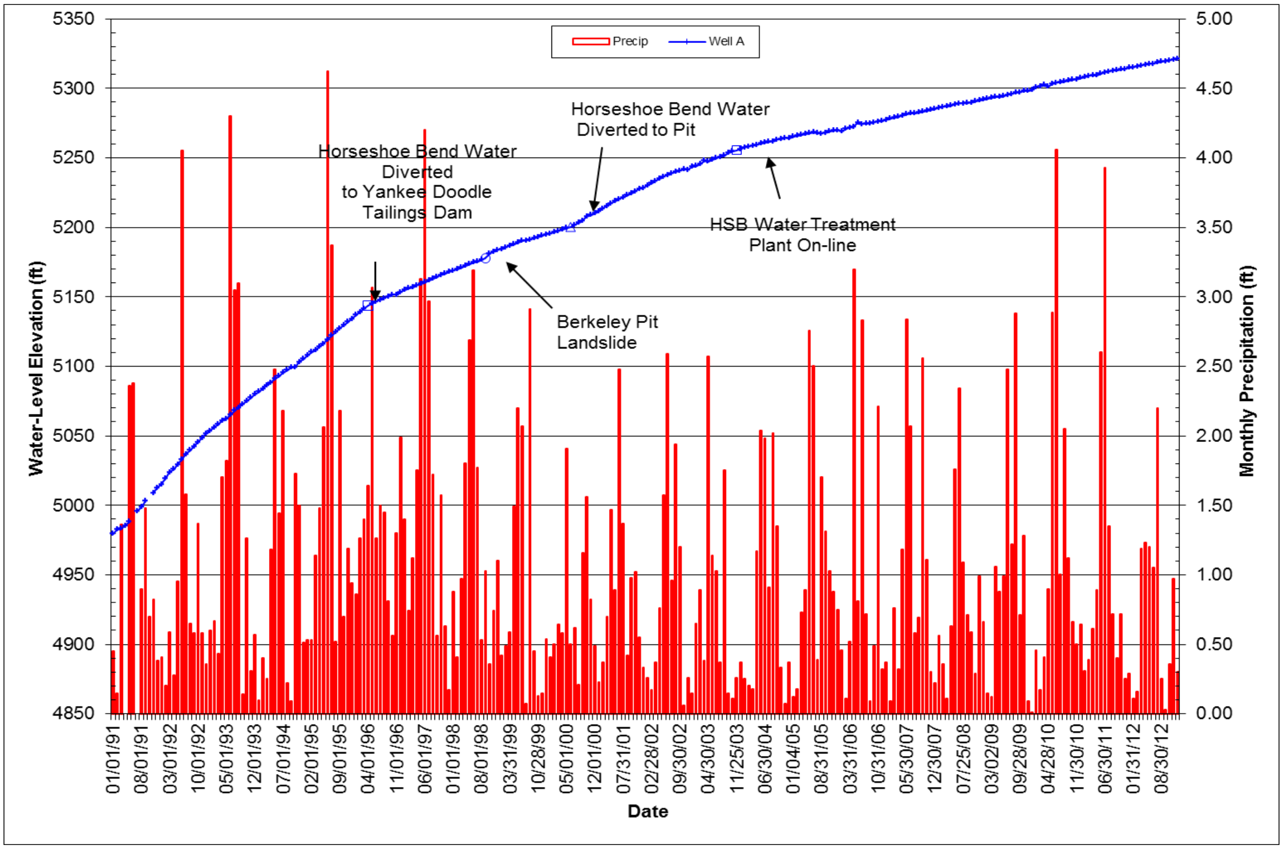


Figure 2-35. Water-level hydrograph for bedrock well A.

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 the other bedrock wells and mine shafts. 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 shown on figure 2-36.

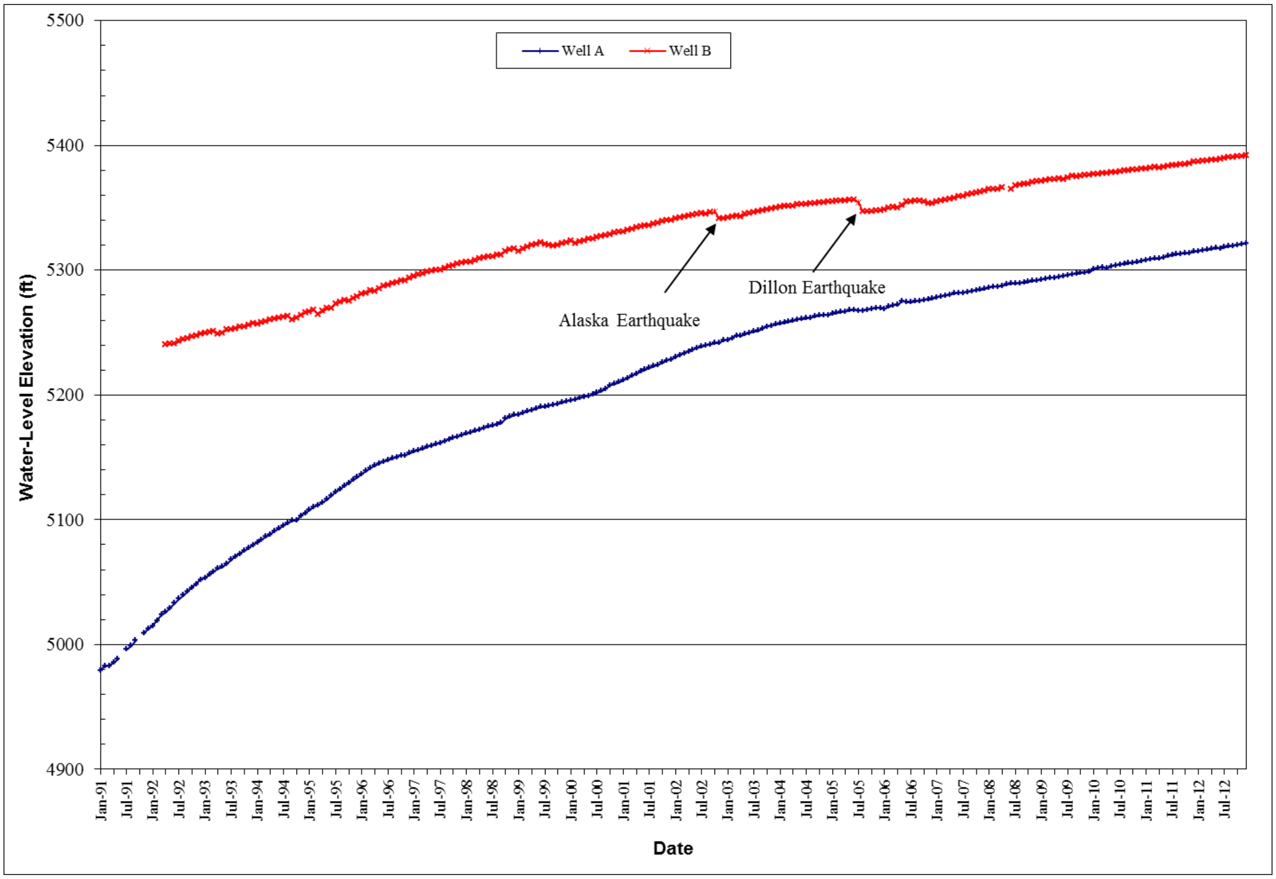


Figure 2-36. Water-level hydrographs for East Camp bedrock wells A and B.

Water levels in wells E and F do not follow the trends seen in the other bedrock wells (fig. 2-37). 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 10 ft over time, while well F has a net increase of less than 2 ft. It is very apparent 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.

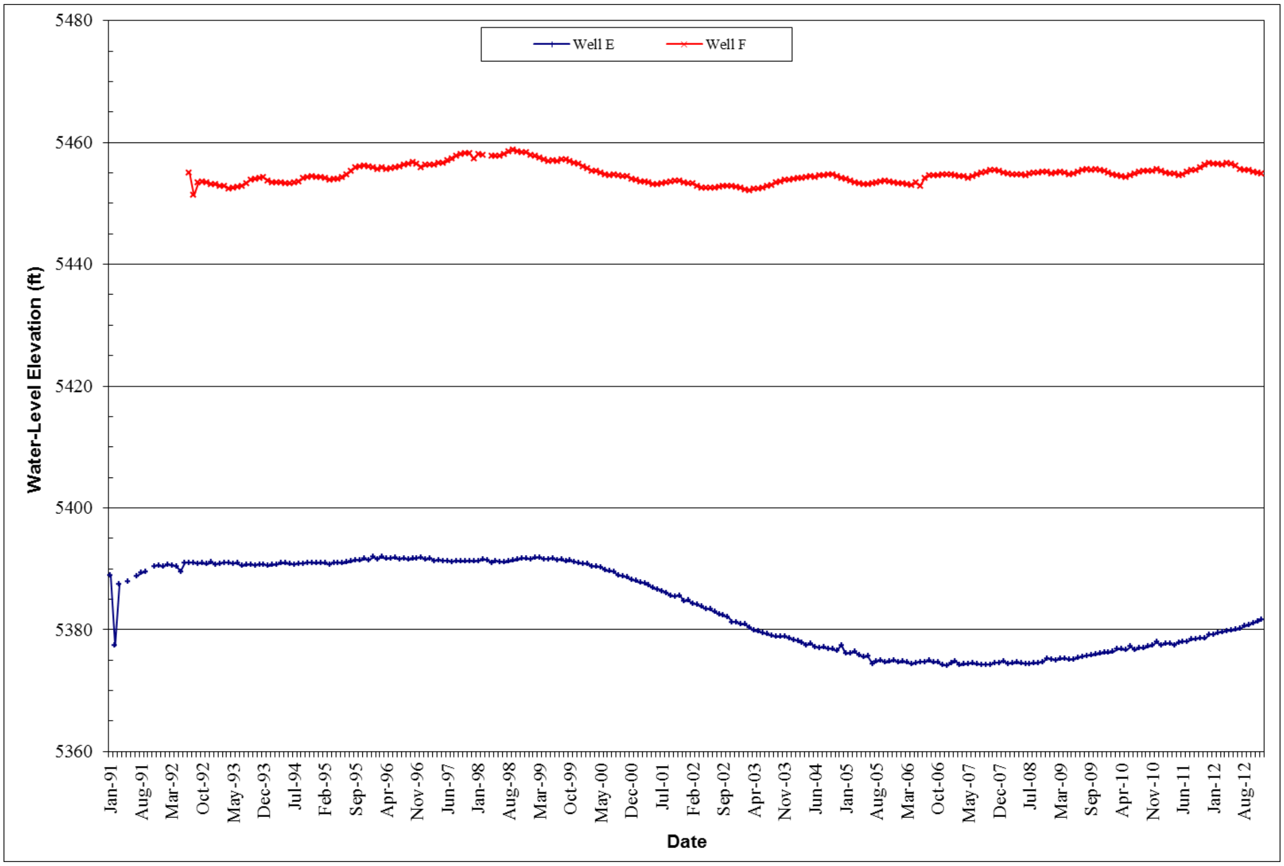


Figure 2-37. Water-level hydrographs for East Camp bedrock wells E and F.

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 on figure 2-38. Historic water levels for well H are shown on 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 plots 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 70 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.

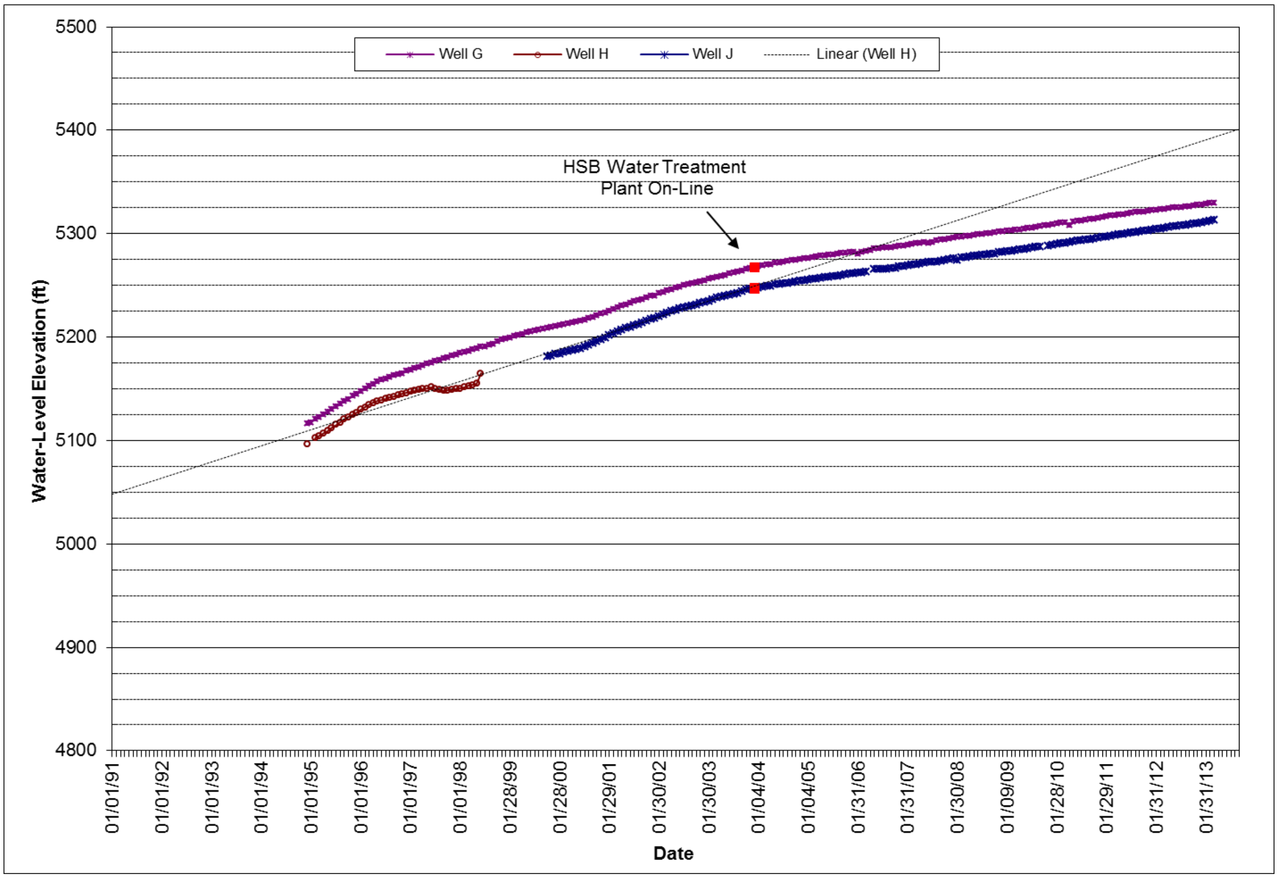
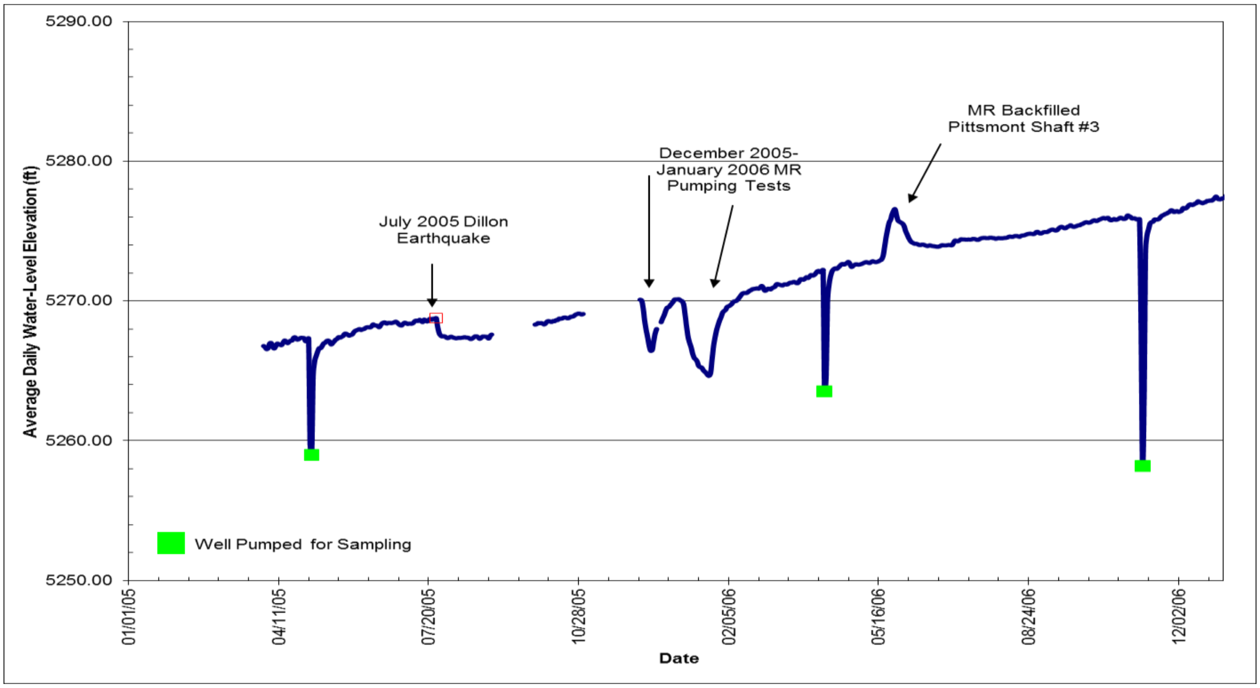


Figure 2-38. Water-level hydrographs for bedrock wells G, H, and J.

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 2-39 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 (a) shows water-level data collected by a transducer and the level of detail when each different event occurred while the bottom graph (b) 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 back filling 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 J, Belmont well #1 and 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. 2-40) for the East Camp bedrock aquifer shows the flow of water from all directions is towards the pit. While there were short-term influences on water levels in a number of these wells, the overall direction of groundwater flow did not change.



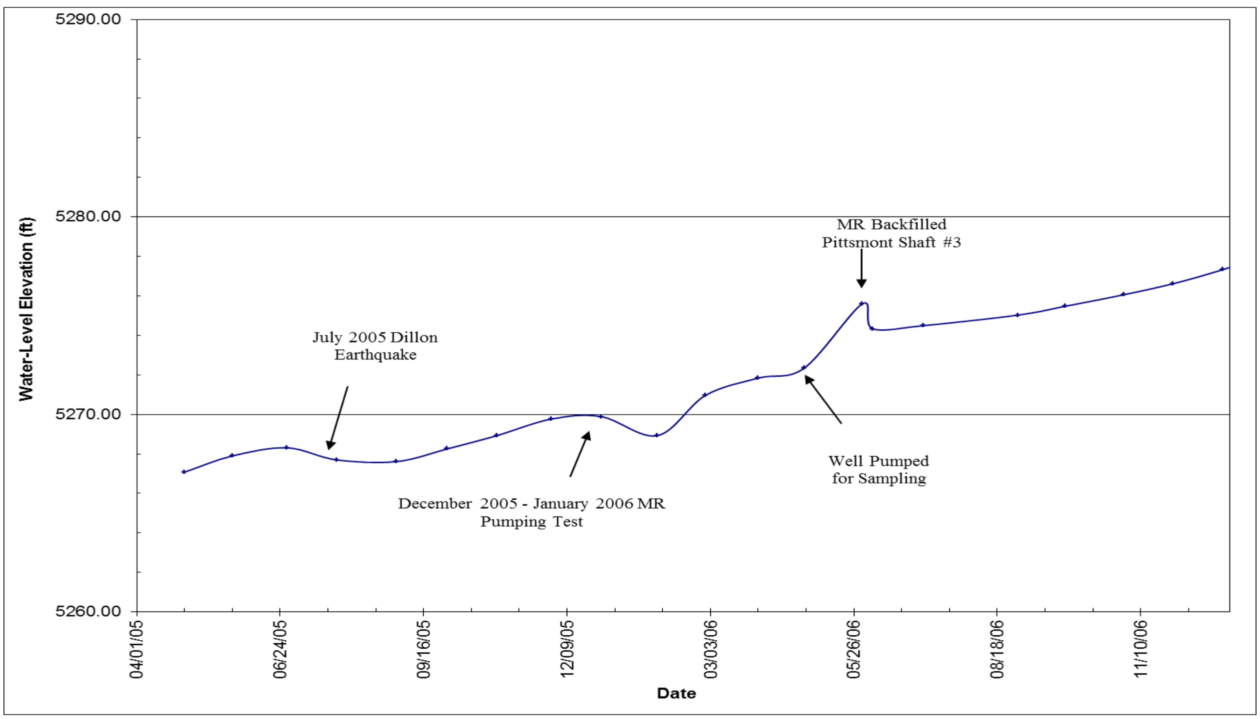


Figure 2-39. Hydrographs for well A comparing (top) daily average water level and (bottom) monthly water level monitoring frequency.

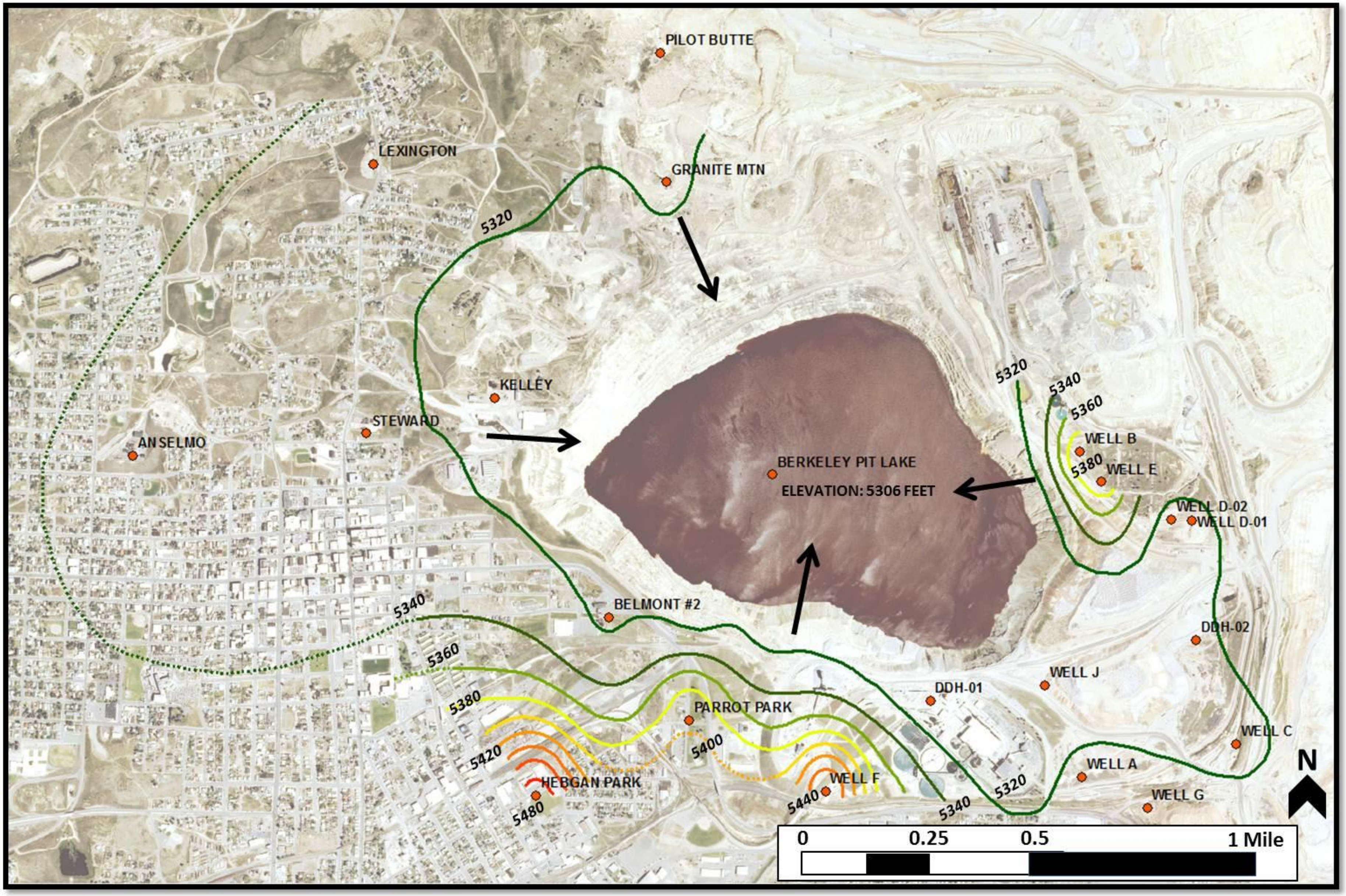


Figure 2-40. Potentiometric map for the East Camp bedrock aquifer, December, 2012; arrows indicate direction of ground-water flow (contour interval is 20 feet).

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 2012 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 SMCL's 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 2-41 shows iron and arsenic concentrations for six of the bedrock wells sampled during the spring of 2012. As can be seen on figure 2-41, 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 is 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. Figure 2-42 is a comparison of selected trace metal concentrations for well A, well J and the Berkeley Pit sample collected 1-ft below the water surface. Well A is the farthest south well 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 2012.

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 two years; arsenic (MCL), iron, manganese, sulfate (SMCL).
F	Y	Unchanged	Sampled every two 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, manganese, sulfate, copper (downward trend) and zinc (SMCL).

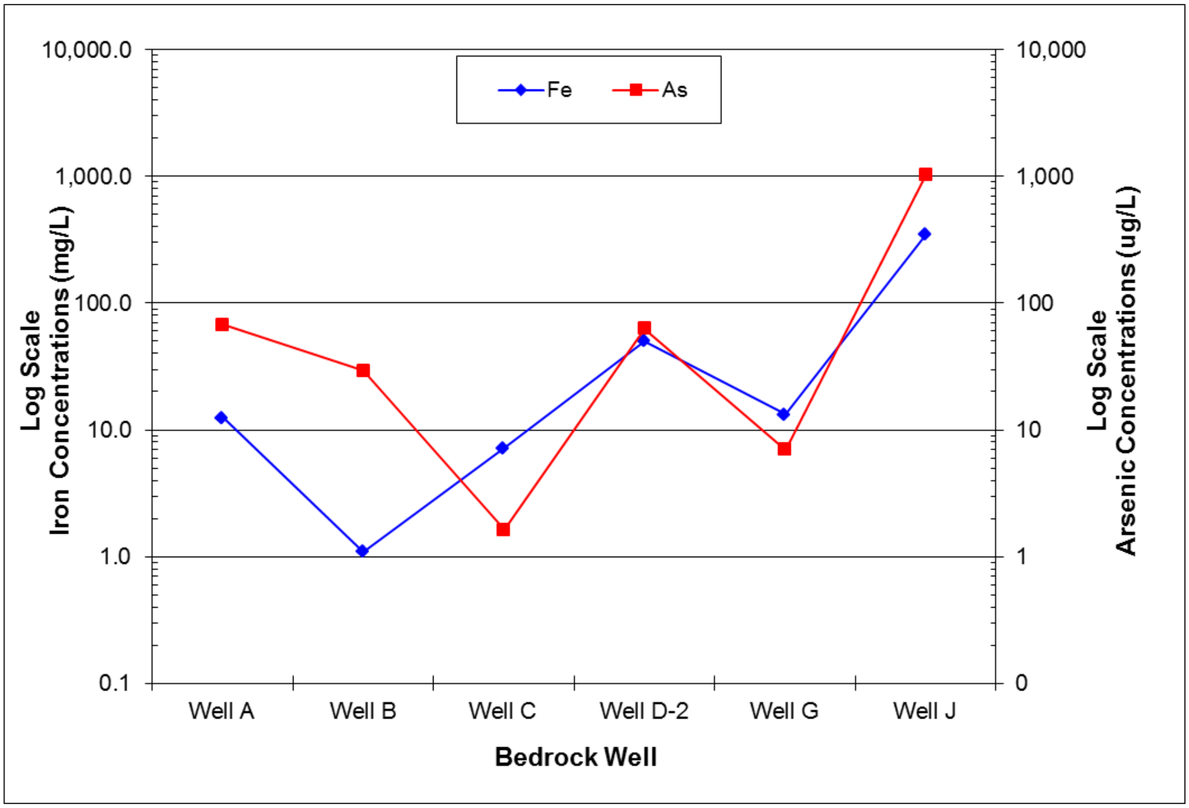


Figure 2-41. Bedrock well iron and arsenic concentration comparisons, spring 2012.

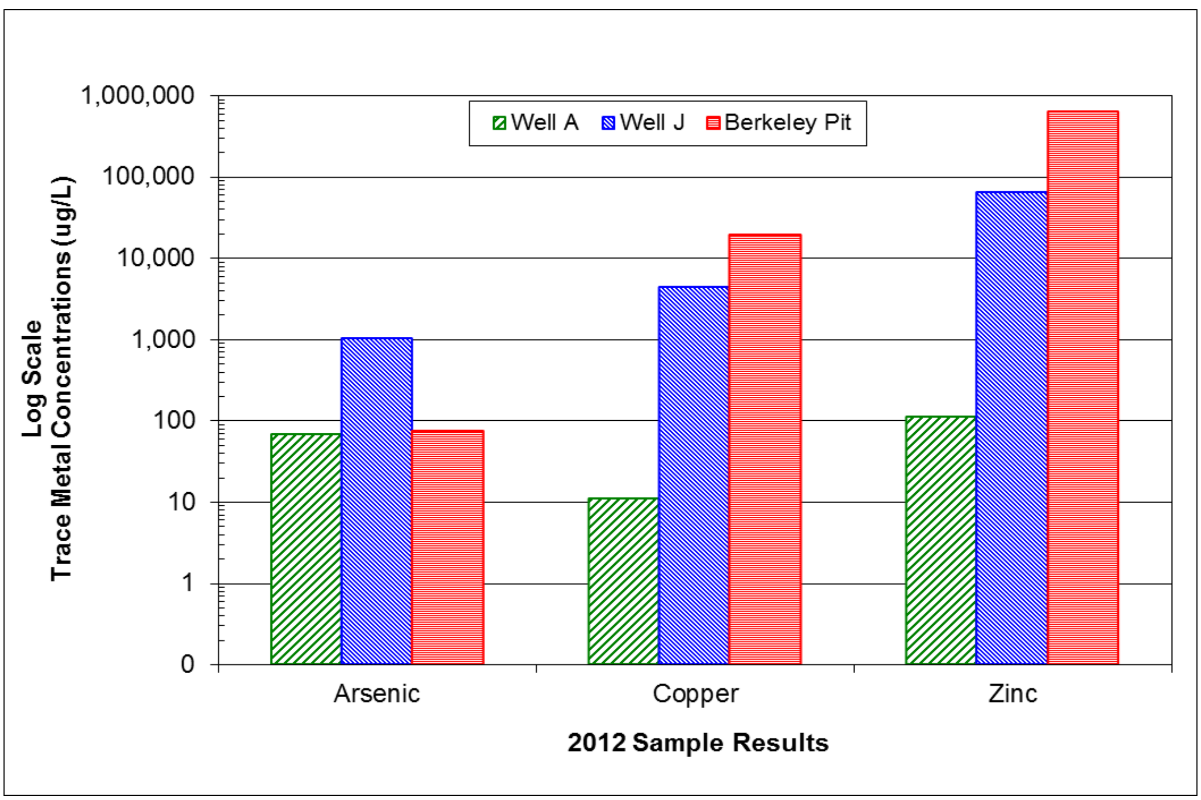


Figure 2-42. Selected trace metal comparisons between bedrock wells A, J and the Berkeley Pit 1-ft depth sample.

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 2012, water levels rose 7.10 and 2.51 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 2-43 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 2012 one-third (2.51 ft) the other bedrock wells, however, the water-level elevation is 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.

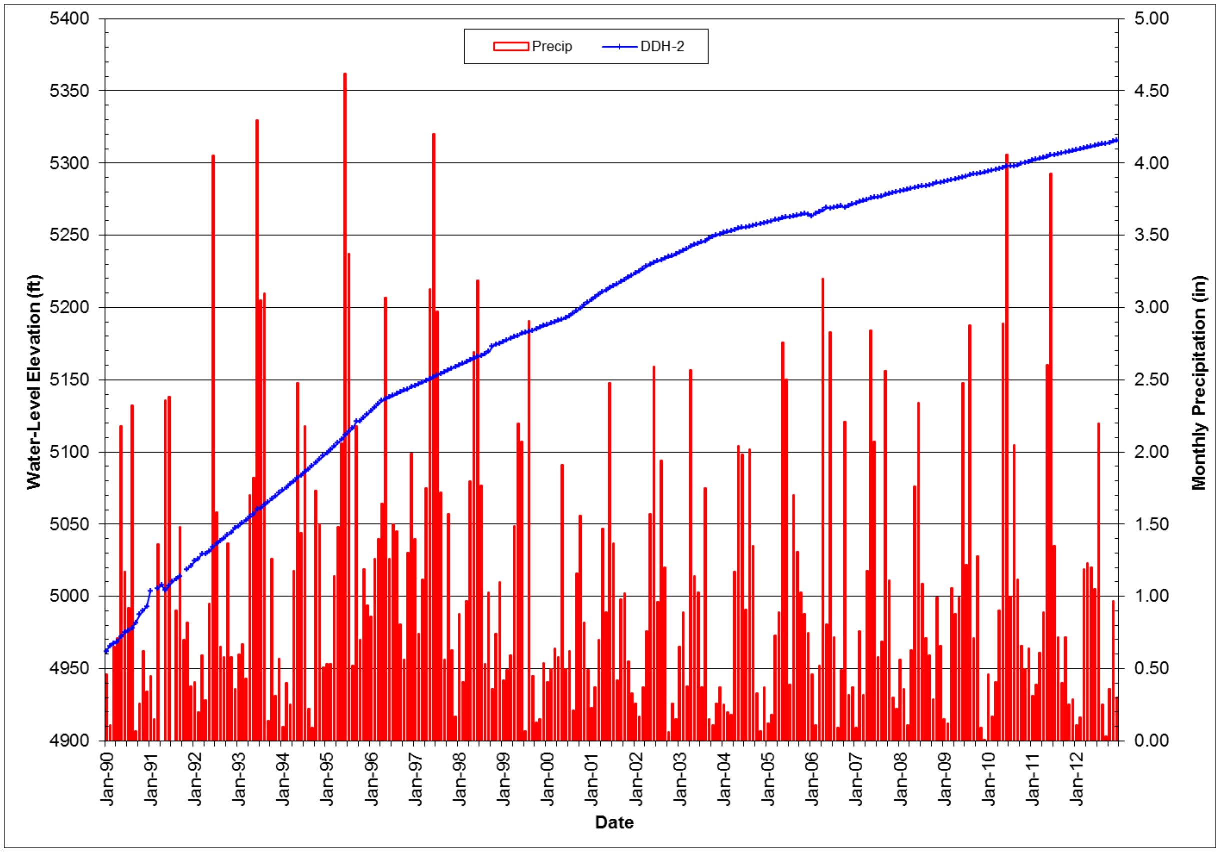


Figure 2-43. Water-level hydrograph for bedrock well DDH-2.

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 2-44 shows the pit's water-level rise since 1991.

The overall trend is similar to that of previous years (6-feet average elevation rise per year). Four noticeable changes on figure 2-44 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 of 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 on-line 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 gallons per minute (gpm) during the period of mine suspension. The overall Berkeley Pit water-level rise for 2012 was 6.32 ft, compared to 7.20 ft for 2010. 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 2-44. Water-level hydrograph of Berkeley Pit, 1995-2012.

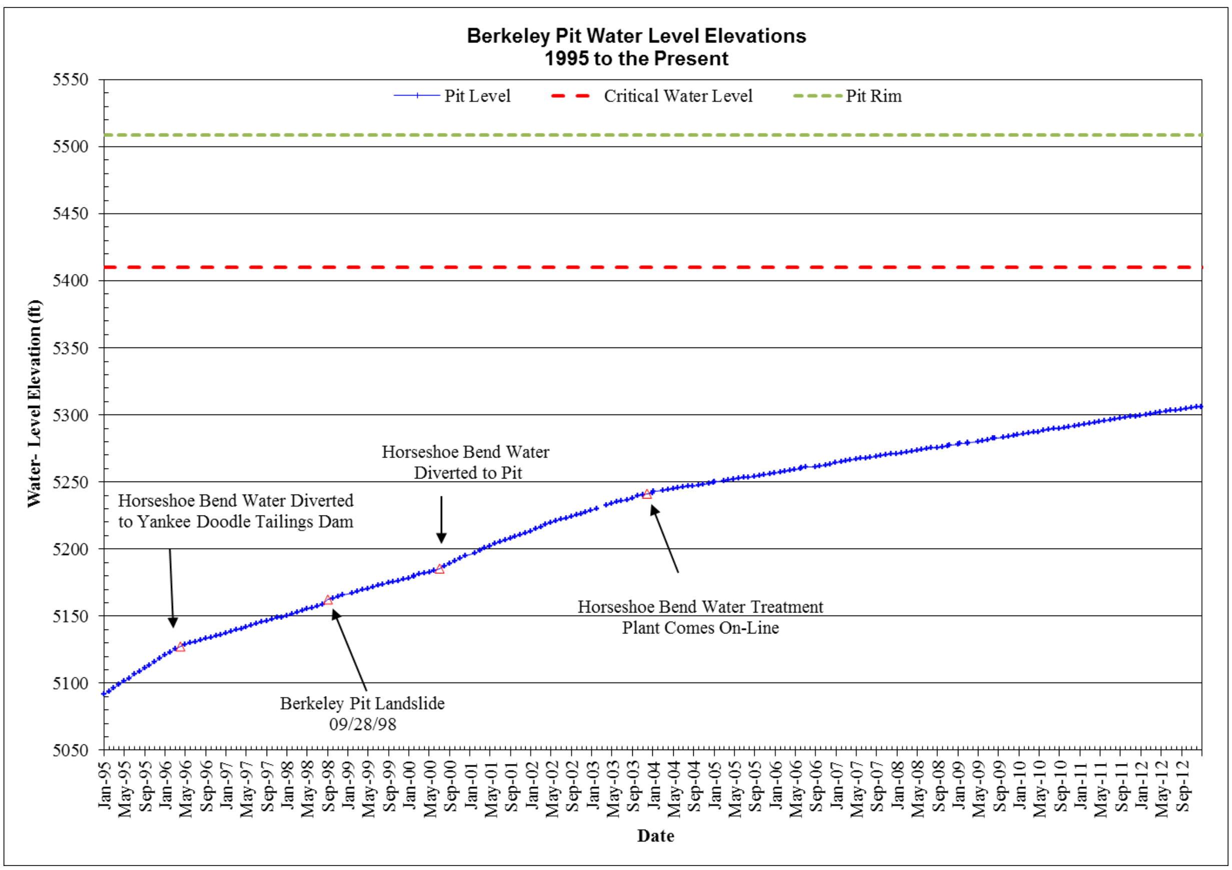


Table 2.3.1 Timeline of Events impacting Berkeley Pit Filling Rates.

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 on-line.	Slows the pit filling rate.

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 material from the high wall into the Berkeley Pit Lake. However, the material displaced by the landslides was insignificant and did not impact water-levels in the Berkeley Pit (fig. 2-44), the underground mine workings, the bedrock system, or the surrounding alluvial aquifer. Photographs showing the southeast corner of the Pit before and after each event are given in figure 2-45.

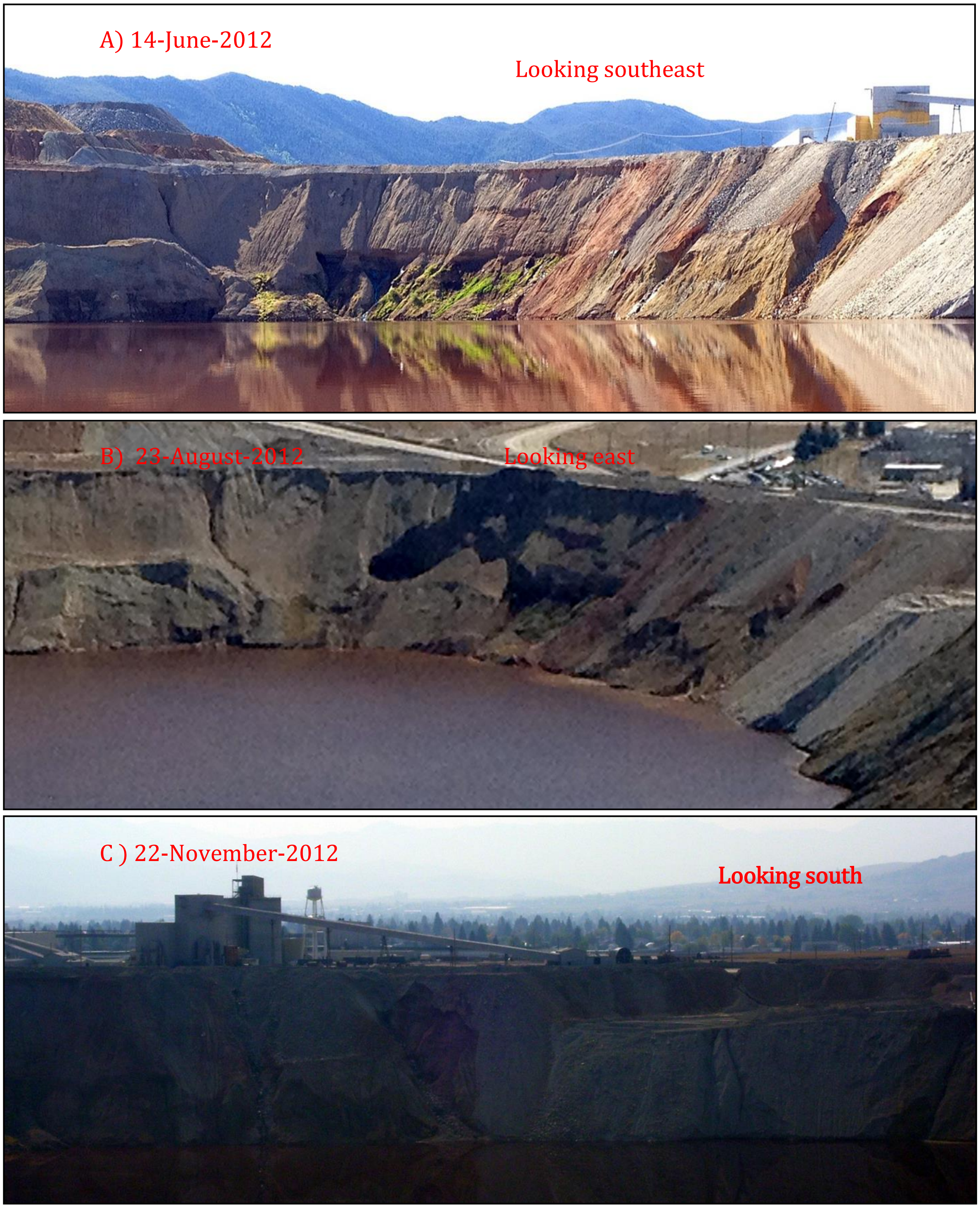


Figure 2-45. Pictures of the southeast corner of the Berkeley Pit prior to the occurrence of the 2012 landslides (A), and after the August (B) and November (C) events.

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 2012 water-level elevation 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 2012.

Point of Compliance	December 2012 Water-Level Elevation (ft)	Depth Below CWL (ft)
Anselmo Mine	5329.78	80.22
Granite Mountain Mine	5321.71	88.29
Pilot Butte Mine	5332.07	77.93
Kelley Mine	5318.31	91.69
Belmont Well #2	5319.32	90.68
Well A	5321.49	88.51
Well C	5317.74	92.26
Well G	5328.19	81.81
Berkeley Pit (not a compliance point)	5306.24	103.76

Flow monitoring of the Horseshoe Bend drainage continued throughout 2012. 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 are ongoing problems associated with monitoring at this site. However, more frequent site visits to clean the transducer and note gauge height readings have 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 year. The 2012 average daily flow rate was 3,589, an increase of 203 gpm from the prior year. A total of 1.89 billion gallons of water flowed through this site in 2012 for treatment in the HSB water treatment plant. Figure 2-46 shows the daily average flow rate from July 2000 through December 2012.

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 2-47 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 last eight years.

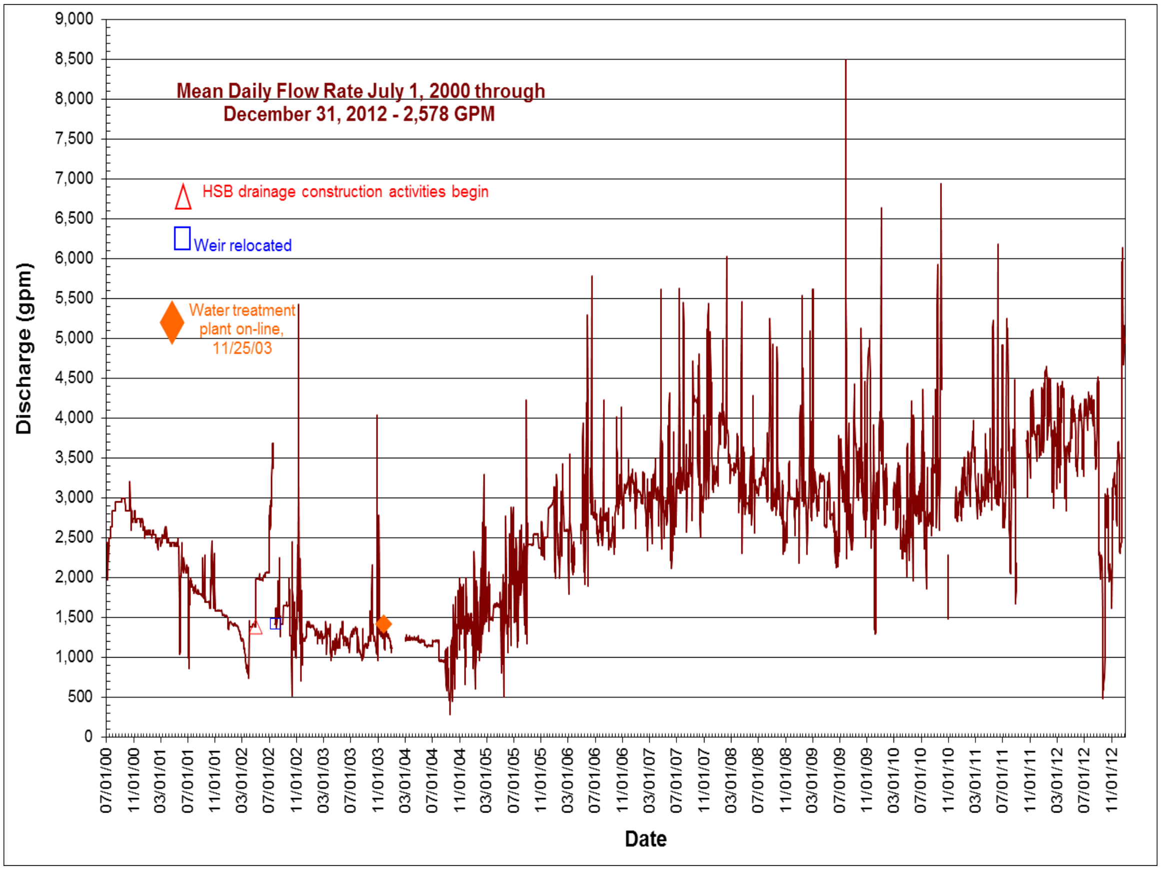


Figure 2-46. Horseshoe Bend Drainage flow rate, July 2000 through December 2012.

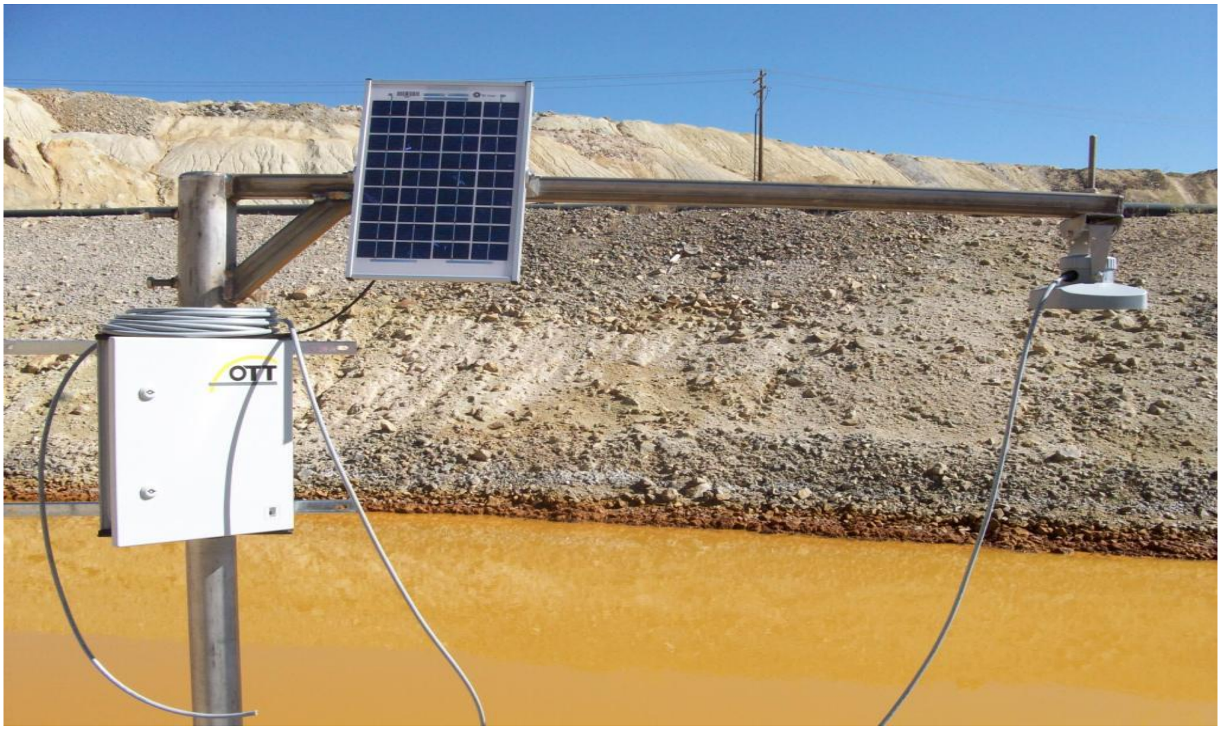


Figure 2-47. Radar system installation at the Horseshoe Bend weir monitoring station.

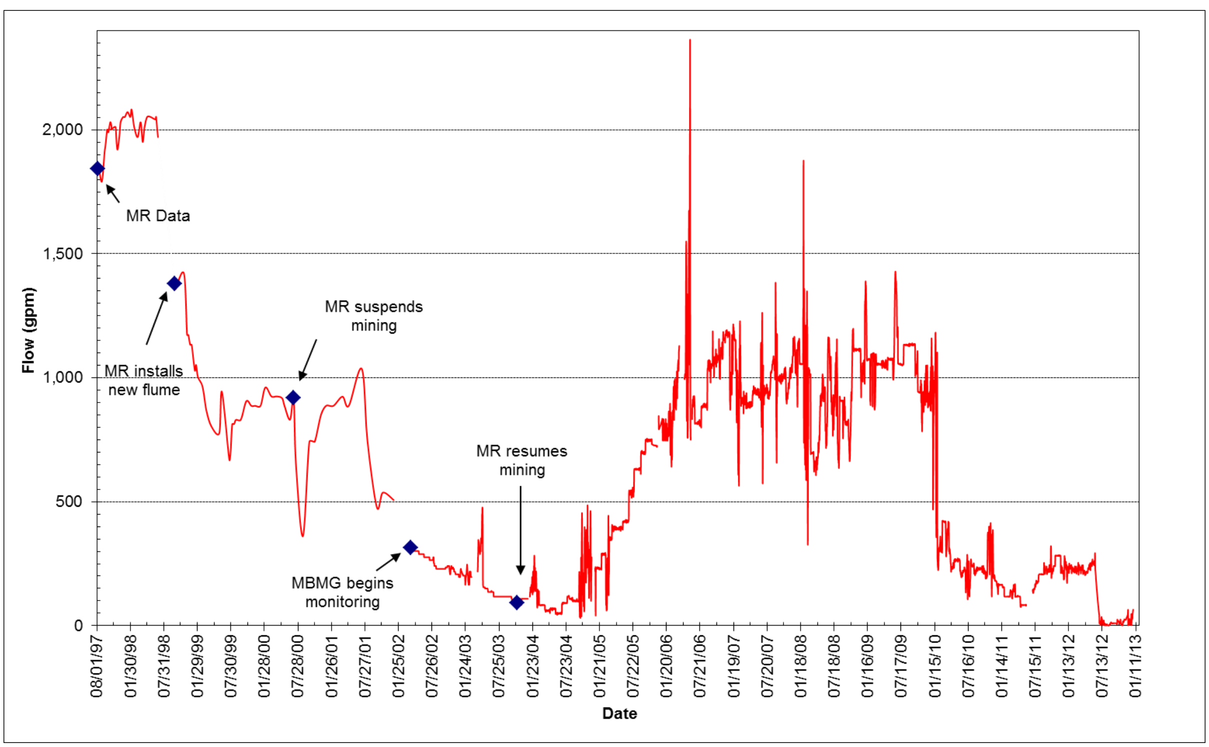


Figure 2-48. Horseshoe Bend Falls long-term daily average flow rates, includes both MR and MBMG data.

Flows measured at the HSB Falls flume averaged 115 gpm for 2012, a decrease of 62 gpm (65 percent) from the 2011 average. The flow in 2010-2012 was considerably less than prior years and the historic flow rates of 1,000 gpm or more reported by MR. Figure 2-48 shows 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.

Section 2.3.1 Berkeley Pit and Horseshoe Bend Drainage Water Quality

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 at the 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 2-49). A point-source bailer was 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 re-opened, 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 (figure 2-50) that provides much safer access to the boat for sampling and monitoring purposes.

Figure 2-49. 1985 Berkeley Pit sampling event.

Figure 2-50. Newly installed (2011) boat dock, with MR pontoon boat used for Berkeley Pit sampling.

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 online 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, turn-over 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, specific conductance (SC), electrical potential (Eh), and temperature) are measured in-situ on a semi-annual basis using Hydrolab multi-parameter sampling equipment from 0-600 feet below water surface. Depth profiles for the 2012 sampling event are presented in figure 2-51, and long-term (2002-2012) changes can be found in figure 2-52. 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 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.

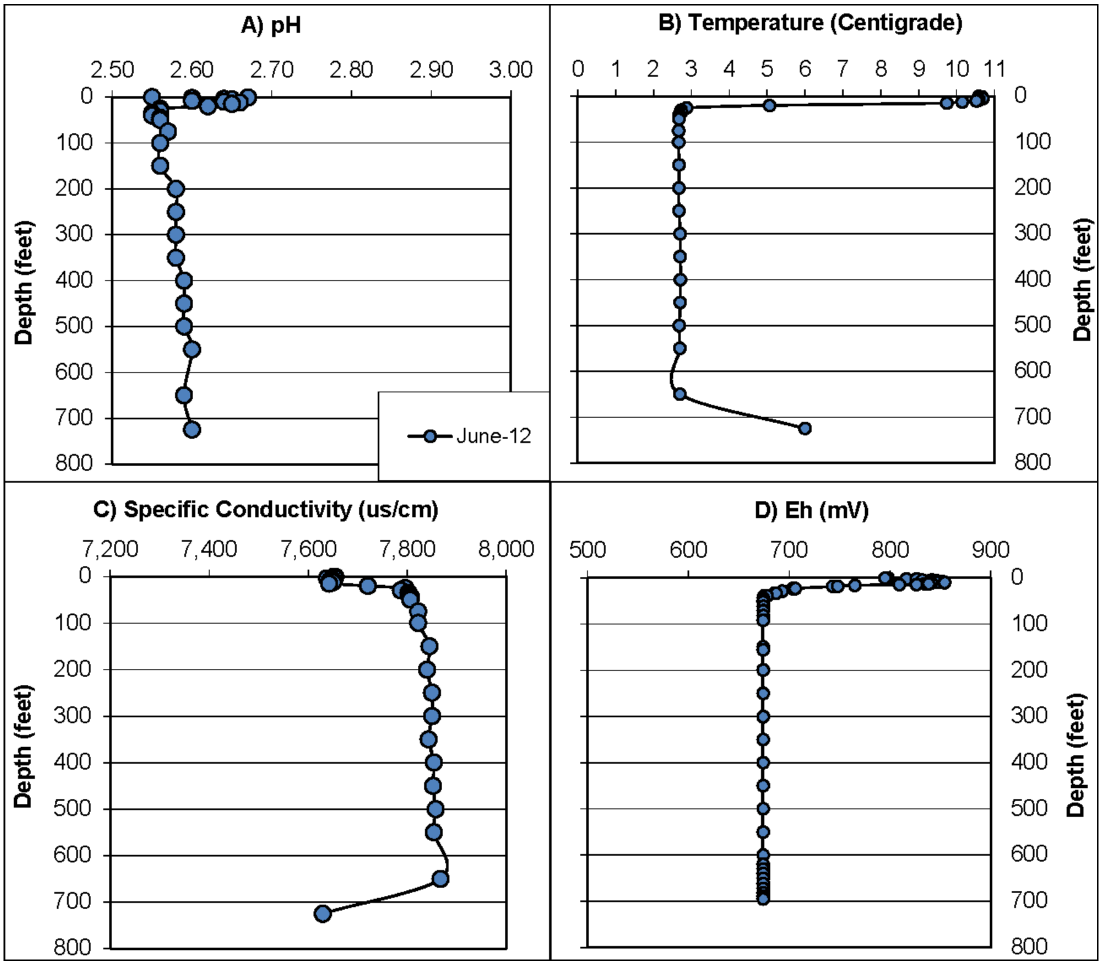


Figure 2-51. 2012 spring depth profiles for pH (A), temperature (B), SC (C), and Eh (D) in the Berkeley Pit Lake System.

Depth profiles of pH(A), specific conductance (C), and Eh (D) were similar to those observed in 2002, prior to the re-establishment of the Cu-recovery operation. Other than changes observed in the surface waters (upper 50 feet) 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 feet. A chemocline, similar to the one observed between 2003 – 2009 (as noted by rapid changes in pH, SC, Eh, and temperature over depth), was not observed in 2012. Temperature at depth (between 25' – 650') 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 feet had to be brought to the surface, and therefore the thermal profile (> 650 feet) was apparently affected by the warm atmospheric temperature on the day of sampling, and are not considered real. The presence of lighter colder water (<4°C) at depth is the first evidence reported which demonstrates that physical turn-over occurs in the Berkeley Pit Lake System. Physical turn-over 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 turn-over in the Pit was unlikely.

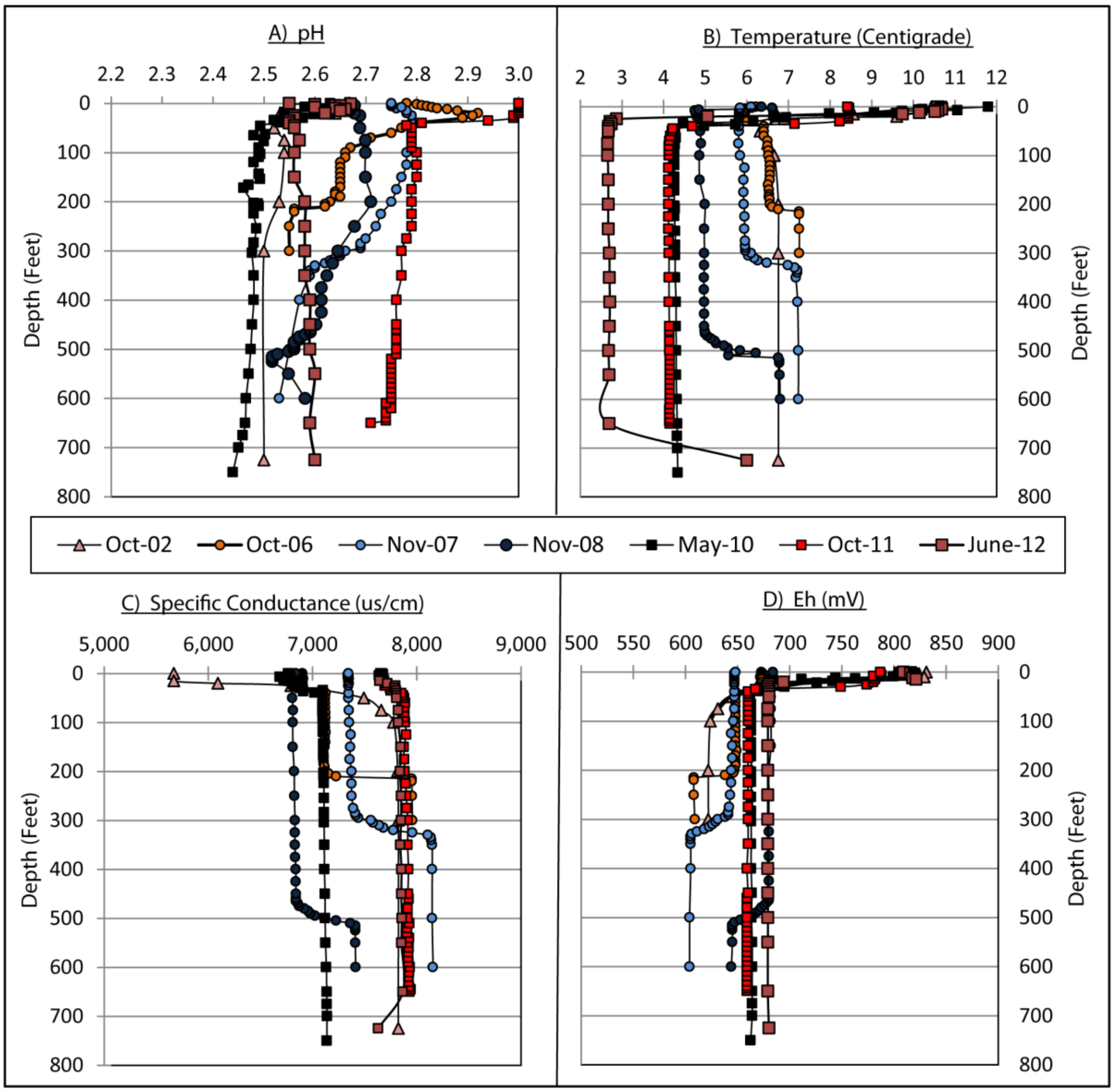


Figure 2-52. Long-term changes in depth profiles for selected parameter in the Berkeley Pit Lake. All data from all years are representative of fall sampling events, and were collected by the MBMG.

Profiles collected in the fall (2010 and 2012 values represent spring monitoring) are shown for six years (2002, 2006, 2007, 2008, 2010, 2011, and 2012) in figure 2-52. 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 three-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 of 2004 Montana Resources began pumping at depth for Cu-recovery operations.

Seasonal temperature profiles (figure 2-52, B) suggests that a thermocline exists in the surface waters (upper 50 feet) 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 the 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 – 2009, the depth of the chemocline increased as a direct result of the pumping from the MR Cu-recovery operations (figure 2-53). 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, Duaime and Tucci 2008, Duaime and Tucci 2010, Duaime and Tucci 2011). The effects of the Cu-cementation process on the chemocline are best observed in the SC profile (figure 2-51C). 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 seven 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 (figure 2-53).

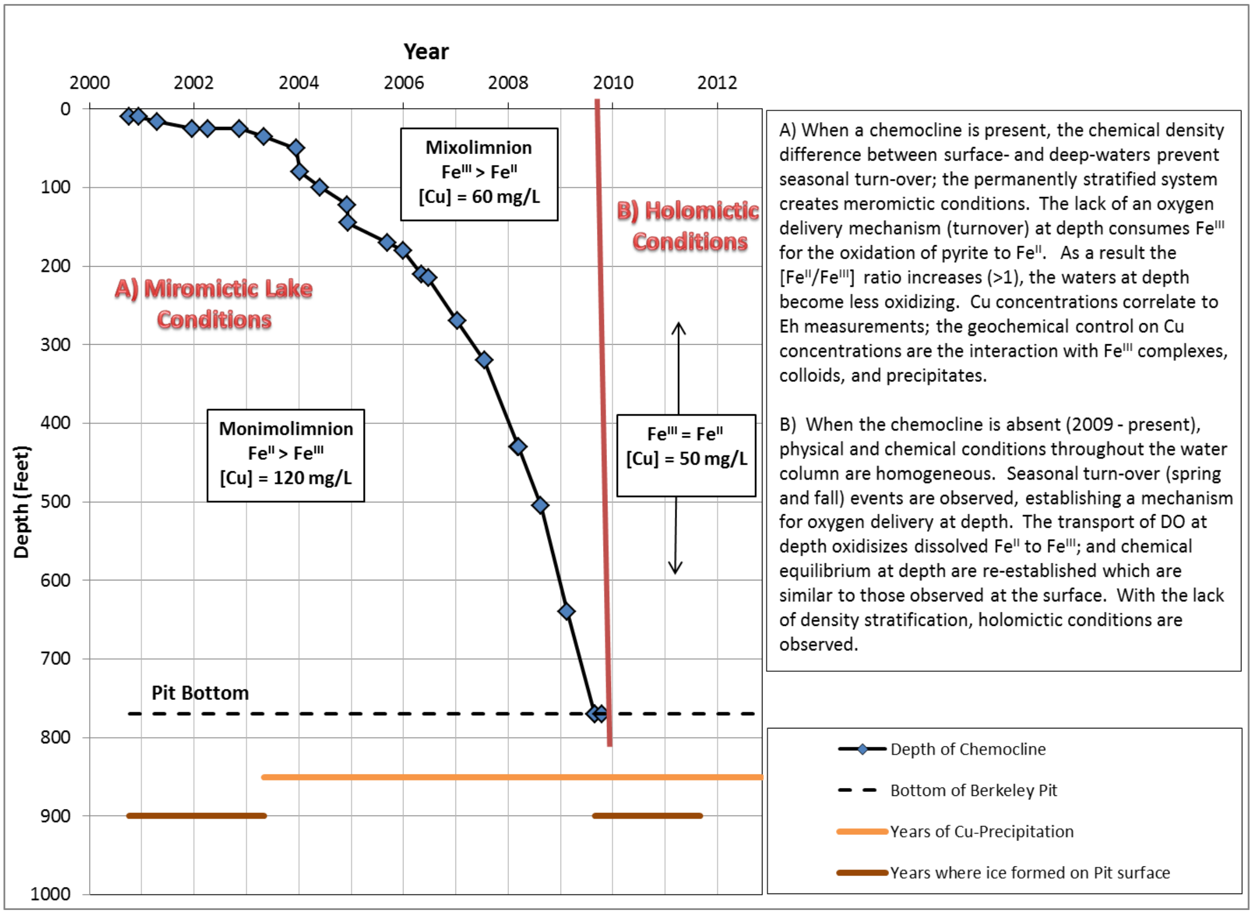


Figure 2-53 The role of the chemocline/chemical density stratification in the Berkeley Pit.

As of November 2009, the density stratification boundary known as the chemocline was pumped to extinction. Subsequent profiling data collected between 2009 - 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 2-53A; chemically stratified conditions, no lake turnover) lake to a holomictic (fig 2-53B)) 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 – 2011, water temperatures at depth were measured at

4°C, the temperature where water is most dense, indicating that seasonal turnover were occurring in the Berkeley Pit. In June-2012, the temperature of the water at depth in the Pit (between 25 – 650 feet) was measured at 3°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 $< 4°C$) 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 (figure 2-52C) and Eh (figure 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 events caused by wind-driven or landslide events would increase the frequency of turnover events. The frequency and extent of mixing will depend on seasonal affects 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 2-52 B), 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.

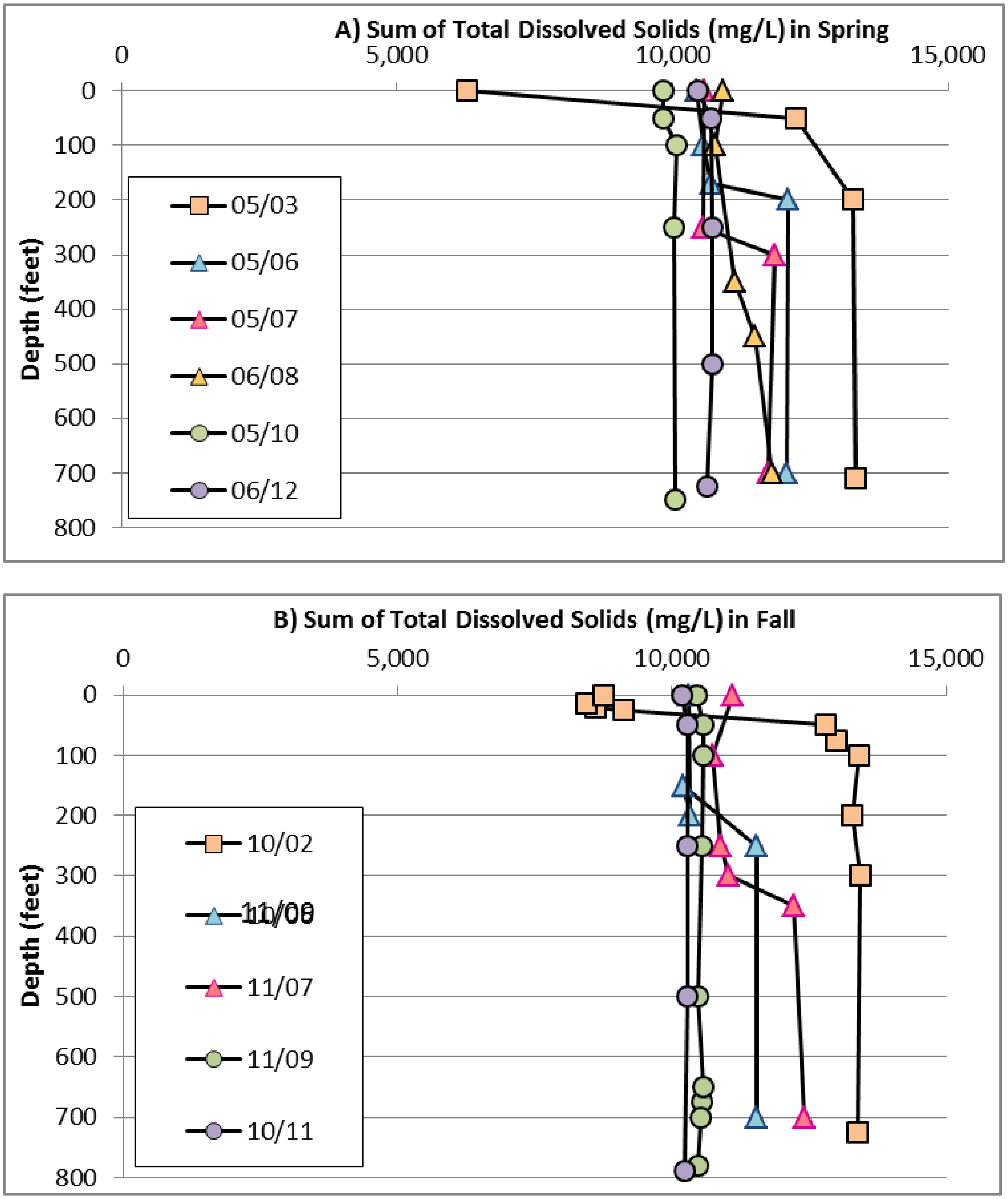


Figure 2-54. Depth profiles of the measured concentration of total dissolved solids in Berkeley Pit water over time. A) TDS during the spring monitoring events between 2002 – 2012. B) TDS during the Fall monitoring events between 2002 - 2012).

Section 2.3.1.4 Chemical Parameters

Depth profiles for total dissolved solids in the Berkeley Pit over time (between 2002 – 2012) are given in figure 2-54. 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. 2-54A) and fall (fig 2-54B) sampling events have decreased an average of 25 percent between 2002-2012.

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 extracted 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 are 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)). Effluent samples, as a result of the ion exchange process 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 Water composition that currently represents the Berkeley Pit Lake System.

	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 (us/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 (Figure 2-55), 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 eight years. Without the presence of a chemocline (Fall-2009), Fe-precipitates do not re-dissolve 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 re-establish.

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 2-56 through 2-58.

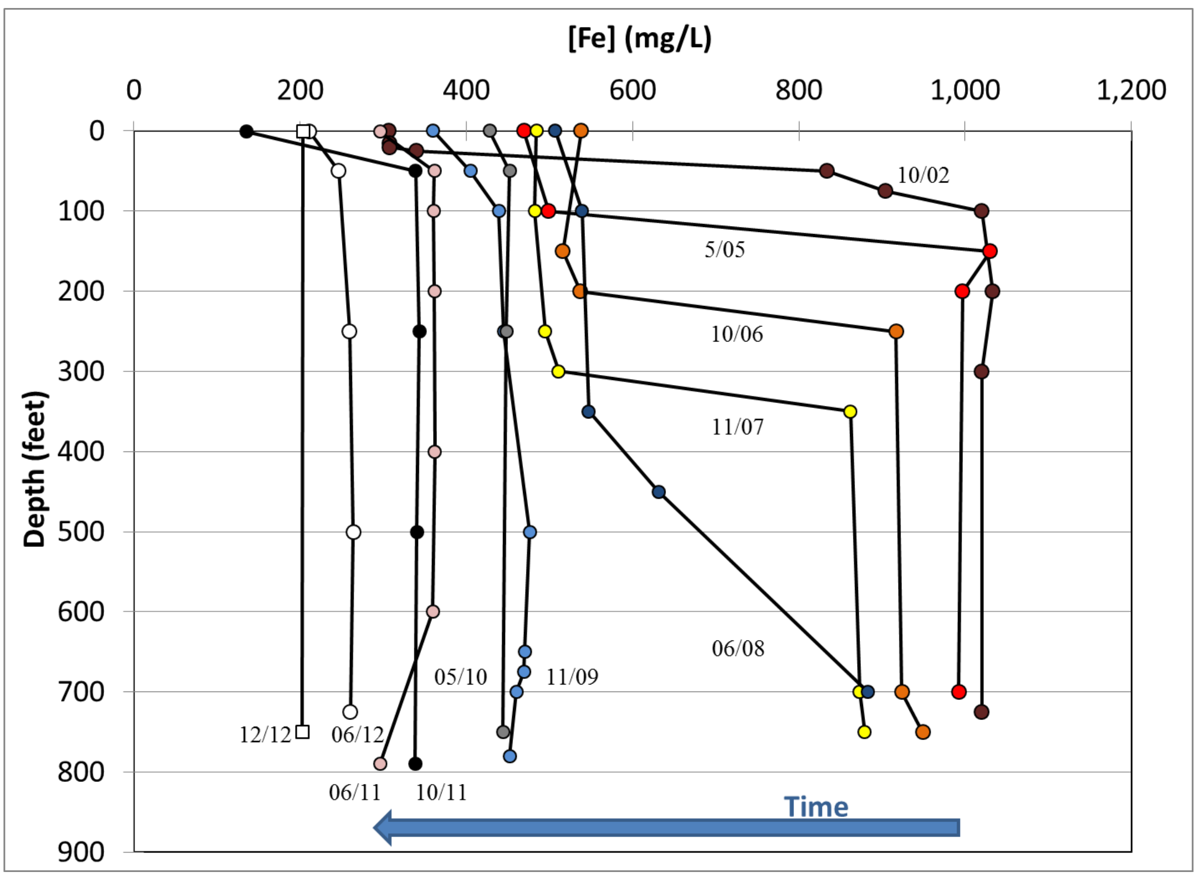
Figure 2-55. Accumulation of secondary iron precipitates in a sediment trap deployed in the Berkeley Pit for 150 days.

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 2-56. Decreasing trends were observed at all depths from 2003 – 2012. The most significant decreases were seen at depth. Between 2009 – 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 2-56. 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 2008-2012 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 (figure 2-50D) 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 of 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 turn-over events.

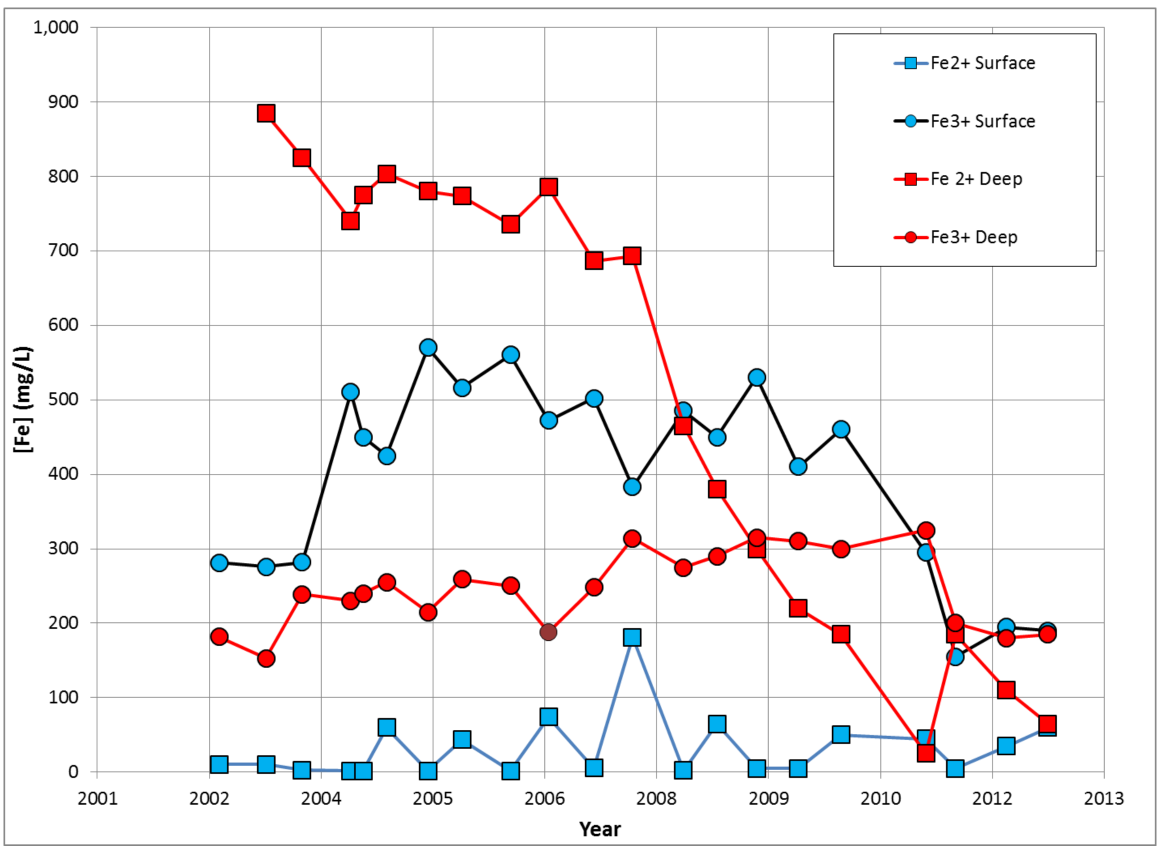


Figure 2-57. Effects of MR Cu-cementation process on Fe speciation.

The effects of the MR copper cementation plant on dissolved copper are presented in figure 2-58. Decreasing trends were observed at all depths from 2008 – 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.

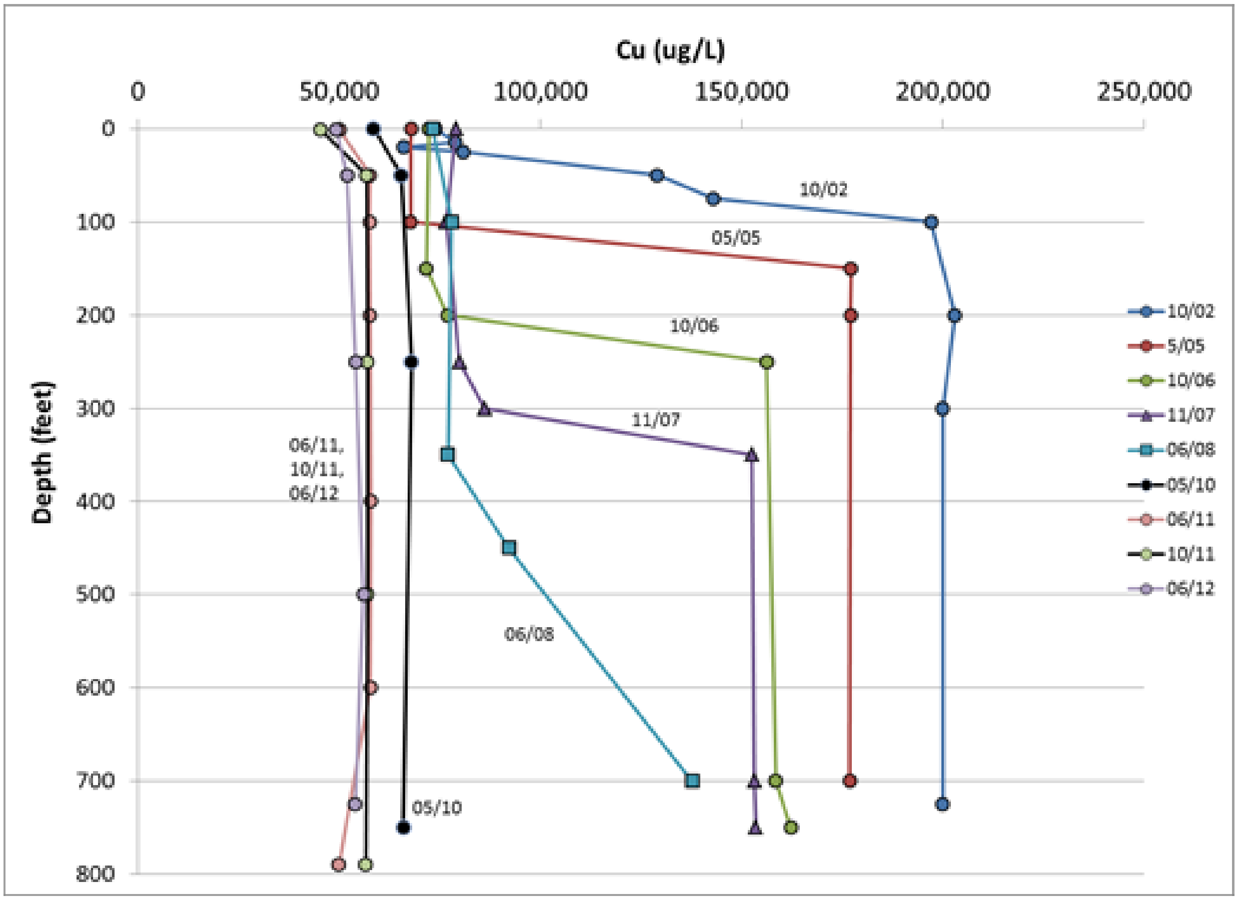


Figure 2-58. Effects of MR Cu-precipitation plant on dissolved copper.

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 2-59 portrays trends in arsenic at all depths since 2002. The significant decrease of As concentrations are 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.

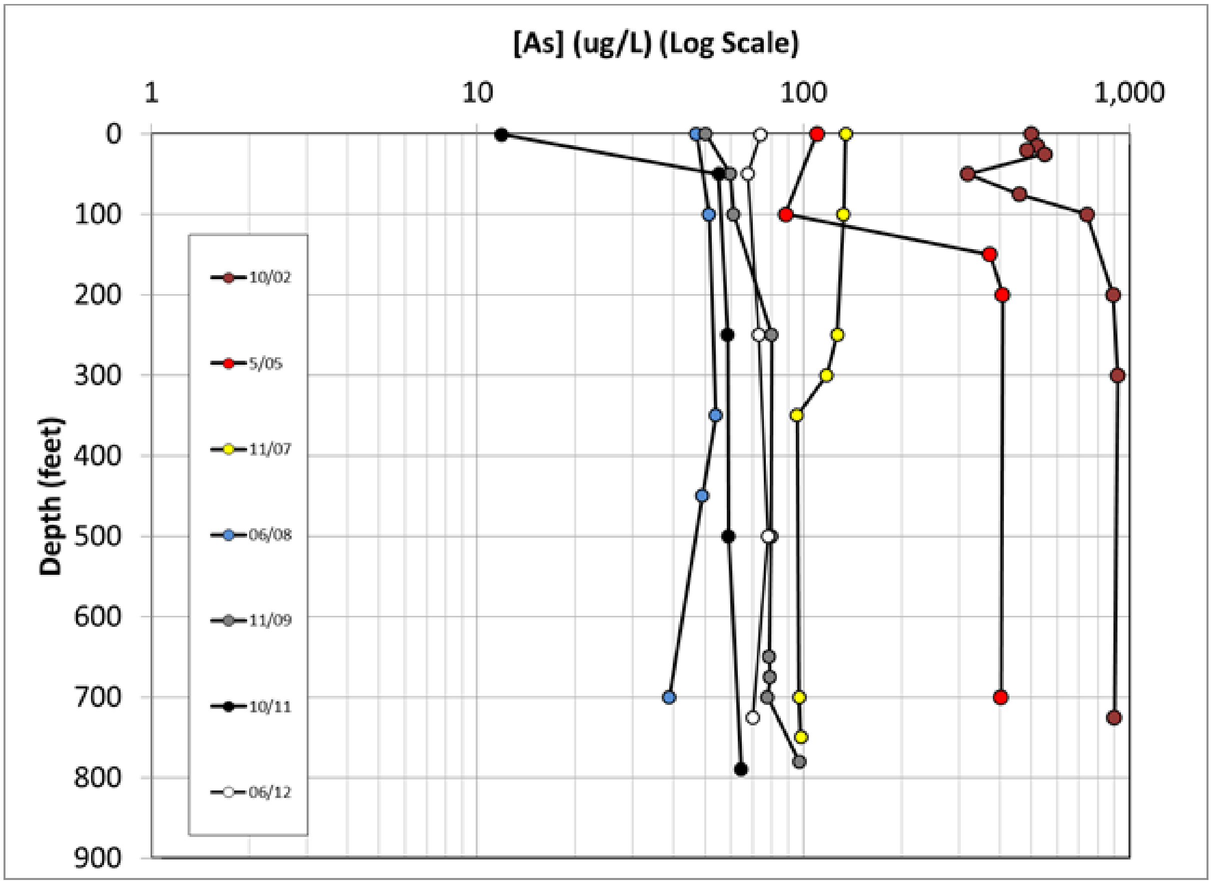


Figure 2-59. Effect of MR Cu-precipitation on dissolved As at all depths.

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, 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 nine years of MR's Cu recovery process have resulted in a

12 percent decrease in total acidity in the Berkley Pit (Figure 2- 60) . A decrease in total acidity results in a significant cost benefit, as less lime at the Horseshoe Bend Treatment Plant is needed to treat pit water. 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 (figure 2- 60).

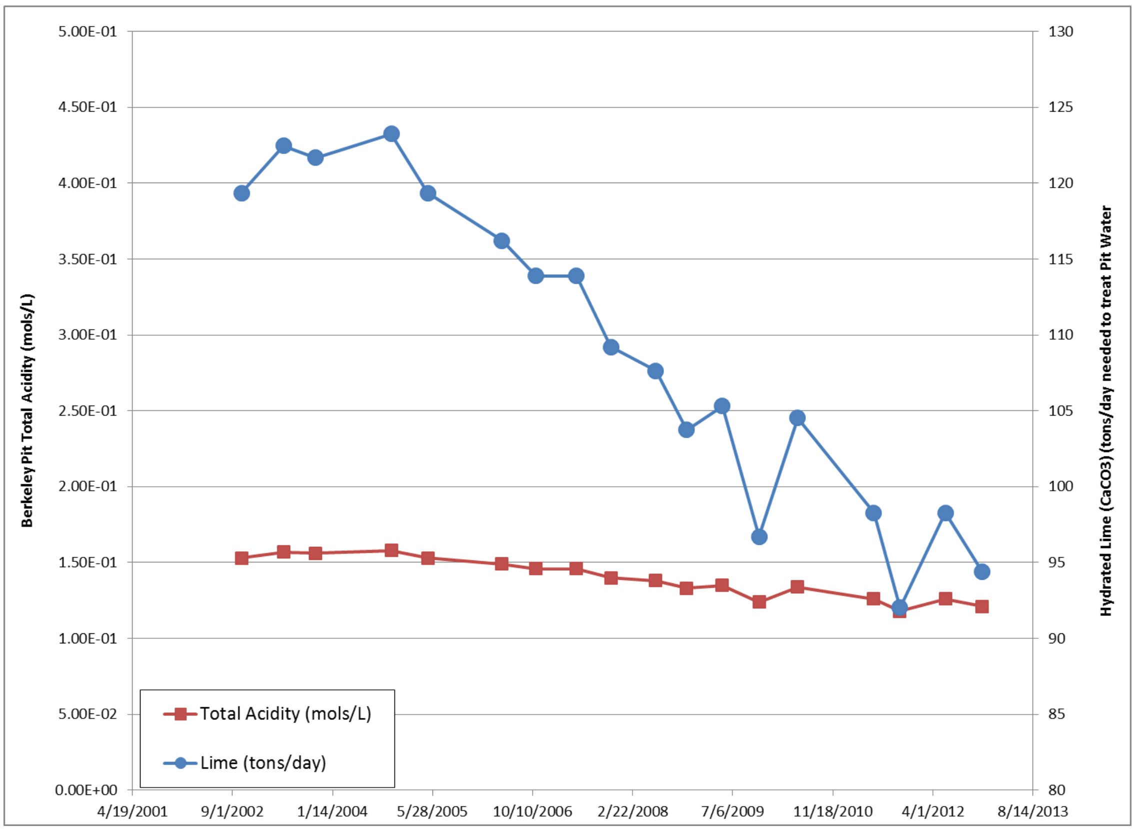


Figure 2-60. The decrease in calculated total acidity in Berkeley Pit water over time (red) corresponds to a considerable reduction in lime-use per day (in Blue) in the HSB treatment plant during remedy. The reduction of lime needed would equate to 25 tons/day.

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 (figure 2-61). 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-2012, the water quality of the HSB drainage has reversed its previously reported trend (Duaime and Tucci, 2010, Duaime and Tucci, 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

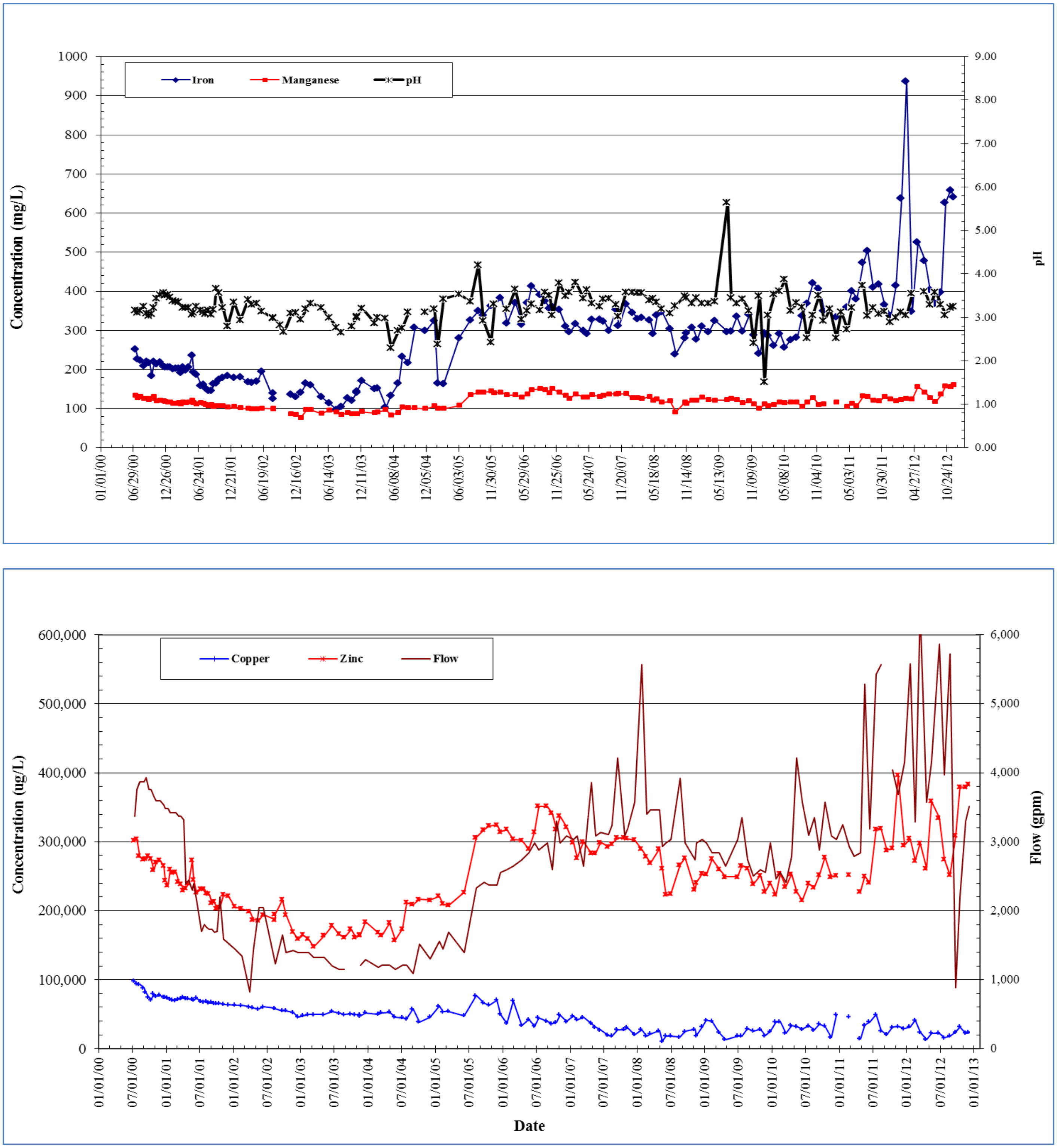


Figure 2-61. Horseshoe Bend water quality comparisons of selected constituents, 2000-2012.

SECTION 3.0 WEST CAMP SYSTEM

Water-level monitoring continued during 2012 in the three mine shafts and six monitoring wells (fig. 3-1) that comprise the West Camp system. West Camp pumping operations were continuous following ARCO's system upgrades of 2011. 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 223.6 acre-ft, or 30 acre-ft less than that pumped in 2011. Water-level increases throughout the underground mine system ranged from 6.25 ft to 7.22 ft. Water levels at the end of 2012 were 11 ft below this sites' 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 (fig. 3-2 through 3-5). These upgrades interrupted pumping for longer periods of time than in previous years, however, additional water-level monitoring was implemented to insure water-levels were maintained at appropriate levels; figure 3-6 shows water-levels in the Travona, Ophir, and well BMF96-1D during the period of construction and throughout 2012.

The quantity of water pumped was less than that for the last 10 years. A total of 223.6 acre-ft of water was pumped during 2012 compared to 252.9 acre-ft pumped in 2011, 253.5 acre-ft of water pumped during 2010 and 247 acre-ft pumped in 2009. 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.

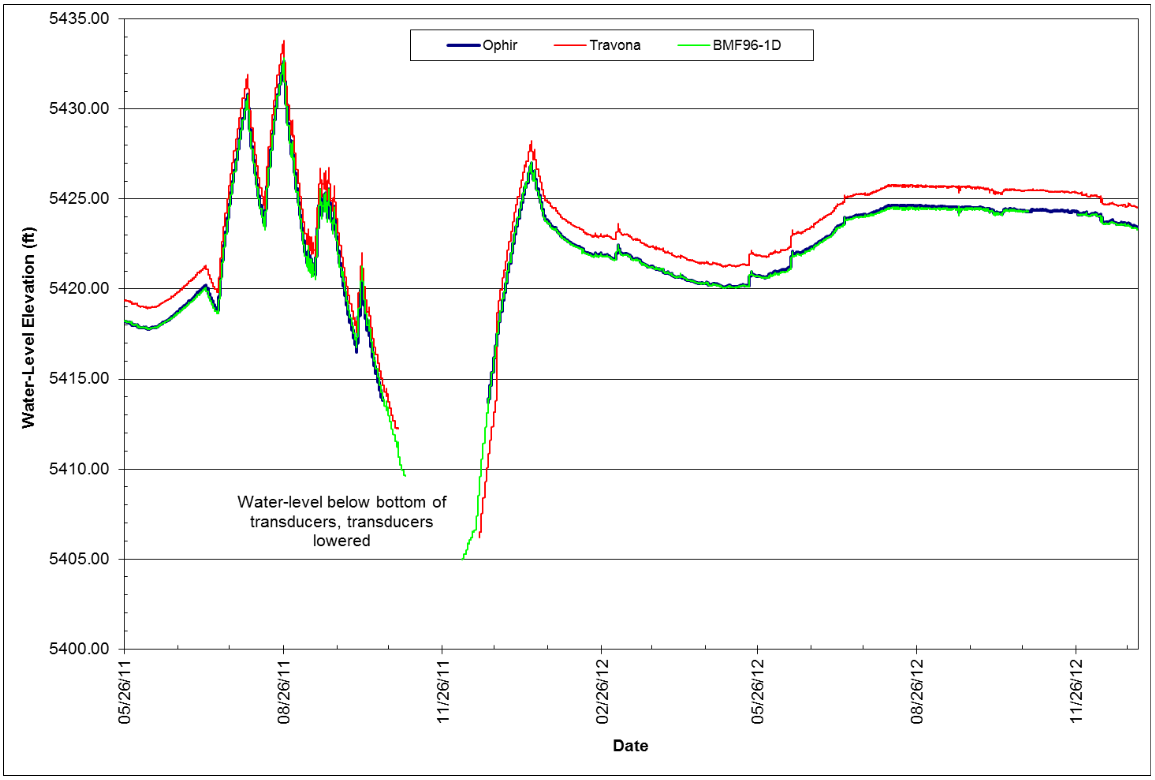


Figure 3-6. Hydrograph showing water-levels in the Travona Mine, Ophir Mine, and well BMF96-1D during 2011 construction activities and throughout 2012.

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

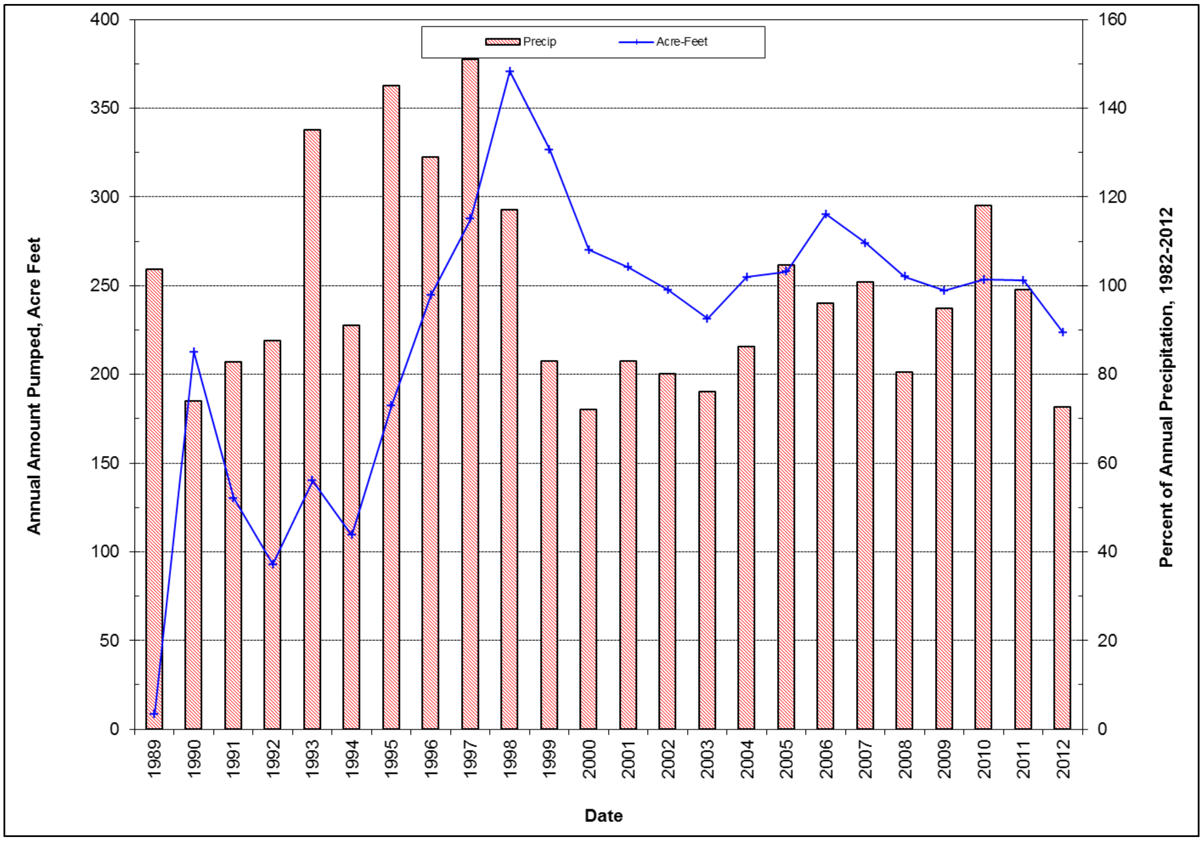


Figure 3-7. Annual amount of water pumped from the West Camp system.

All three mines had a net water-level increase between 6.25 ft and 7.22 ft during 2012. 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 more than 11 ft below the West Camp action level of 5,435 ft stipulated in the 1994 ROD.

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

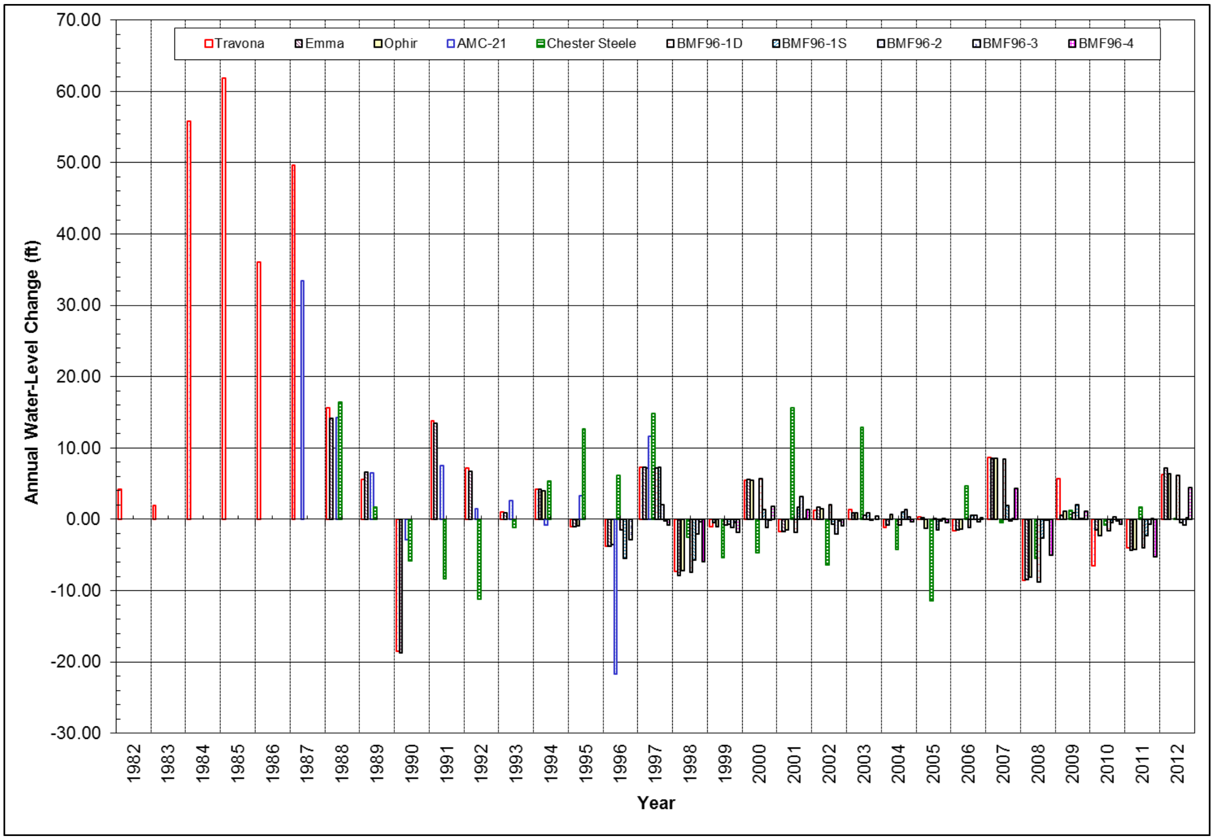


Figure 3-8. Annual water-level changes for West Camp site

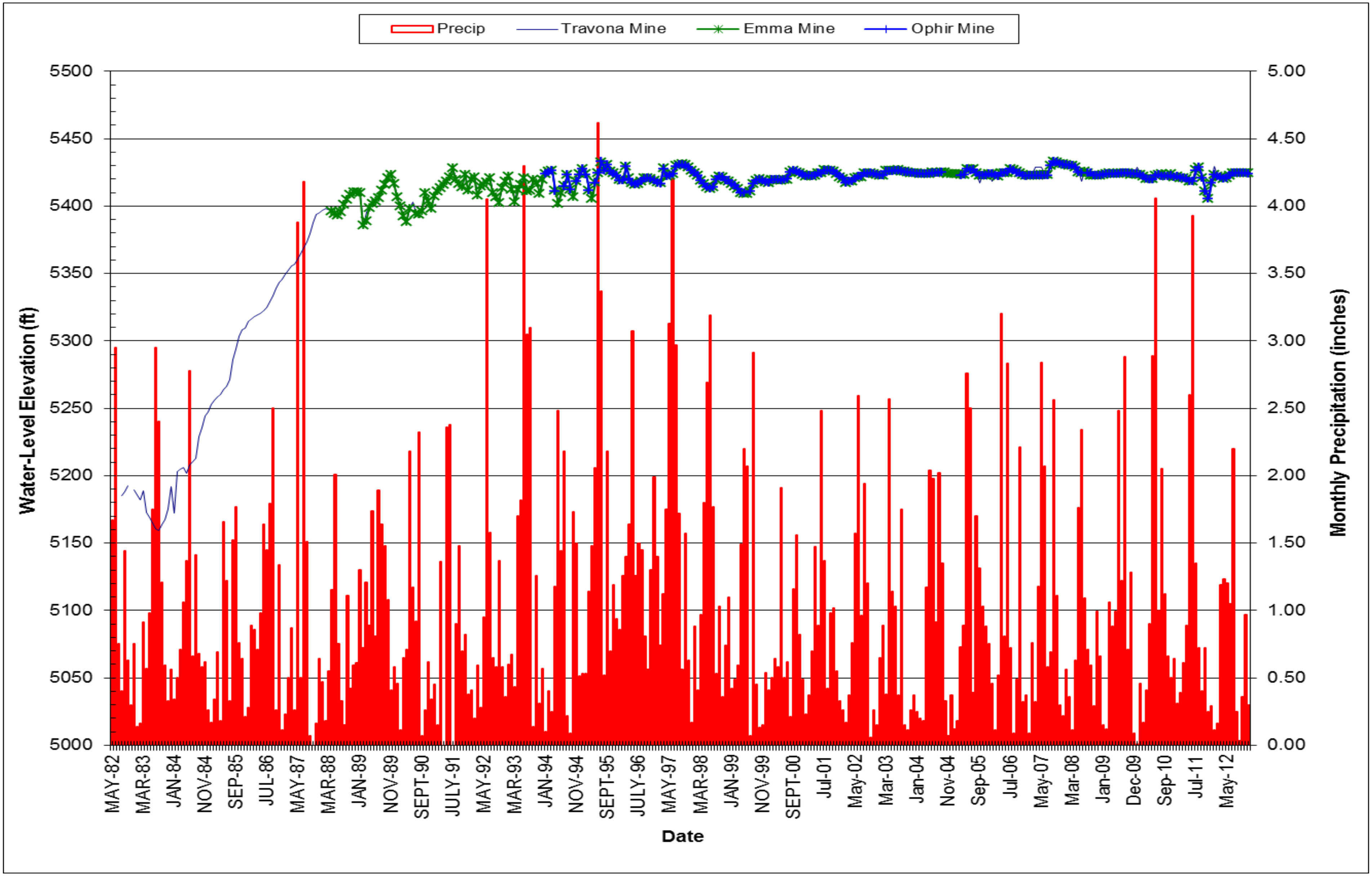


Figure 3-9. Water-level hydrographs for West Camp mines.

Section 3.2 West Camp Monitoring Wells

Water levels increased in four of the six BMF96 West Camp wells during 2012. Well BMF96-1D, which was completed into the Travona Mine workings, had a water-level change (increase) similar to the West Camp mines. These changes are shown in table 3.2.1 and on 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 has 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 1960's 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 well BMF96-4 was not completed into mine workings. During periods of continued water-level change in wells BMF96-1D and BMF96-4, there appears to be a similarity in water-level change in well BMF96-1S. Well BMF96-1S is located adjacent to well BMF96-1D, but was completed at a much shallower depth in the weathered bedrock of the Missoula Gulch drainage. This well also shows a response to pumping in the WCPW. There was no change in longer term trends in any of these wells from those described in the previous reports.

Water levels in wells BMF96-2 and BMF96-3 are 20 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 2012 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 2011, related to the West Camp upgrades. Water levels rise with precipitation and with infiltration from snow melt, 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, in feet.

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**
Change Years 31-40	**6.25**	**7.22**	**6.43**	**0.12**	**6.20**	**-0.46**	**-0.82**	**0.21**	**4.47**
Net Change*	**239.47**	**28.64**	**4.46**	**26.27**	**3.46**	**-2.31**	**-0.56**	**-3.42**	**-6.85**

(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.

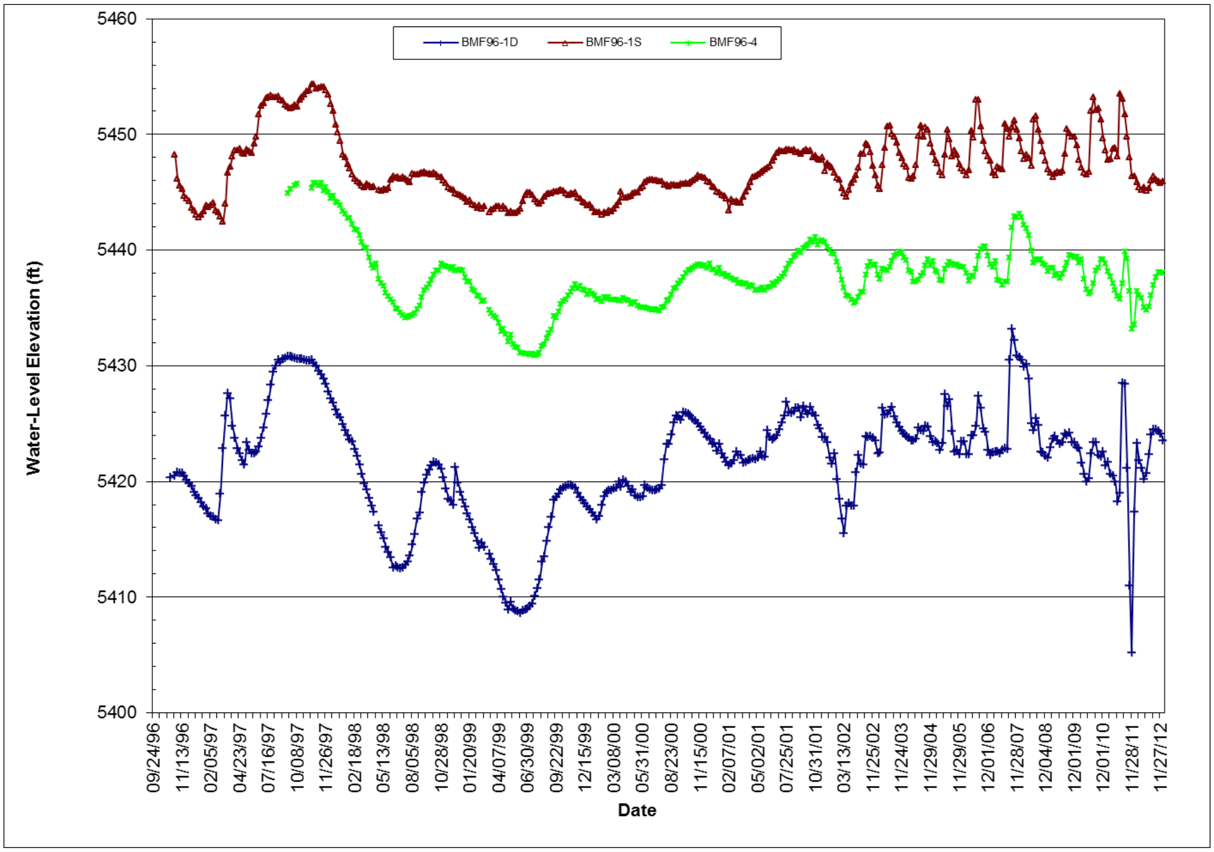


Figure 3-10. Water-level hydrographs for West Camp wells BMF96-1D, BMF96-1S, and BMF96-4.

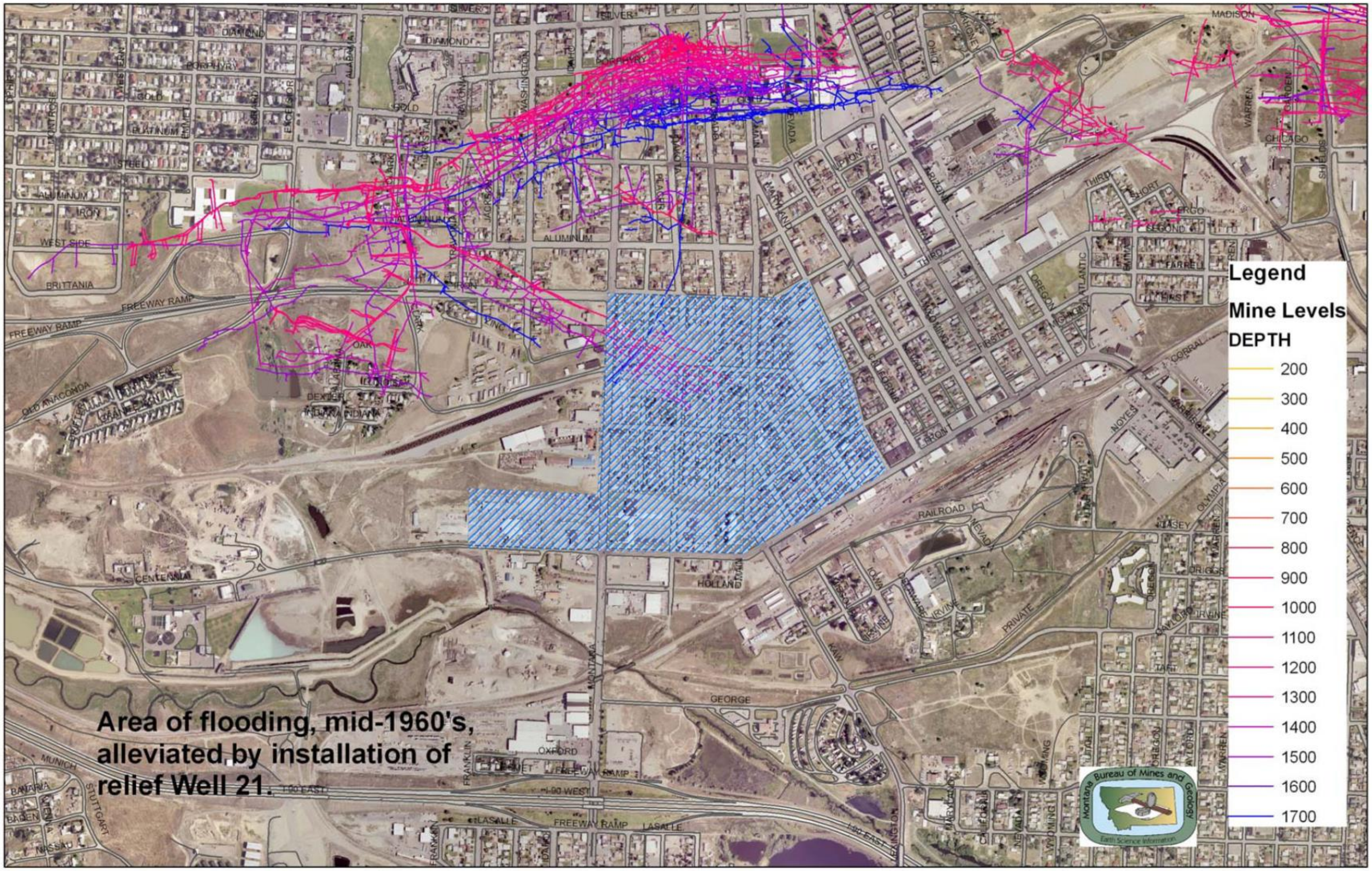


Figure 3-11. Area of the West Camp affected by basement flooding problems, 1960s. Blue hatch area outlines problem locations.

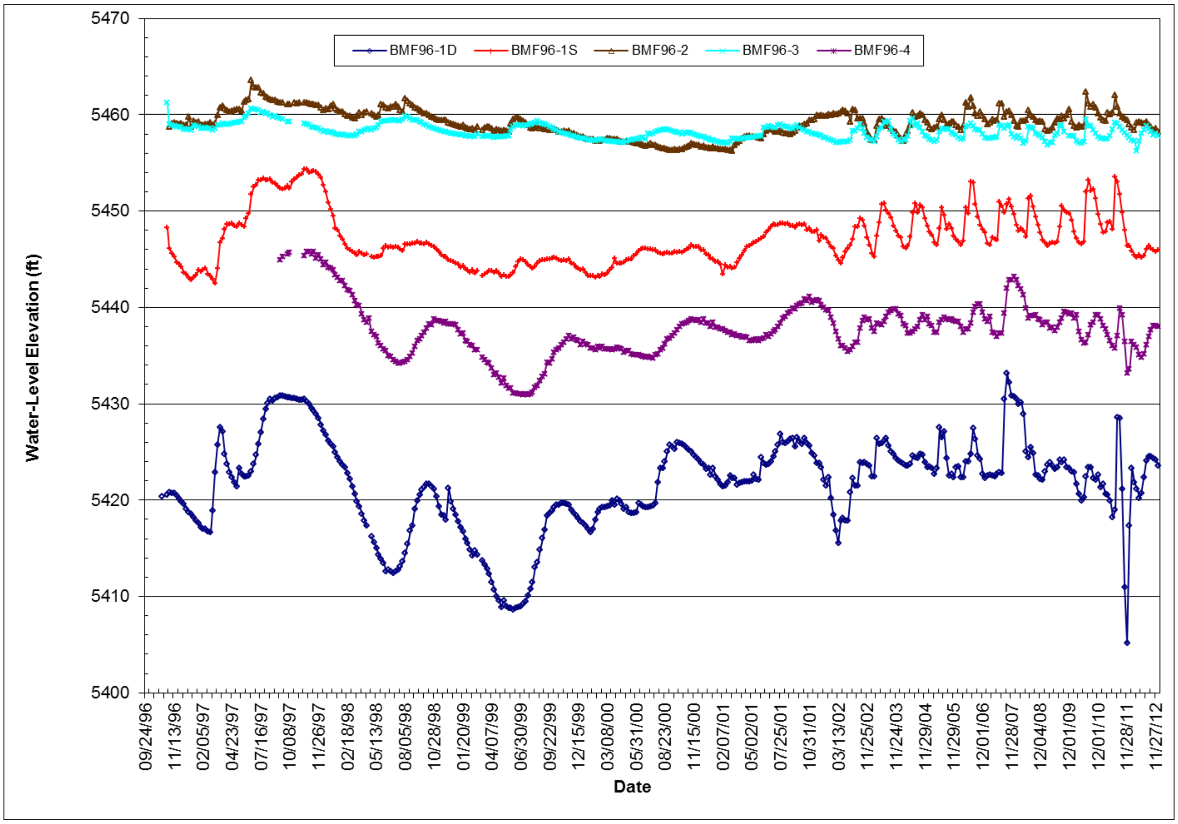


Figure 3-12. Water-level hydrographs for BMF96 series wells.

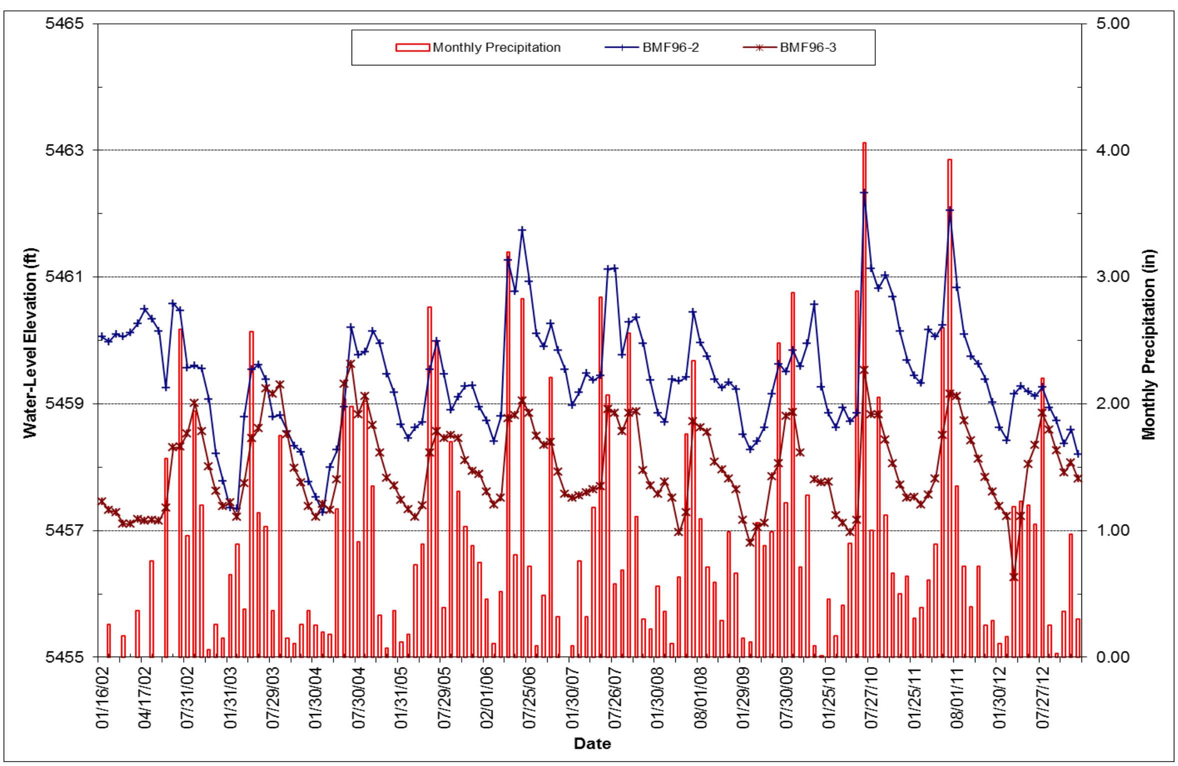
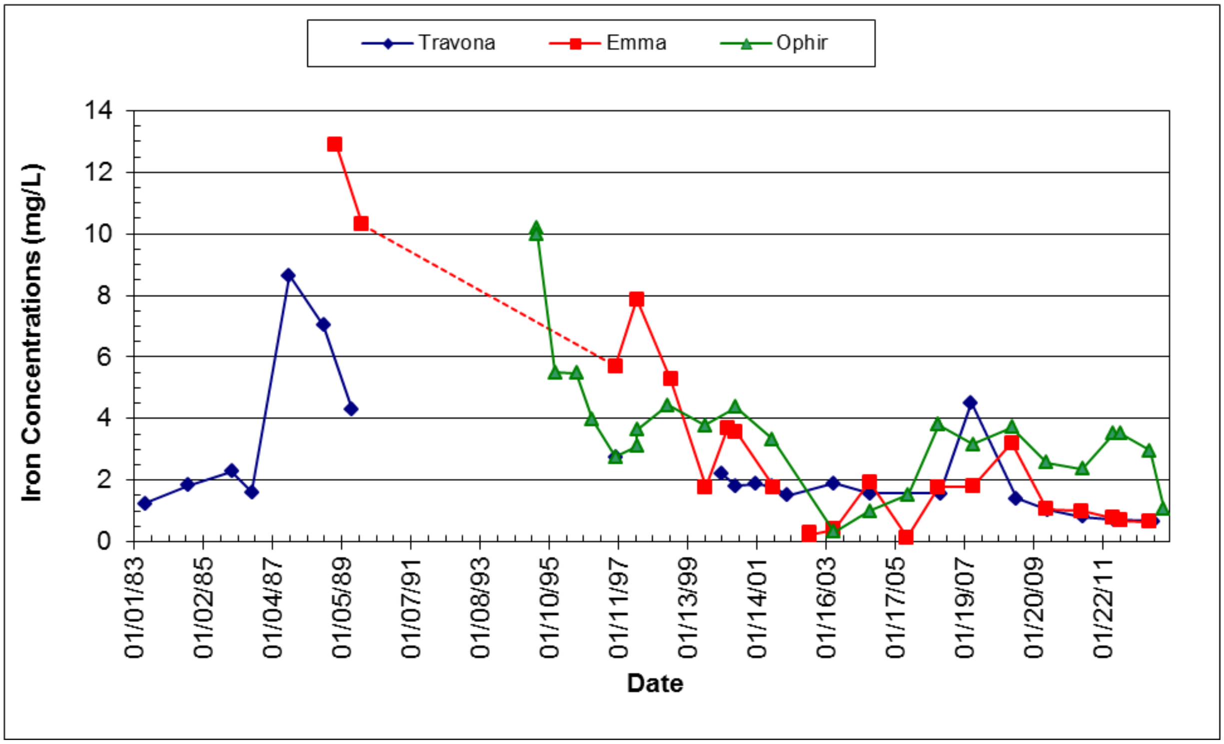


Figure 3-13. Water-level hydrographs for wells BMF96-2 and BMF96-3, 2002-2012.

Section 3.2.1 West Camp Mines and Monitoring Wells Water Quality

Water-quality data for the West Camp monitoring system in 2012 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 only.

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 (fig. 3-14 and 3-15). The concentrations of most dissolved metals in well BMF96-4 are low and continued to exhibit a slight downward trend through 2012 (fig. 3-16). Concentrations of zinc showed some variation from 2003-2007; 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.



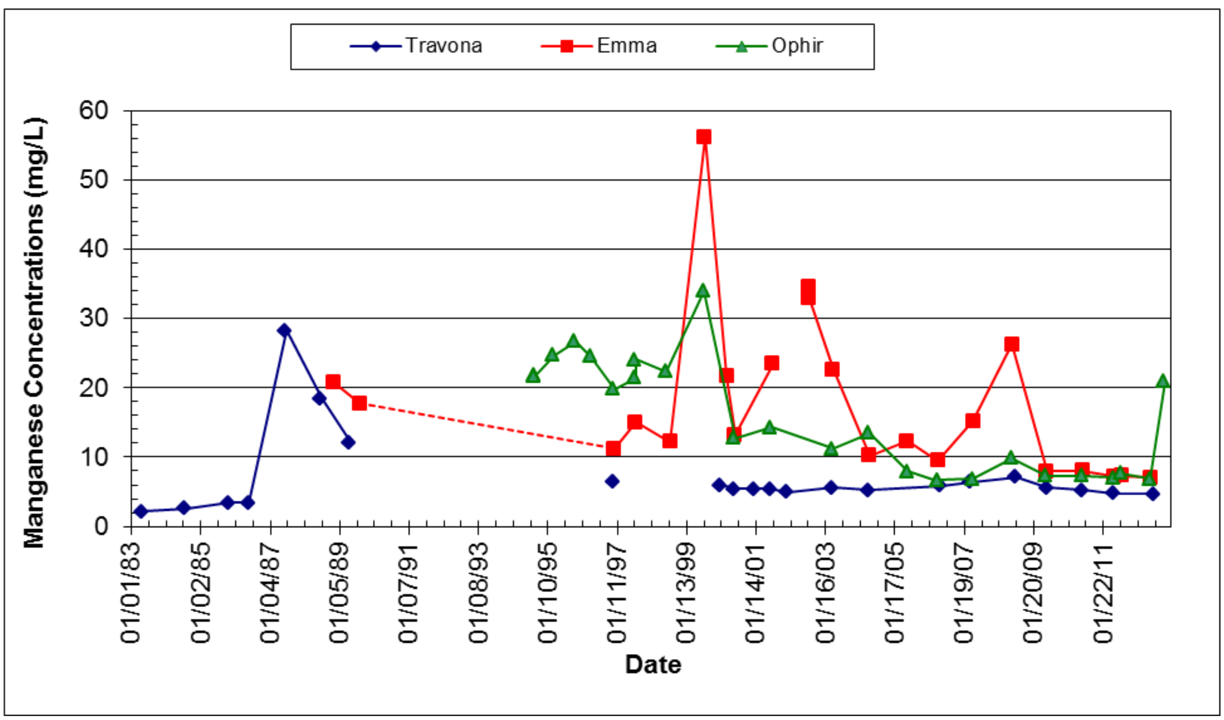


Figure 3-14. Iron and manganese concentrations in the West Camp mines.

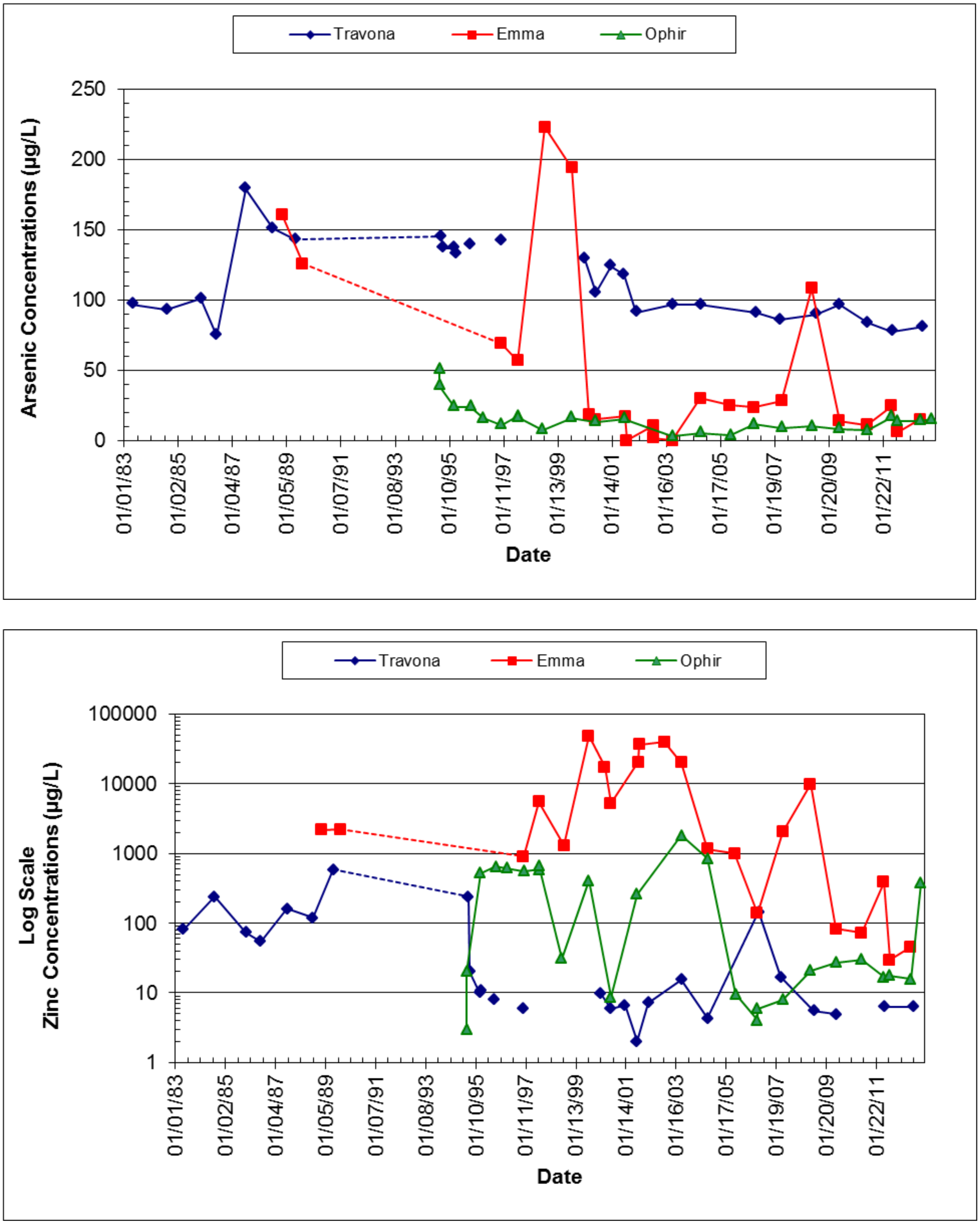


Figure 3-15. Arsenic and zinc concentrations in West Camp mines.

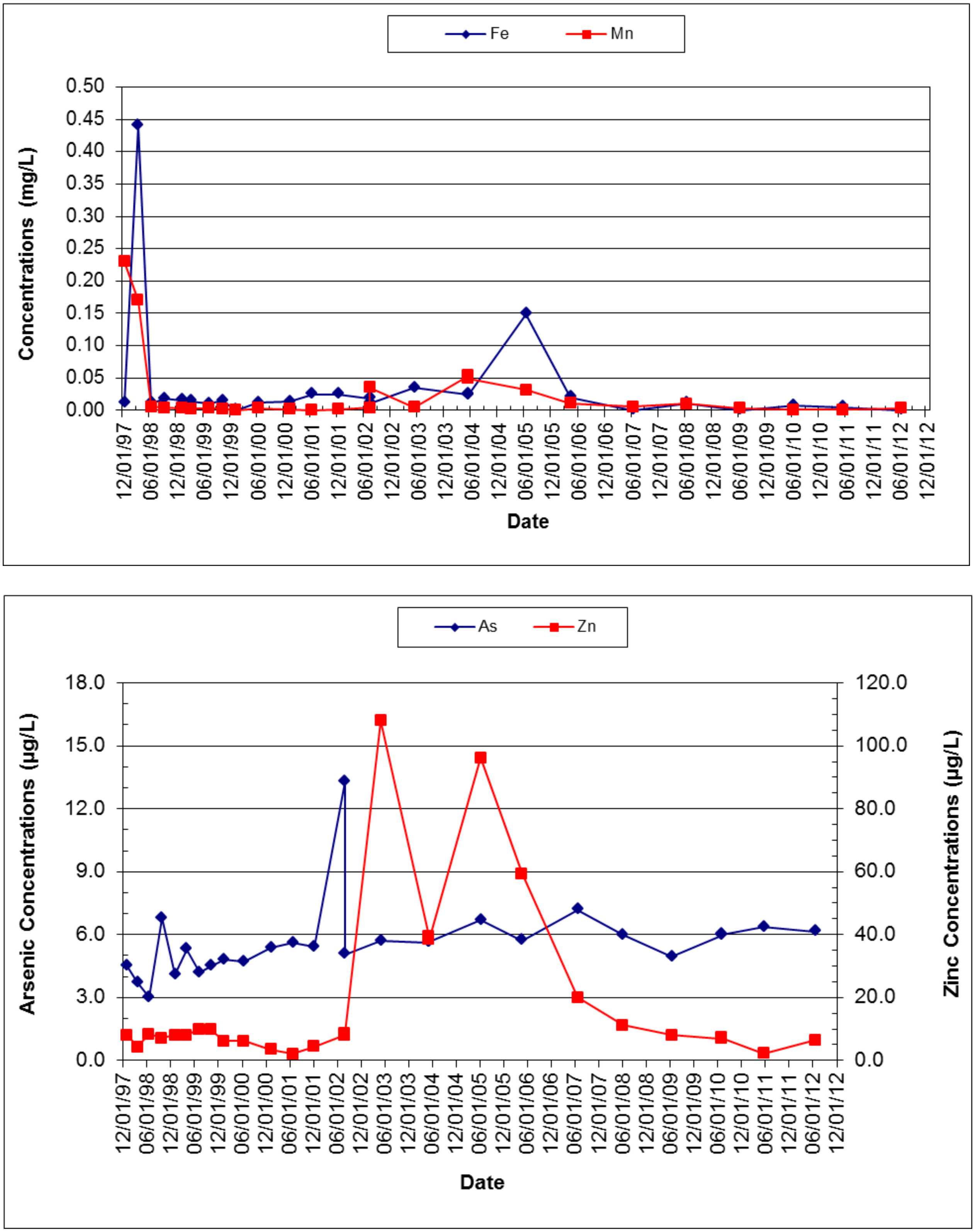


Figure 3-16. Selected water chemistry for West Camp well BMF96-4.

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 condition, 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; however, 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 2009-2011, water levels have increased in at least three of the four sites; water-levels decreased at all four sites in 2012. 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 two 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, showing no seasonal trend. Water-level changes in 2012 varied from a decline of 4.76 ft in the MT Tech well to a decline of 5.77 ft in 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, in feet.

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
Change Years 21-30	**3.55**	**6.81**	**9.18**	**5.40**
Total Change*	**30.76**	**37.01**	**30.76**	**13.54**

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

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

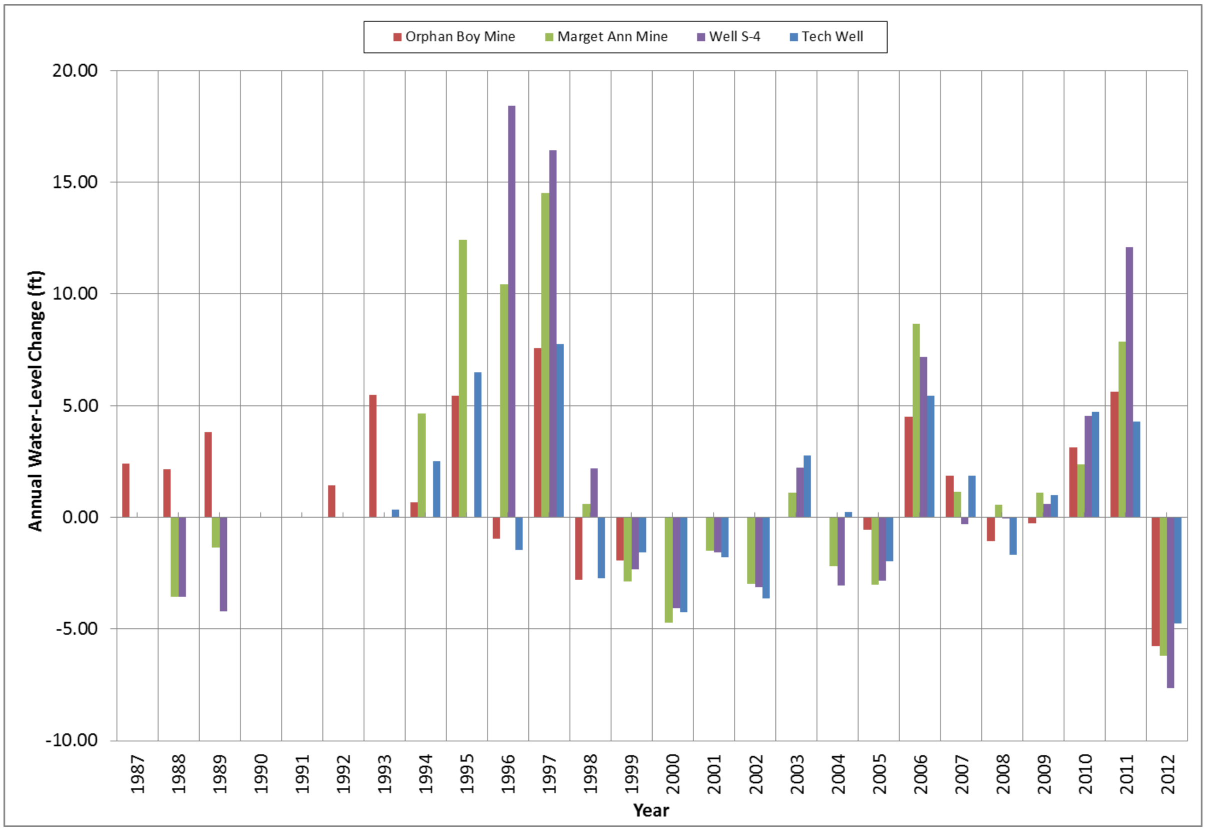

Figure 4-2. Outer Camp sites annual water-level change.

The water level in the Marget Ann Mine declined 6.21 ft during 2012; this is a change following six years in a row that water levels increased. The water level in well S-4 decreased by 7.66 ft during 2012 following three 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 continued to raise 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 2012. The magnitude of the 2011 water-level rise in both sites was the largest increase seen during the period of monitoring. Similar to 2003, considerable precipitation occurred in May and June 2011 which may account for the large increases in water-levels. This is the same trend observed in the MT Tech well and Orphan Boy Mine, although to a lesser degree.

Water levels in all four of the Outer Camp sites have a net increase since monitoring began. The increases vary from over 13 ft at the MT Tech well to over 37 ft in the Marget Ann Mine.

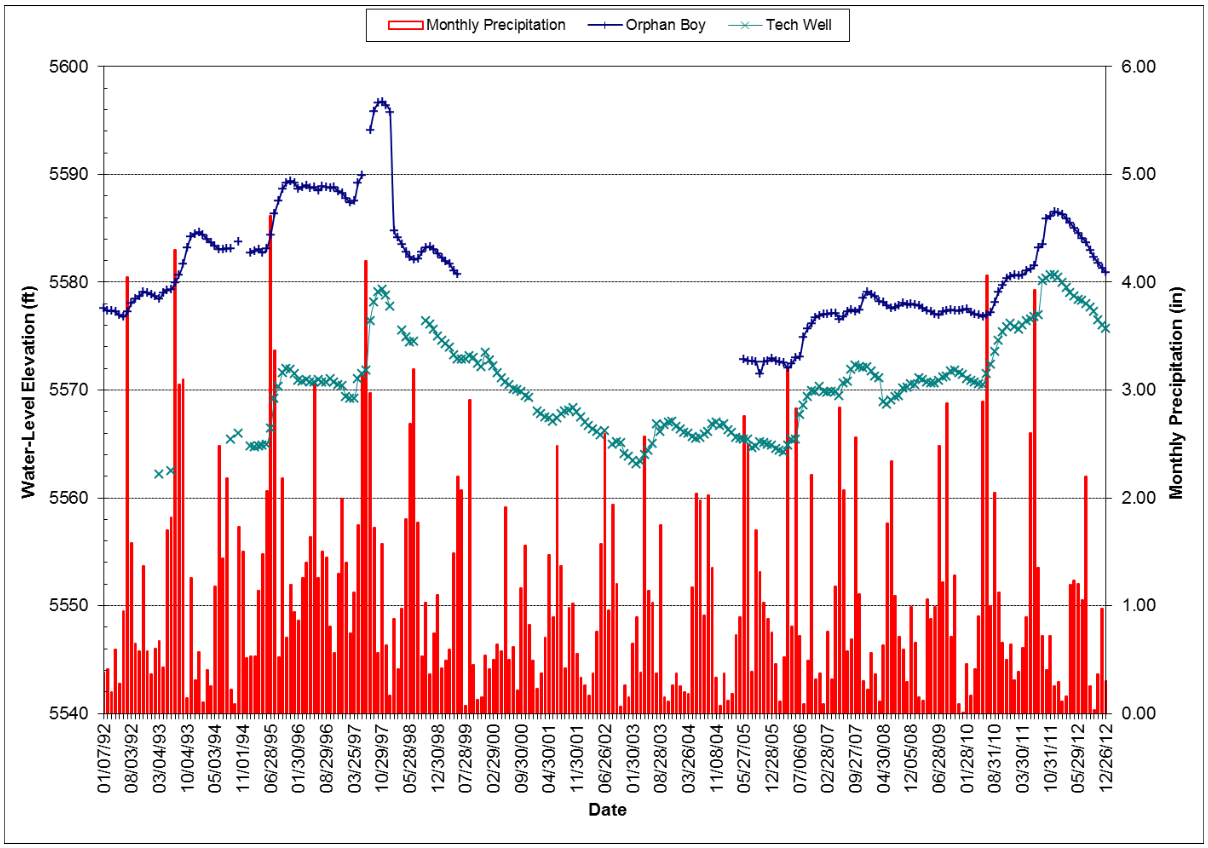

Figure 4-3. Water-level hydrograph for the Orphan Boy Mine and Montana Tech well.

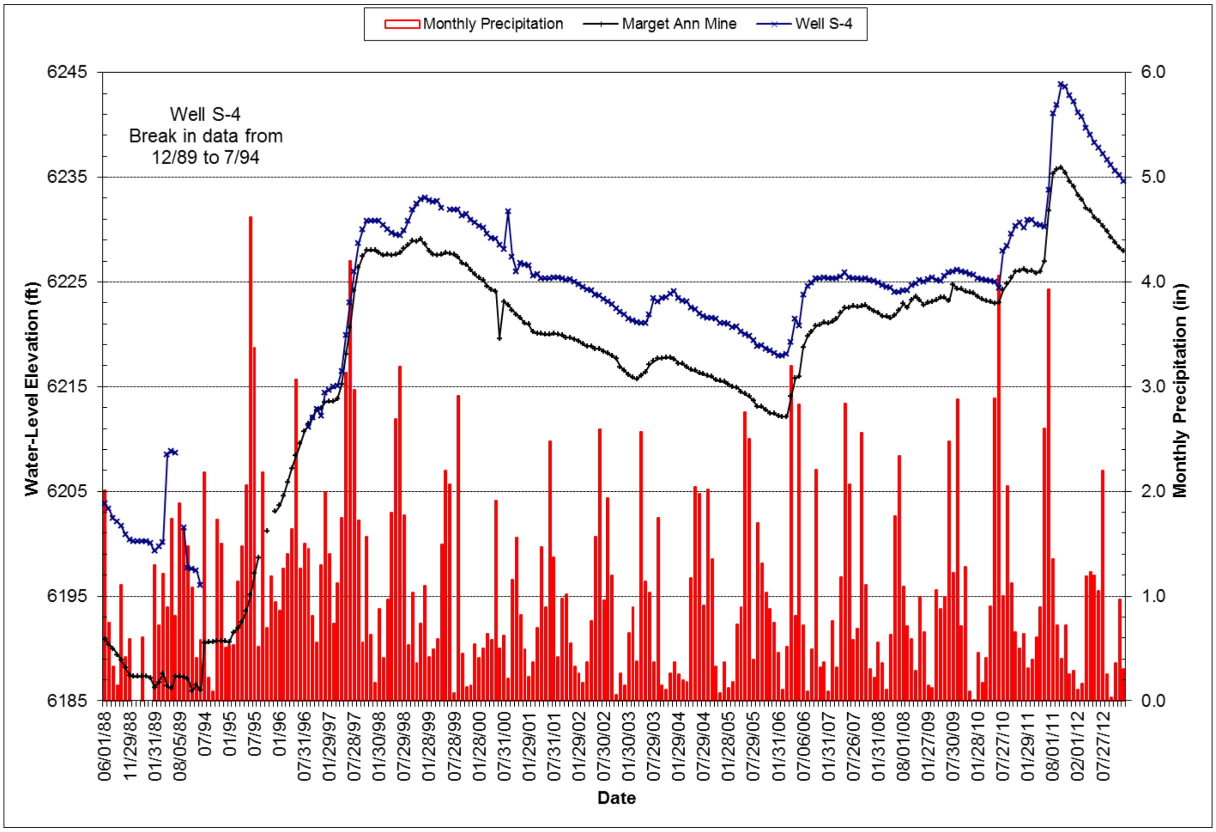

Figure 4-4. Water-level hydrograph for the Marget Ann Mine and well S-4.

Section 4.2 Outer Camp Water Quality

Water-quality samples were collected from all four locations within the Outer Camp System during 2012 (the Marget Ann Mine and MT 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, the exception being zinc, which increased from 2005-2010; concentrations have varied during 2011-2012. 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 collected by installing a pump into the shaft and pumping for several hours 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.

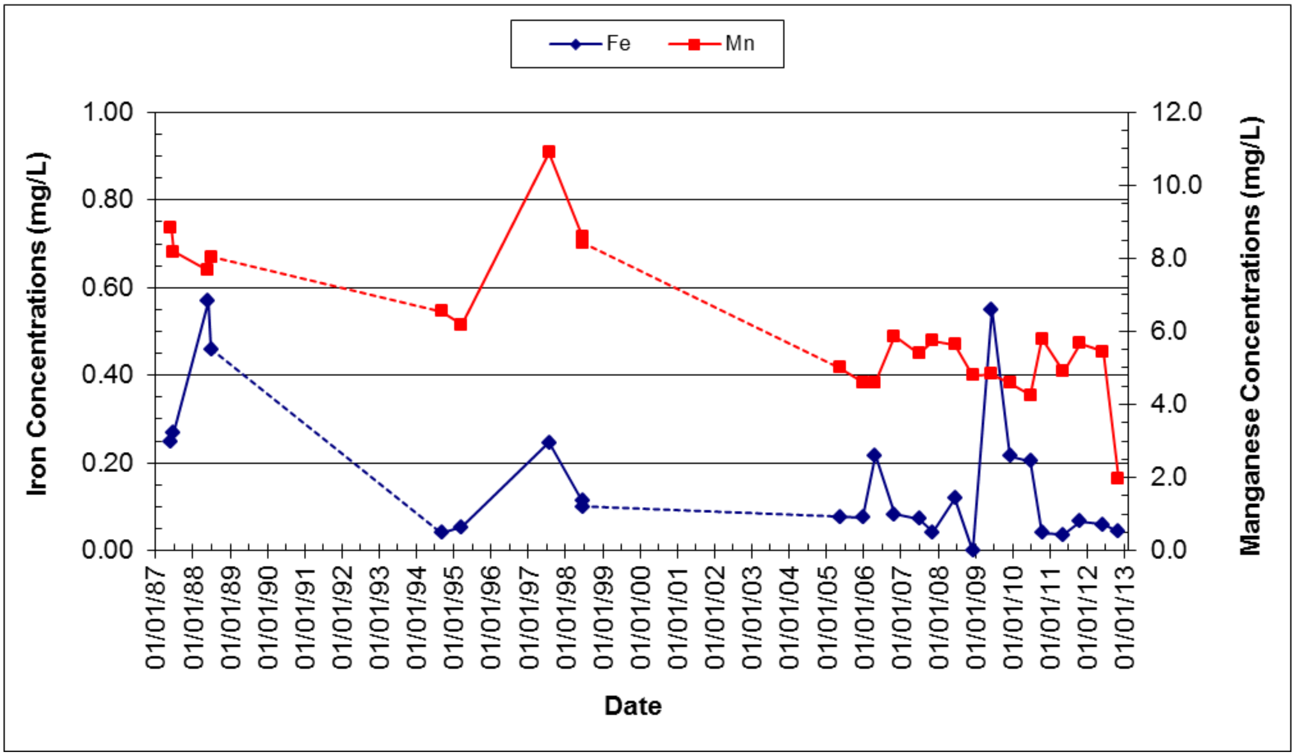

Figure 4-5. Iron and manganese concentrations for the Orphan Boy Mine.

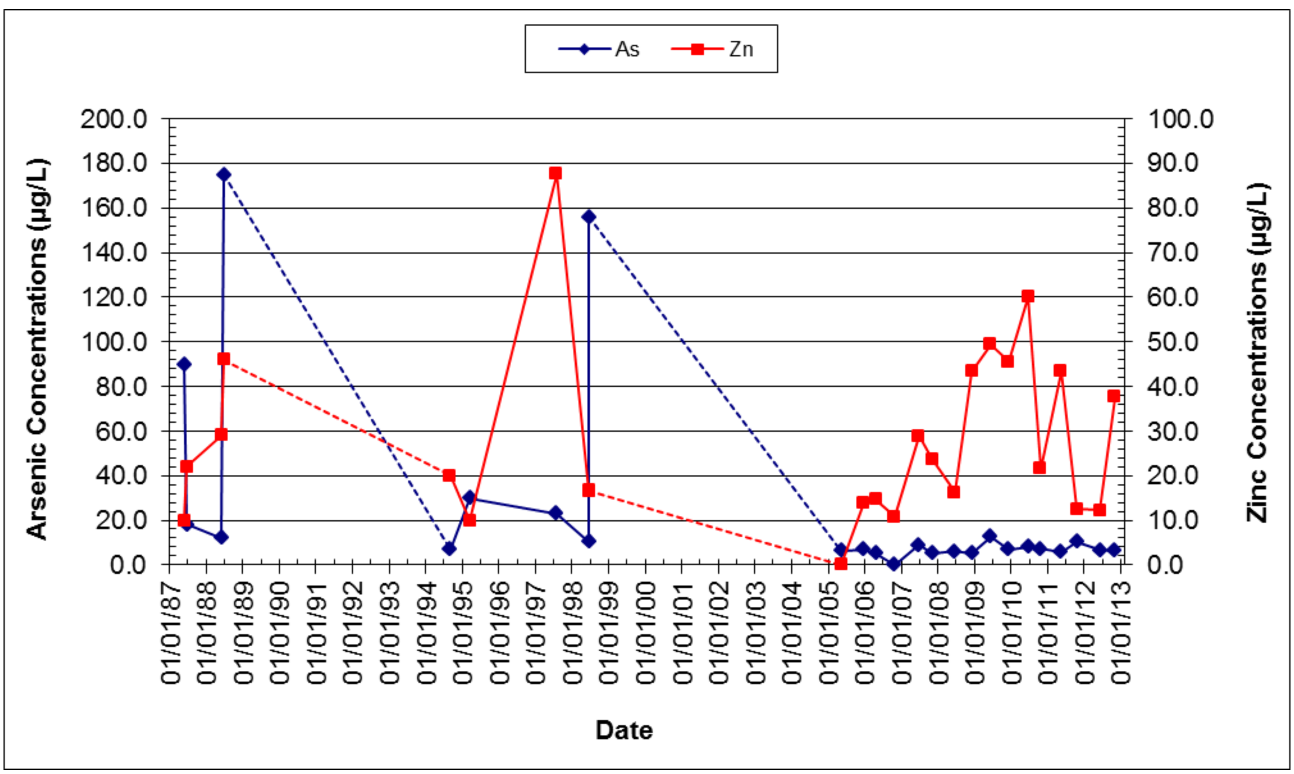

Figure 4-6. Arsenic and zinc concentrations for the Orphan Boy Mine.

SECTION 5.0 PARK WELLS

The locations of the park monitoring wells are shown on figure 5-1. The Hebgen Park and Parrot Park wells are both part of the monitoring program specified in the 2002 CD. The Belmont Well #1 has been added to this group of wells since it is a bedrock well, located within the East Camp system and is part of the CD monitoring program.

Section 5.1 Park Wells' Water Levels

Annual water-level changes are listed in Table 5.1.1 and shown on 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 0.6 ft and 7 ft in the Hebgen and Parrot Park wells, while falling more than 10 ft in Belmont Well #1.

Table 5.1.**1** Annual water-level change for miscellaneous wells, in feet.

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.)

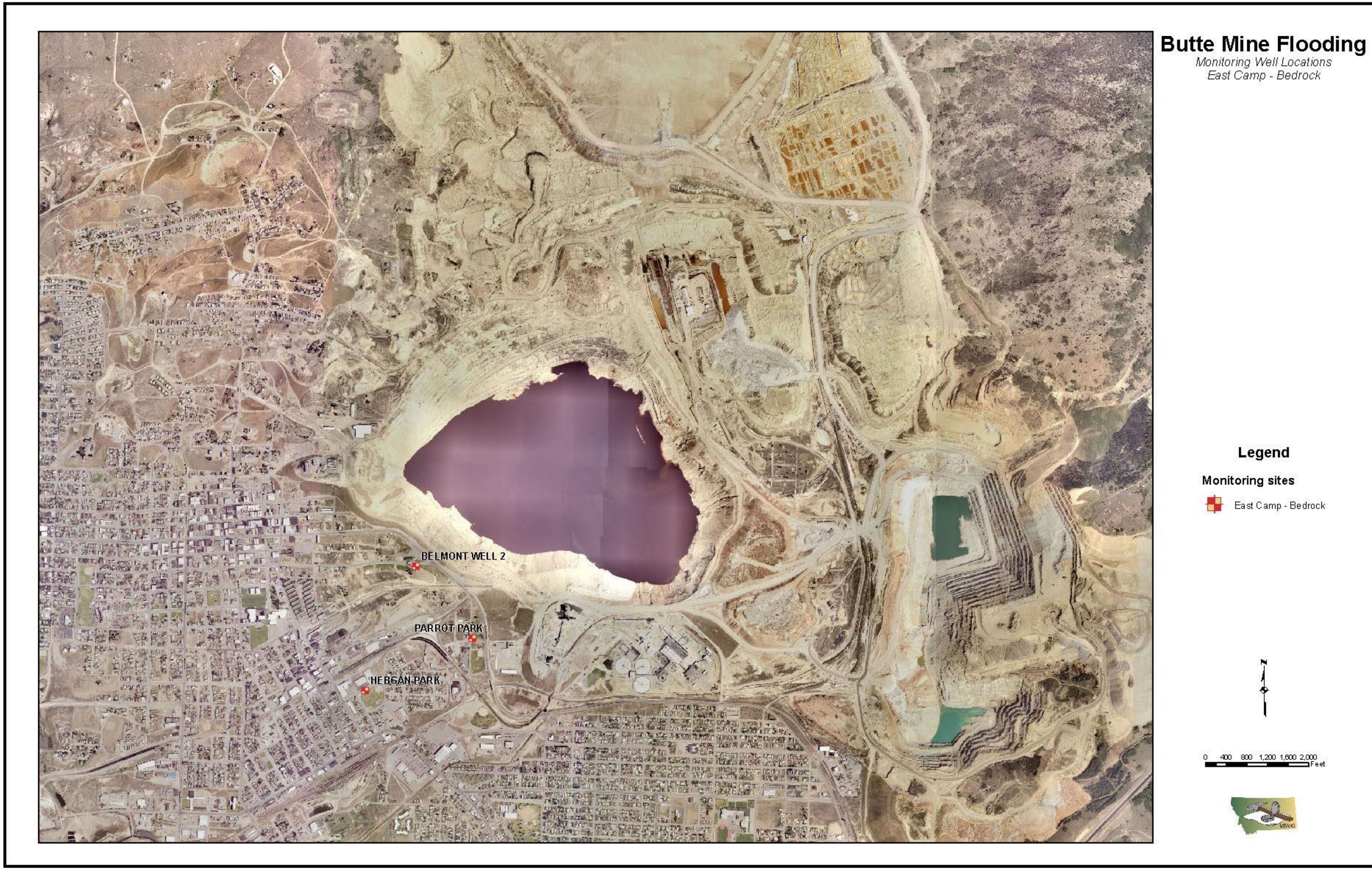

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Figure 5-1. East Camp Park monitoring wells location map.

Table 5.1.1 Annual water-level change for miscellaneous wells, in feet. (cont.)

Year	Hebgen[(1)]	Parrot	Belmont Well #1	Year	Hebgen[(1)]	Parrot	Belmont Well #1
2003	1.25	3.52	-54.19	2013			
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**				
Net Change* Years 1-29	**0.63**	**6.90**	**-10.84**				

(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.

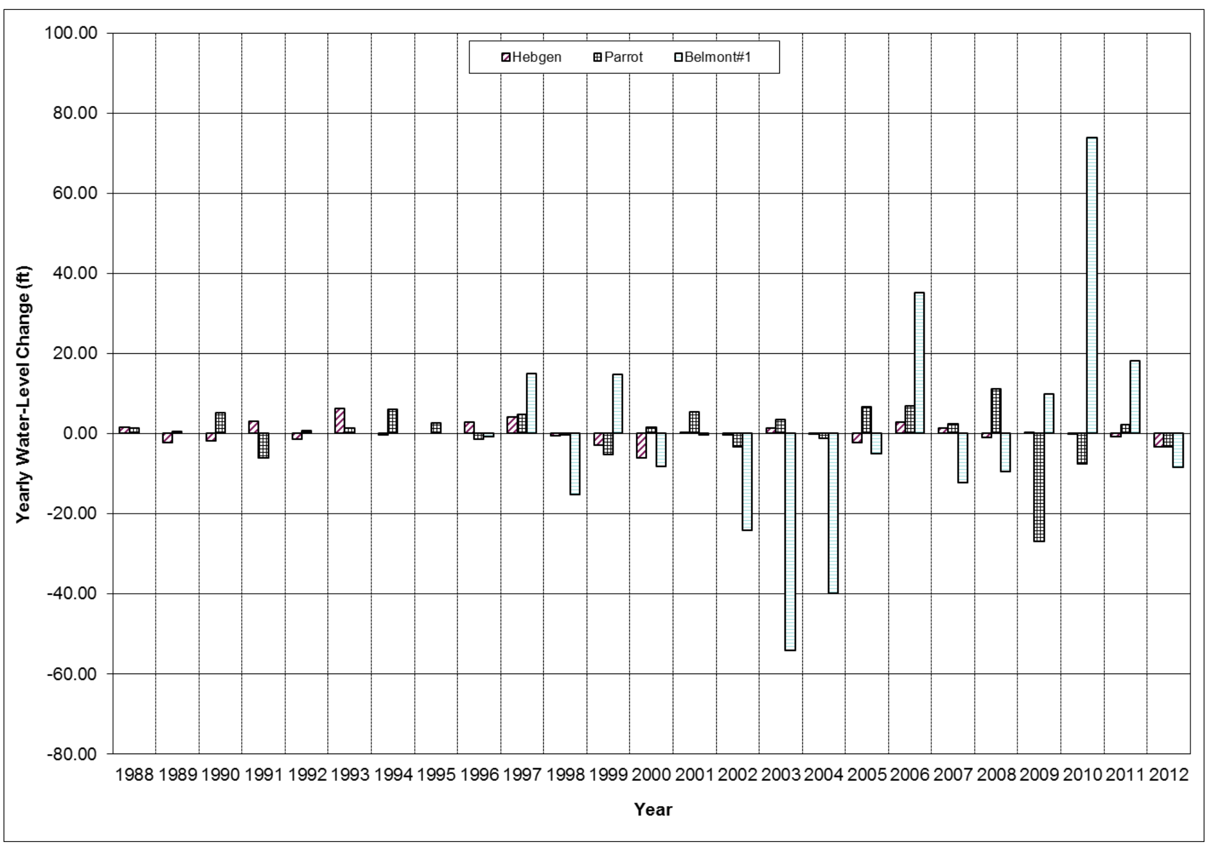

Figure 5-2. Park wells annual water-level changes.

Water-level responses during 2012 at the Hebgen Park well (fig. 5-3) were similar to those seen in prior years, although the magnitude of the increases were much smaller than previous 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 of, does not appear to influence water levels once they begin to rise in the spring. Since the water-level rise extends into the fall and early winter, it is probable that 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 3.28 ft during 2012; since monitoring began at this site, water levels have increased 0.63 ft

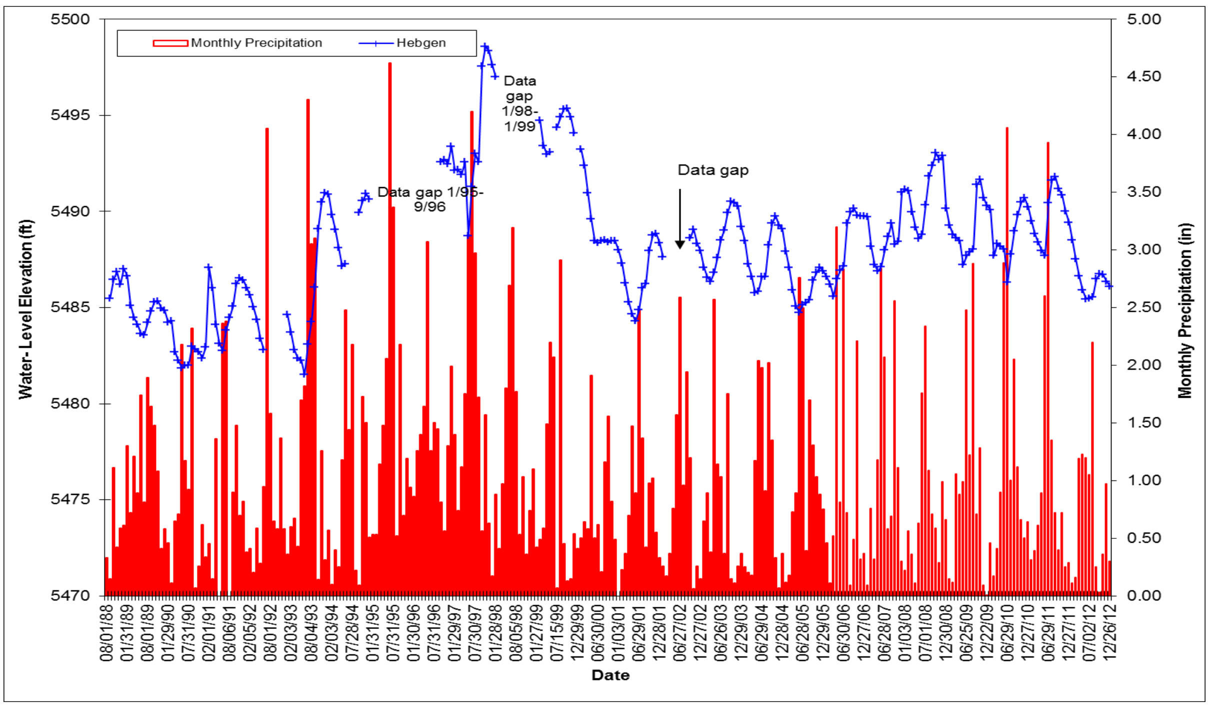

Figure 5-3. Water-level hydrograph for the Hebgen Park well.

The water-level hydrograph for the Parrot Park well is shown on figure 5-4, along with monthly precipitation totals. Water levels declined during most of 2002 before leveling off and rising during December of 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 of 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 2011-2012 water-levels had more of a seasonal trend. The water level at this site has risen almost 7 ft since monitoring began in 1988.

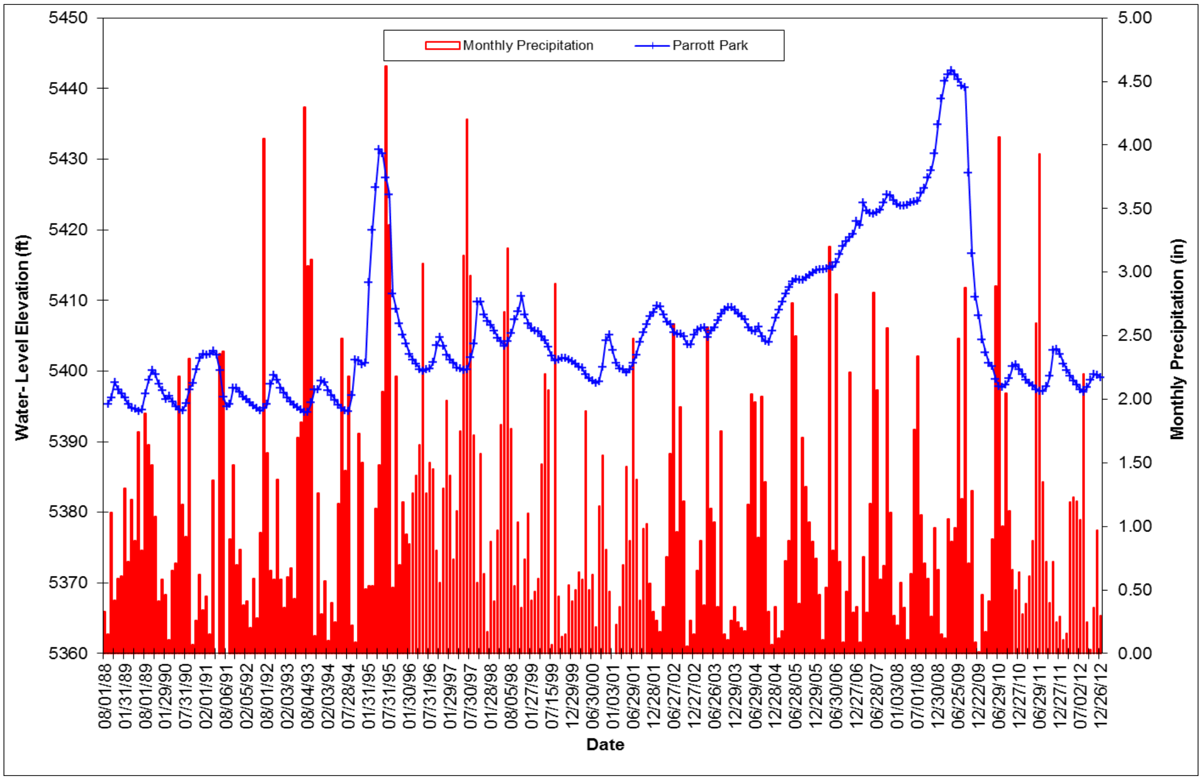

Figure 5-4. Water-level hydrograph for Parrot Park well.

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 increases seen in the Parrot well from 2004 through 2008 are not seen in the Hebgen well, nor is the decline that began the middle of 2009 and continued into the middle of 2010. 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 climatic changes.

The 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 (figure 5-6). 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.

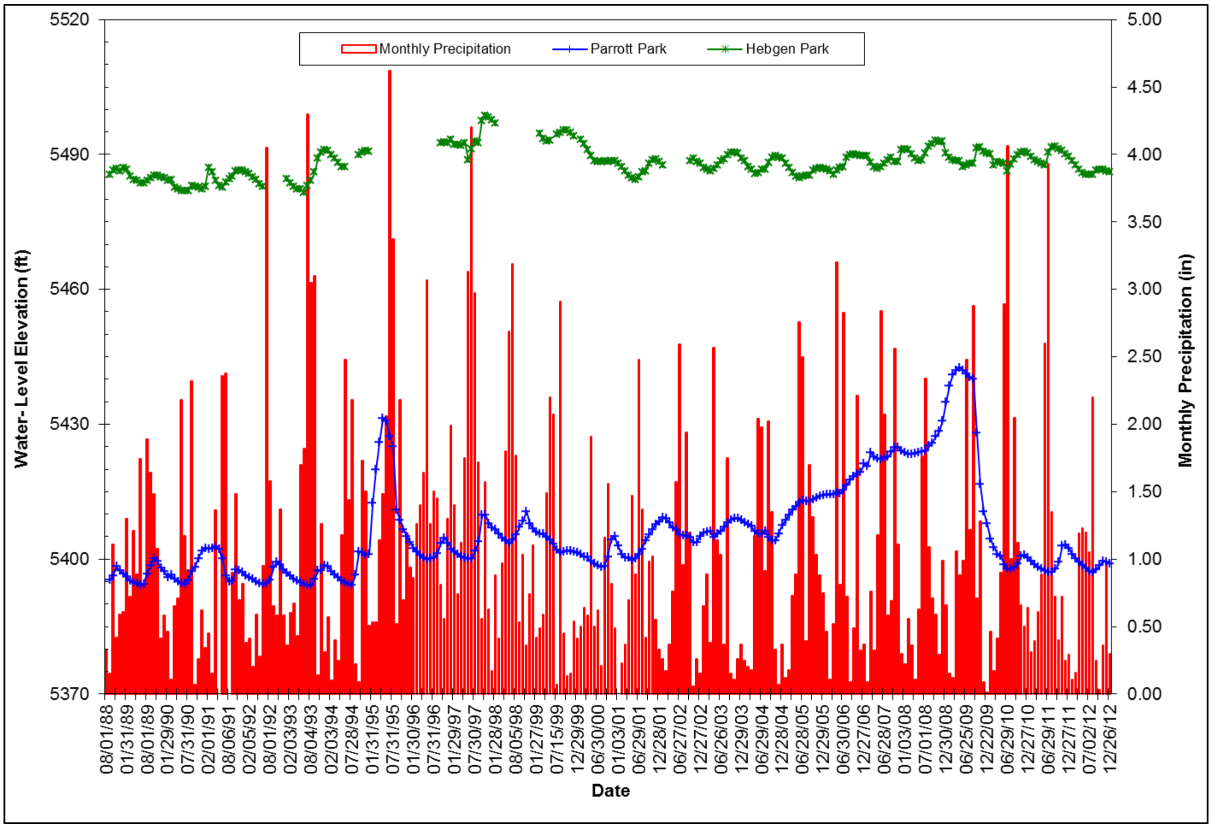

Figure 5-5. Water-level hydrographs for Parrot Park and Hebgen Park wells.

The water-level changes between 2003 and 2009 initially appeared to be in response to precipitation and or lawn irrigation when water levels and precipitation are compared (figure 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 2012 showing daily average water levels. The seasonal water-level changes are more pronounced on 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.

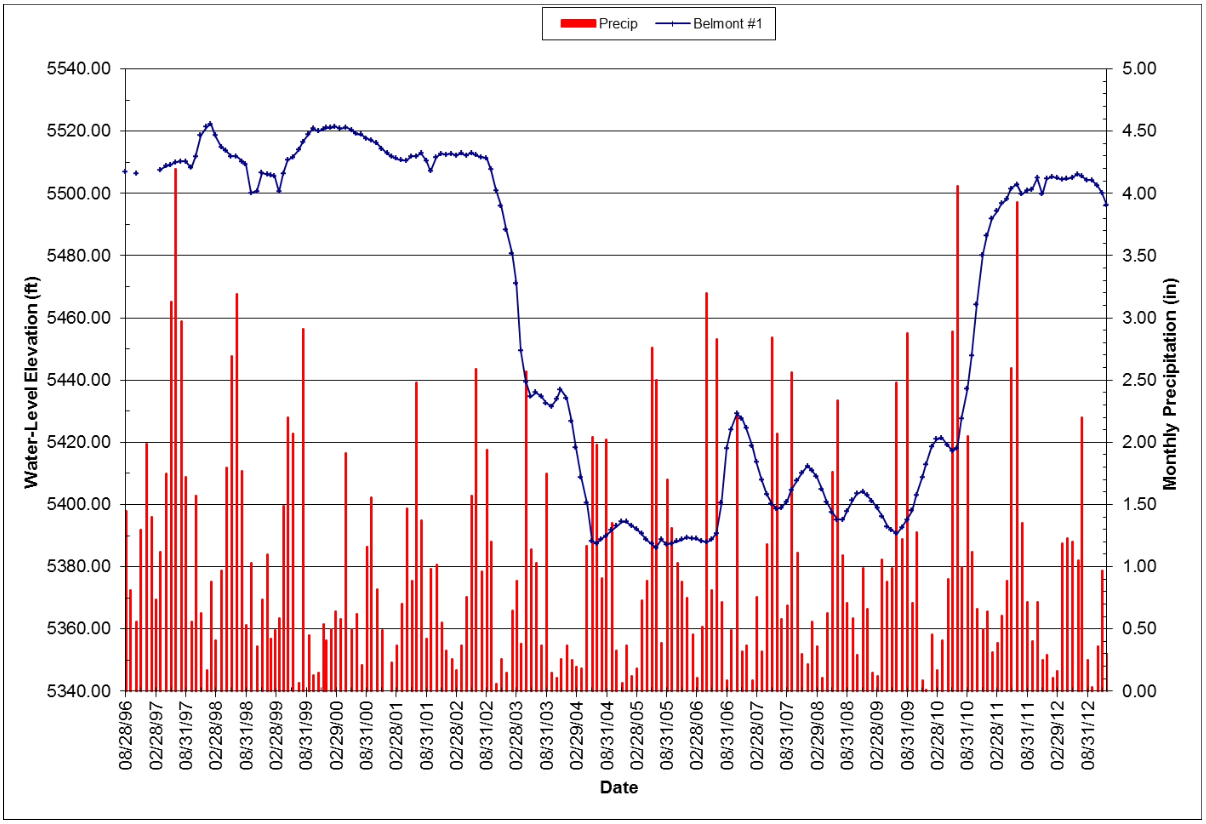

Figure 5-6. Water-level hydrograph for Belmont Well #1.

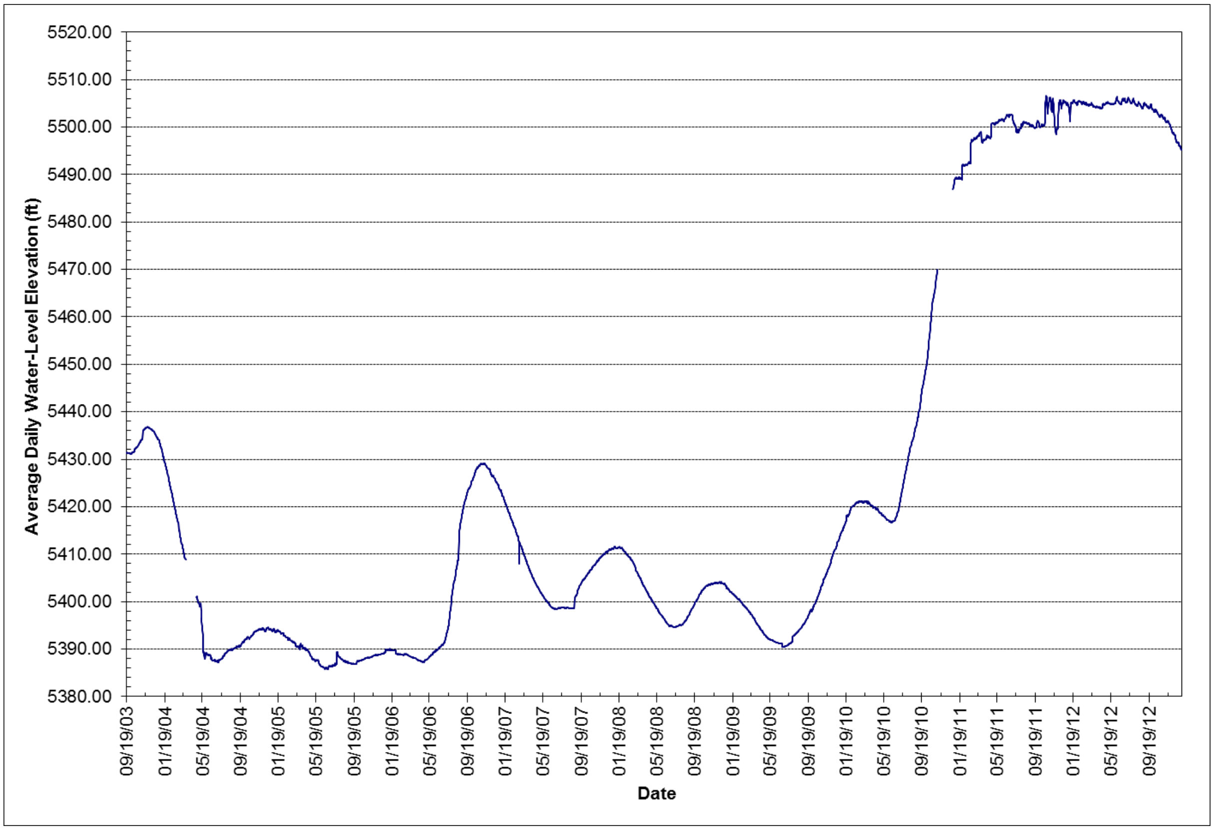

Figure 5-7. Hydrograph showing average daily water-level elevations for the Belmont Well #1.

Section 5.2 Park Wells' Water Quality

Water-quality samples were collected only from the Parrot Park well during 2012. 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 - 2012 were well above the MCL. Concentrations increased for arsenic, copper and cadmium while remaining similar for zinc in 2012, figures 5-8 and 5-9.

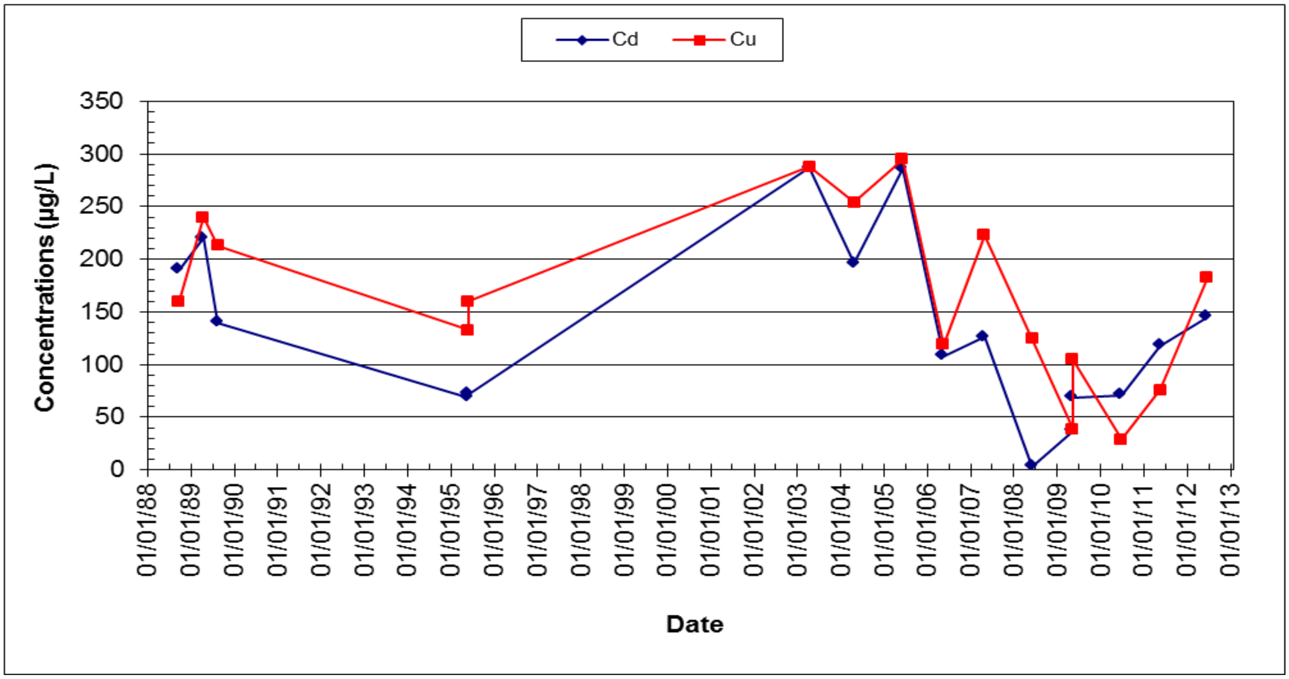

Figure 5-8. Cadmium and copper concentrations for the Parrot Park well.

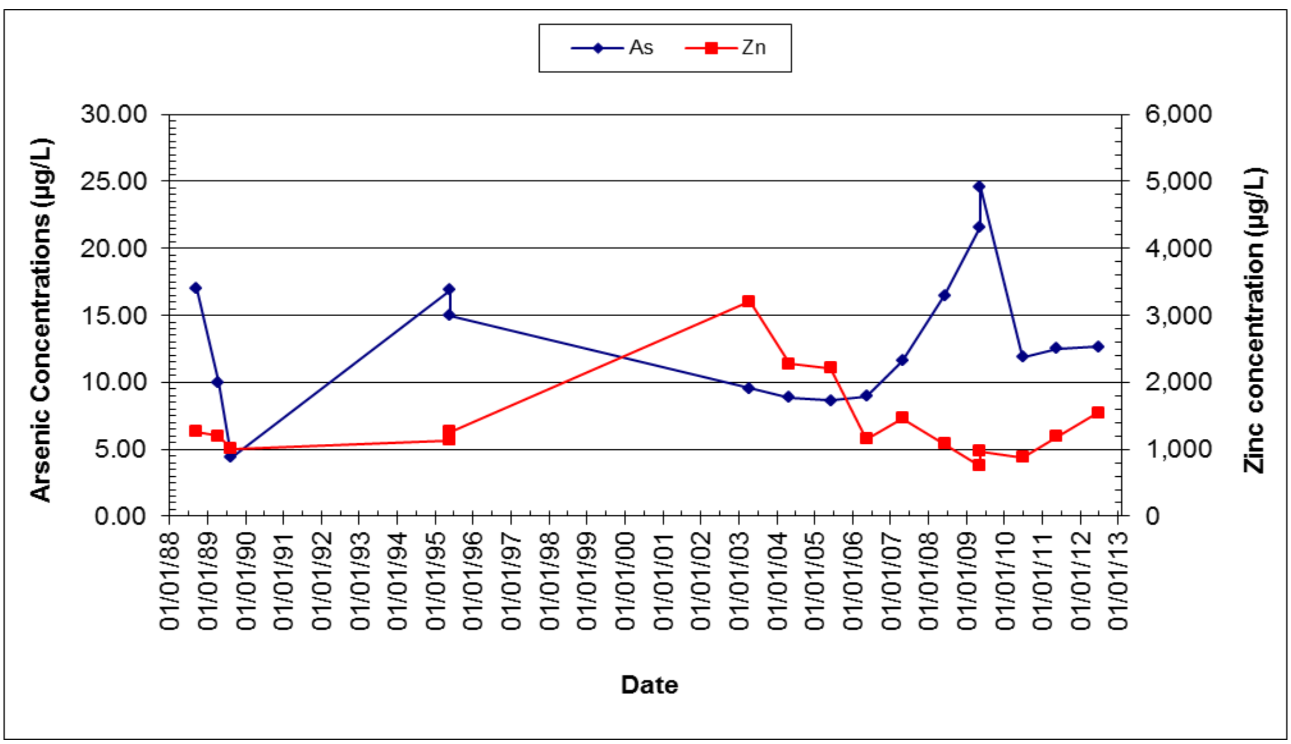

Figure 5-9. Arsenic and zinc concentrations for the Parrot Park well.

SECTION 6.0 DOMESTIC WELLS IN BUTTE AREA

Section 6.1 Butte Alluvial and Bedrock Controlled Ground Water Area

The Butte Alluvial and Bedrock Controlled Ground Water 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 ground water 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 ground water 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 approximately 8.11 square miles, with maximum vertical depths of over 300 feet in the northeast, thinning to less than 10 feet at the western edge. The bedrock portion of the area has a maximum vertical depth of approximately 1500 feet 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 Board of Health (BSB), 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 applies 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 6.1.1 Sampling Activities in 2012

Based upon site requests from the BSB Health Department, the MBMG collected ground water samples from nine privately-owned wells during 2012. 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.

Table 6.1.1 General site information for the domestic wells sampled in 2012 for BABCGWA. The elevation, depth and static water level (SWL) data are listed in feet.

GWIC ID	SITE NAME	LAT	LONG	ELEVATION	DEPTH	SWL
174040	BOWLER	45.99673	-112.55196	5450	32	12.3
269353	MILLER	45.99727	-112.55403	5450	25	17.92
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

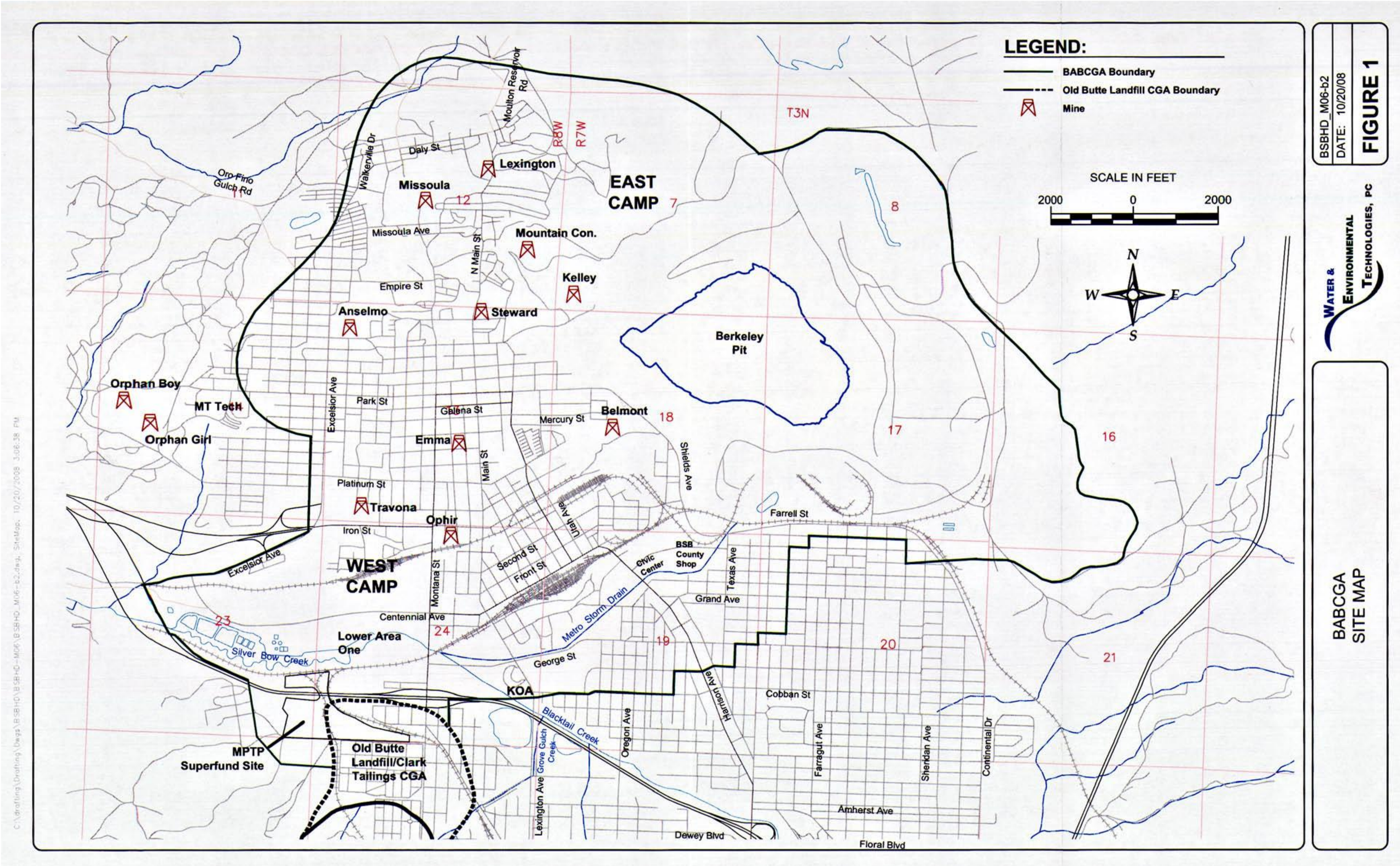

Figure 6-1 Site Map for BABCGWA- prepared by Water & Environmental Technologies, included in the Final Order (DNRC).

Prior to purging water from each well, the static water level (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 down-hole 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, Eh, specific conductivity (SC), and dissolved oxygen (DO)) in 5-10 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 $<\pm 0.5°C$; pH $<\pm 0.1$; Eh $<\pm 20$ mV specific conductance $<\pm 5\%$) 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 contaminants of concern (COC), a complete analysis of these water samples was conducted in the MBMG laboratory, using methods approved by the U.S. Environmental Protection Agency 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

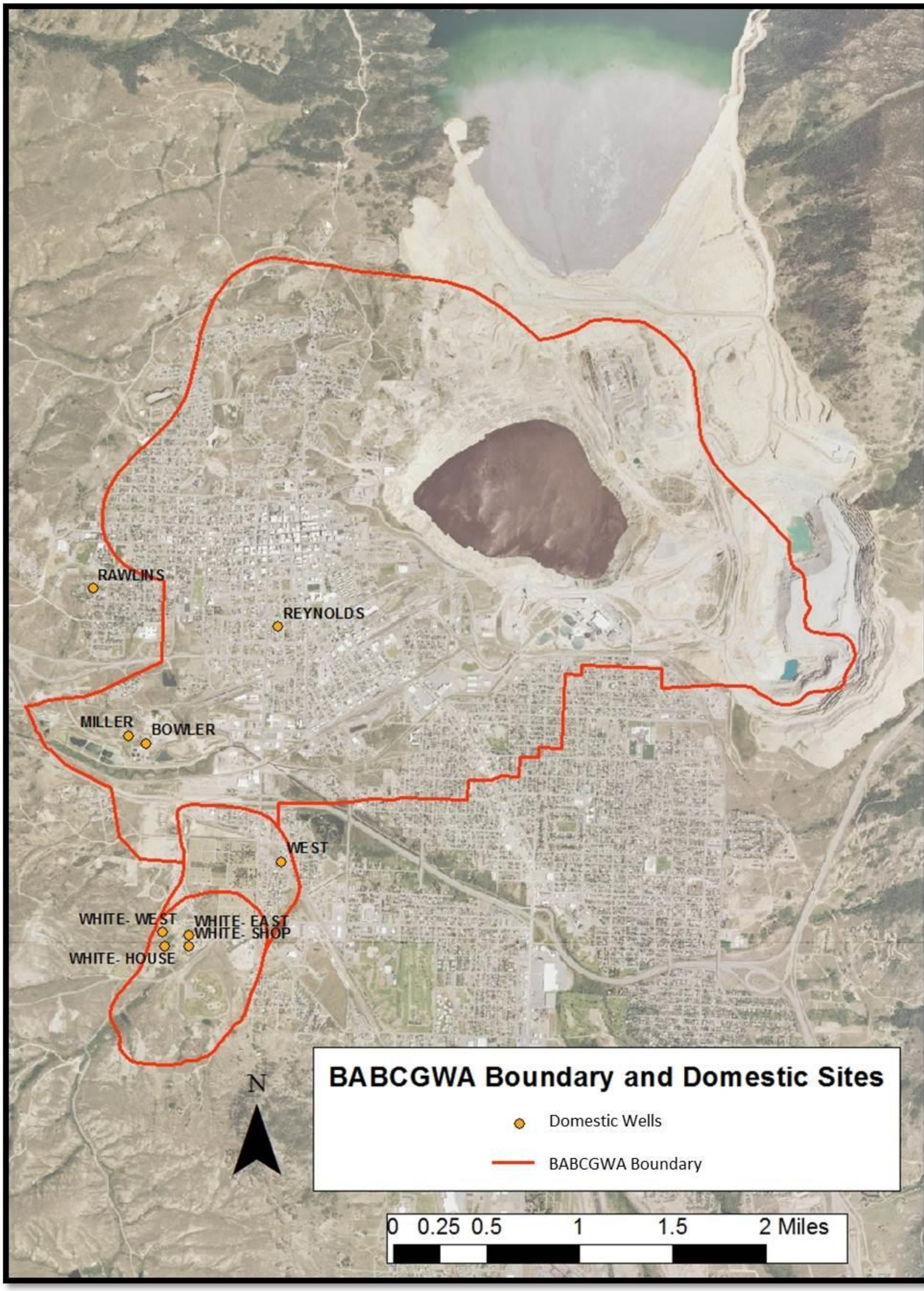

Figure 6-2 Site Map for domestic well sampling locations; BABCGWA boundary is shown in red.

Section 6.1.2 Water Quality Results

The laboratory results for the five COC (arsenic, cadmium, copper, lead, and zinc) are given for each well in Table 6.1.2.1, with a comparison to the established drinking water MCLs (DEQ-7). Complete water quality results from each site are summarized in a table in Appendix A.

Table 6.1.2.1 A comparison of the DEQ-7 MCLs for COC to the 2012 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**	**1,300**	**15**	**2,000**
174040	BOWLER	12/7/2012	<0.250 U	0.390 J	3.16	<0.150 U	19.29
269353	MILLER	12/6/2012	6.58	<0.250 U	69.86	<0.150 U	83.76
50357	RAWLINS	7/17/2012	3.66	<0.100 U	8.15	0.060 J	9.94
4819	REYNOLDS	7/17/2012	1.46	<0.250 U	63.8	0.120 J	8.41
156158	WEST	7/24/2012	0.89	0.330 J	12.99	0.27	235.75
171277	WHITE- EAST	7/16/2012	3.37	<0.250 U	2.69	0.430 J	24.86
171276	WHITE- HOUSE	7/16/2012	2.81	<0.100 U	6.97	<0.040 U	4.13
171278	WHITE- SHOP	7/17/2012	1.08	<0.100 U	0.340 J	<0.040 U	216.22
255690	WHITE- WEST	7/16/2012	1.21	<0.100 U	0.79	<0.040 U	14.95

Every domestic well sampled in 2012 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 2012 results, each well owner was sent a letter which 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 6.1.2.2. There were no exceedances in the Rawlins (#50357) or White-Shop (#171278) wells.

Table 6.1.2.2 A comparison of the DEQ-7 MCLs and SMCLs to the 2012 exceedances.

Gwic Id	Site Name	Exceeded Analyte	2012 Result	MCL	SMCL
174040	BOWLER	Fe	15.255 mg/L	-	0.3 mg/L
174040	BOWLER	Mn	4.799 mg/L	-	0.05 mg/L
174040	BOWLER	SO_4	277.300 mg/L	-	250 mg/L
269353	MILLER	SO_4	407.800 mg/L	-	250 mg/L
4819	REYNOLDS	SO_4	415.000 mg/L	-	250 mg/L
4819	REYNOLDS	NO_3	13.890 mg/L	10 mg/L	-

4819	REYNOLDS	Al	55.880 µg/L	-	50 - 200 µg/L
4819	REYNOLDS	U	56.740 µg/L	30 µg/L	-
156158	WEST	Mn	0.101 mg/L	-	0.05 mg/L
171277	WHITE- EAST	U	91.260 µg/L	30 µg/L	-
171276	WHITE- HOUSE	U	54.870 µg/L	30 µg/L	-
255690	WHITE- WEST	U	55.480 µg/L	30 µg/L	-

A number of these wells are not used for drinking water, like the White- East and West wells (#171277 and 171276) and the Bowler well (#174040), which was previously used for drinking but is now only used for yard irrigation. The wells sampled during 2012 will continue to be sampled in the future, unless the site list changes after consultation with BSB and DEQ.

Section 6.2 Moulton and Bull Run Gulch Area

The Moulton and Bull Run Gulch Area (MBRGA) is not an officially demarcated or regulated zone created through Superfund activities in the watershed. Rather, this general area is shown in Figure 6-3, and it is located to the north of Butte and Walkerville, along Moulton Reservoir Road to the northeast and Bull Run Gulch Road to the northwest. Moulton Reservoir, which is located at the northern end of the area, is used as a public water supply for Walkerville and parts of Butte. The MBRGA is excluded from the BABCGWA and the regulations that were discussed in the previous section. However, part of the area is adjacent to the Yankee Doodle Tailings Pond (YDTP), and some areas are included within the BMFOU boundary (Figure 6-4). All of the land adjacent to the YDTP is owned and maintained by MR.

After reviewing other domestic wells in the Butte area, questions were raised about whether or not a connection exists between area groundwater and the YDTP, and if so, how would that influence the water quality in nearby wells. The majority of the groundwater wells found in the MBRGA are used as domestic water sources (based upon data in GWIC database). However, this area was not included in the rigorous sampling and monitoring associated with Superfund activities in Butte, so most of the wells in the area had not been sampled for water quality or monitored for water elevations, and a few of the wells were not even included in GWIC. This lack of data made it difficult to fully address the questions about the possible influence on domestic water quality. Therefore, a short-term sampling program took place in from October to December of 2012 as an extension of the domestic sampling schedule. This sampling program was a cooperative effort between MBMG, DEQ, EPA, and MR.

The goals of the sampling program were to gain more information about the groundwater elevations in the area and to collect samples for water quality and stable isotope analyses. These data are key to determining if there is a connection between the YDTP and area wells, but they also fill GWIC data-gaps and serve as background data, which might be useful for comparison to data collected in the future. The following discussion summarizes the field data and water quality data that resulted from this sampling program.

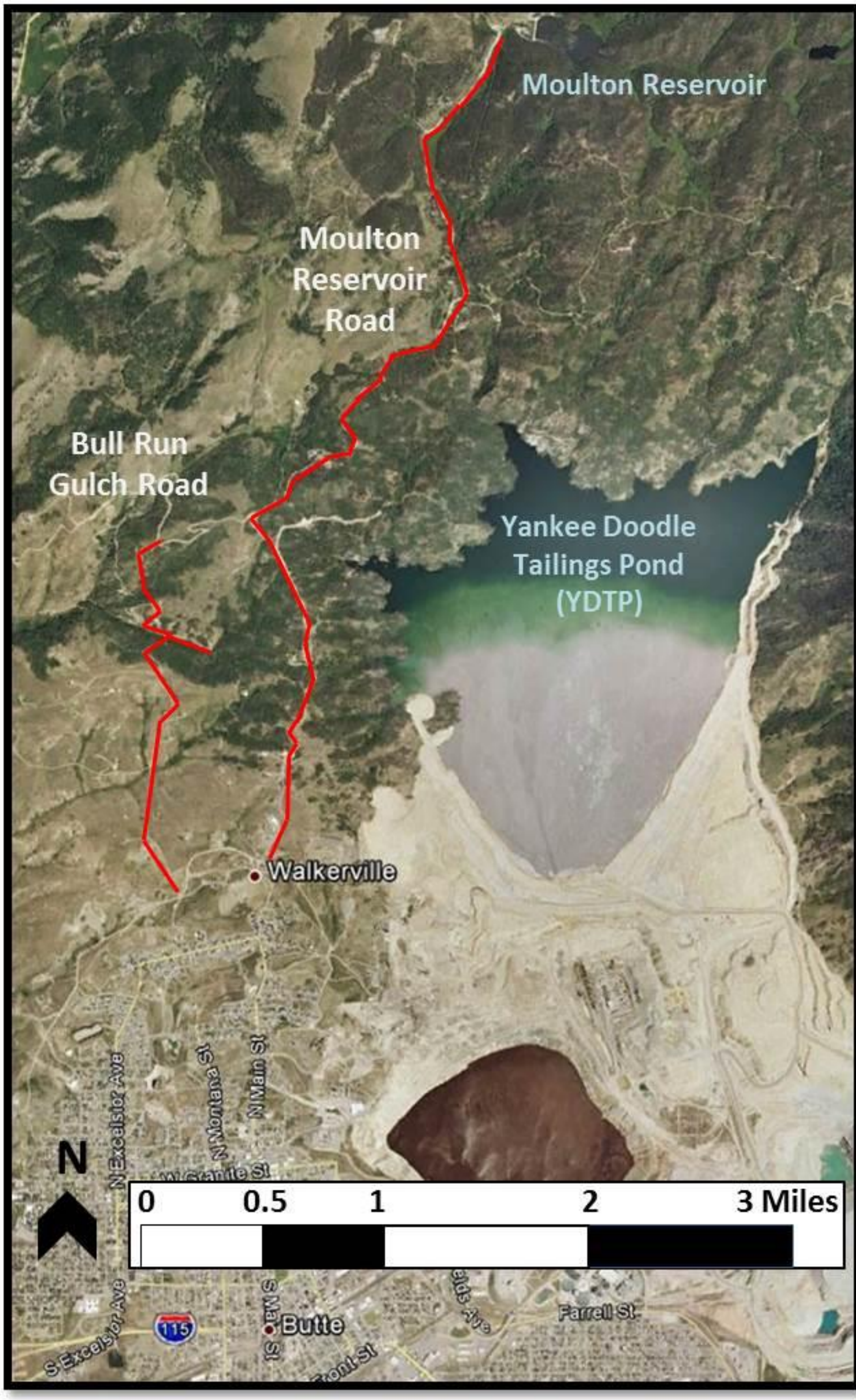

Figure 6-3 General site map, showing the Moulton and Bull Run Gulch Area (MBRGA)

Section 6.2.1 Sampling Activities in 2012

Using the available data from GWIC, the MBMG created a priority list of domestic wells in the area which are located closest to the YDTP. After soliciting well-owner cooperation through letters, phone calls, and door-to-door contact, a total of 18 wells were visited during a two-month period. A number of well-owners did not respond to any form of contact and two people explicitly declined to have their wells sampled. Of the 18 wells that were visited, two were disconnected from seasonal use, so only 16 wells were sampled (shown in Figure 6-4). Similarly, some of the wells were buried or sealed, so water elevations and total depths could not be measured at every site. A list of the sites that were visited (including YDTP) is given in Table 6.2.1, along with general site information.

Table 6.2.1 General MBRGA site information

GWIC ID	SITE NAME	LAT	LONG	TWN/RNG/SEC	ELEVATION	DEPTH	SWL
227189	METESH	46.04430	-112.53453	03N/08W/1	6,434	320	32.12
199357	BRADLEY	46.07104	-112.51291	04N/07W/30	6,535	80	5.75
145971	MCCLOSKEY	46.07322	-112.51397	04N/07W/30	6,620	100	N/A
153761	NEARY, J.	46.04514	-112.54288	03N/08W/1	6,310	180	55.60
197462	COTTON	46.04231	-112.53537	03N/08W/1	6,440	450	39.93
268805	NEARY, M.	46.04526	-112.54454	03N/08W/1	6,290	240	46.35
263277	RULE	46.04547	-112.53261	03N/08W/1	6,445	300	N/A
163566	ZIELER	46.04113	-112.53468	03N/08W/1	6,440	260	N/A
269001	SULLIVAN	46.03918	-112.53395	03N/08W/1	6,430	140	79.50
197271	DAILY- OLD	46.04876	-112.53233	04N/08W/36	6,440	380	31.11
196757	DAILY- NEW	46.04821	-112.53187	04N/08W/36	6,430	273	61.57
124175	SMITH	46.06862	-112.51702	04N/07W/30	6,690	412	117.85
158789	JOHNSTON	46.06167	-112.52887	04N/07W/30	6,560	222	54.51
206013	VARNAVAS- OFF	46.04988	-112.54052	04N/08W/36	6,260	260	22.65
153525	VARNAVAS- USED	46.04973	-112.54018	04N/08W/36	6,260	180	18.17
269126	CALLAHAN	46.06594	-112.52245	04N/07W/30	6,685	320	36.26
183655	REILLY	46.06699	-112.53055	04N/08W/25	6,490	60	41.08
50991	KELLY	46.07820	-112.51939	04N/07W/19	6,666	85	N/A
139260	YDTP- SURFACE	46.05969	-112.48312	04N/07W/32	6,256	N/A	N/A

The sampling procedures for the MBRGA wells were very similar to those for the BABCGWA. 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 some of the sites, those measurements were not possible because the wells were sealed or buried, with no down-hole 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. The surface water samples taken from YDTP were collected just below the water's surface on the northeastern shore of the pond, near MR's pumping barge.

Before sampling, the water at each site was measured for the physical/chemical parameters of temperature, pH, Eh, specific conductivity (SC), and dissolved oxygen (DO) in 5-10 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 $<\pm0.1$; Eh $<\pm20$ mV specific conductance $<\pm5\%$) 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
- 60 mL filtered and unpreserved, with minimal headspace (for water isotopes)

Like the samples collected for the BABCGWA, a complete analysis of the MBRGA water samples was conducted in the MBMG laboratory, using methods approved by the U.S. Environmental Protection Agency for the following species:

3. 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
4. Anions – SO_4, HCO_3, CO_3, Cl, and NO_3

In addition to these typical water-quality analyses, samples were also collected for the analysis of stable isotope ratios in the water molecule (i.e. deuterium and oxygen-18; δ^2H or δD, $\delta^{18}O$). These isotope samples were analyzed by IsoTech Laboratories in Champaign, Illinois. A general discussion of water isotope analysis and the interpretations for the MBRGA are found in Section 6.2.4.

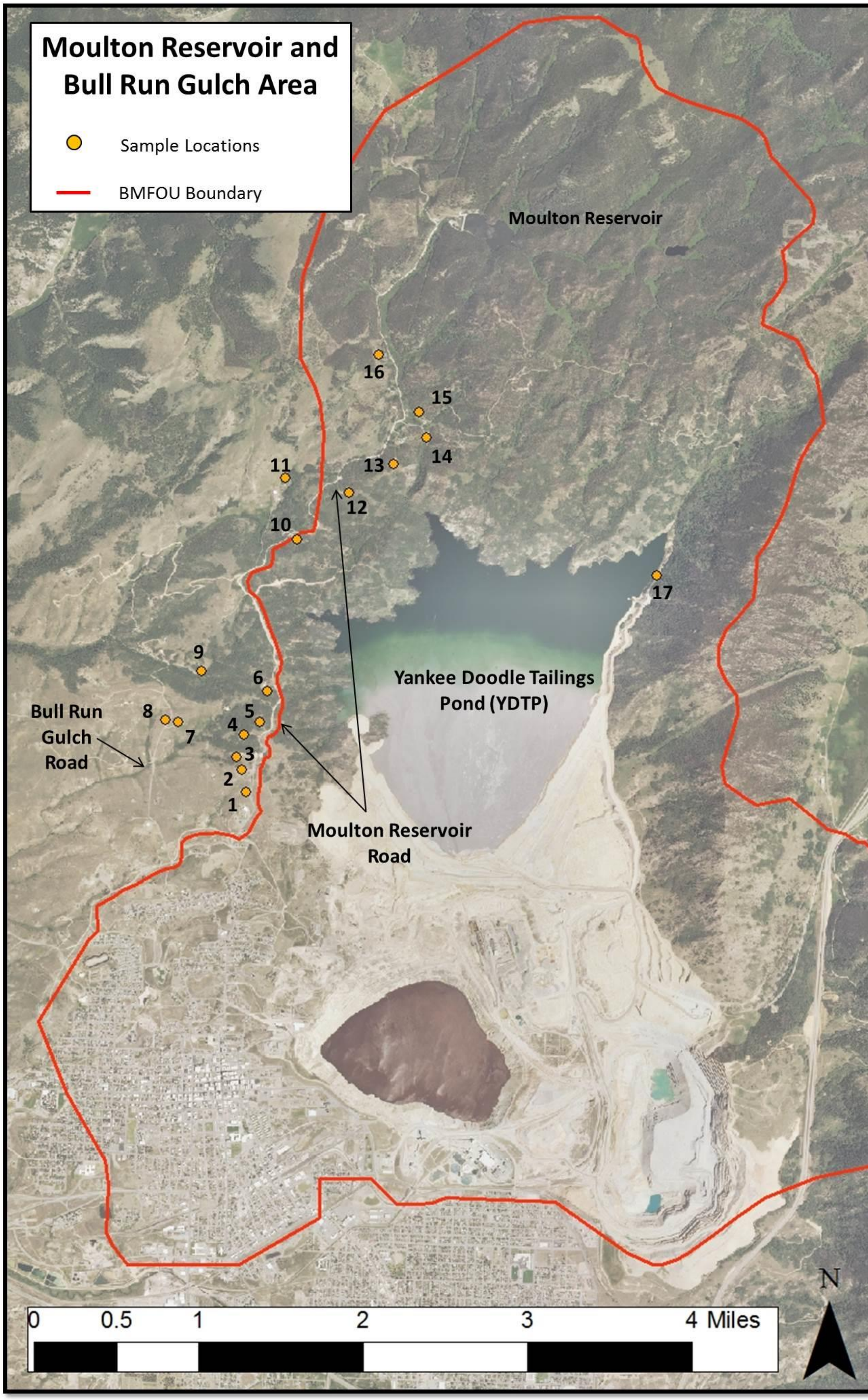

Figure 6-4 Site map for MBRGA sampling locations, with the BMFOU boundary shown in red. The map numbers correspond with the information found in Table 6.2.2.1

Section 6.2.2 Field Data and Groundwater Elevations

The physical and chemical parameters that were measured in the field prior to sampling are summarized in Table 6.2.2.1. The map numbers given in this table correspond to the locations shown in Figure 6-4. Two of the wells listed in Table 6.2.1 were disconnected and could not be sampled ("Daily- Old"-#197271 and "Varnavas- Off"-#206013), so those wells have been excluded from Table 6.2.2.1.

Table 6.2.2.1 List of sampling locations and the associated field parameters, sorted by sample date. The "map number" identifies the locations shown in Figure 6-4.

SITE NAME	MAP NUMBER	SAMPLE DATE	T (°C)	pH	SC (µS/cm)	ORP (mV)	DO (mg/L)
METESH	4	10/23/2012	7.48	7.15	312.3	367	1.40
BRADLEY	14	10/23/2012	6.57	6.93	257.1	391	6.51
MCCLOSKEY	15	10/24/2012	7.76	6.44	234.4	412	1.86
NEARY, J.	7	10/24/2012	8.51	7.55	524.3	343	2.52
COTTON	3	10/25/2012	8.45	7.38	538.6	355	1.65
NEARY, M.	8	10/25/2012	8.50	7.01	492.5	357	2.13
RULE	5	10/29/2012	7.83	7.03	472.5	295	0.08
ZIELER	2	11/1/2012	8.86	7.42	343.7	348	1.01
SULLIVAN	1	11/1/2012	8.61	6.92	459.9	342	1.38
DAILY- NEW	6	11/2/2012	8.07	6.95	433.4	353	1.88
SMITH	13	11/7/2012	7.80	7.18	380.8	341	3.83
JOHNSTON	10	11/7/2012	6.93	7.24	267.9	357	0.22
VARNAVAS- USED	9	11/14/2012	8.12	6.87	498.5	136	0.03
CALLAHAN	12	11/14/2012	7.78	6.61	310.9	584	5.96
REILLY	11	11/26/2012	7.87	5.90	186.9	365	7.22
KELLY	16	11/28/2012	6.31	5.48	128.2	427	4.29
YDTP- SURFACE	17	12/4/2012	1.43	10.39	2,109.0	370	9.72

Without considering the water quality results from the laboratory, there appear to be significant differences in the water chemistry between the YDTP and the domestic wells in the MBRGA, based solely upon field parameters. While the ORP measurements are variable for all of sites (within the range of 136-584 mV), the SC and pH values measured in the YDTP are quite different than those measured in the domestic wells. All of the domestic wells had pH values between 5.48 and 7.55, while the YDTP water reflected its history of chemical processing and recycling around the mine-site, with a pH of 10.39. Similarly, the SC values for the domestic wells ranged from 128.2 to 538.6 µS/cm, while the SC of the YDTP water was much higher, at 2,109.0 µS/cm. The temperature and DO data for the YDTP stand out from the groundwater sites as well, but the lower temperature and higher DO readings from the pond are consistent with what would be expected from surface water during winter. More detailed water quality results are discussed below, in Section 6.2.3.

With a number of the domestic wells being sealed or buried, groundwater elevations were only measured in 13 domestic wells. All of these wells and water levels are listed in Table 6.2.2.2, with the ground surface elevations estimated from the Butte North 24K topographic map. These elevations are based upon the North American Vertical Datum of 1988 (NAVD88). According to lithologic logs in GWIC, all of the wells are completed in the Boulder Batholith (211BDBT) from 60 to 450 feet from surface. The wells listed as 211BDBT* do not have lithology assigned to them in GWIC, but by comparing the depth and location of those sites with nearby wells, it is safe to assume they are also completed within the Boulder Batholith.

Within this geologic unit, groundwater levels varied from 5.75 to 117.85 feet from the top of well casing. The water elevations (rounded to the nearest foot) that are given in Table 6.2.2.2 were calculated by using the estimated ground elevation, the measured water level, and the casing stick-up. Due to the error associated with topographic map estimations (actually less than the error from Navigational GPS units' vertical data), these water elevations should be considered to be close approximations (likely within 5-10 feet).

The water elevation given for the YDTP was taken from information provided by MR, in the cross-sectional figure "Yankee Doodle Tailings Dam, FMA Meeting, Plate IV" (S. Czehura and S. Huckeby, 2/21/2013). In this diagram of the tailings dam, the pond elevation is given as 6,310.34 feet. However, this elevation is based upon the local Anaconda Co. Datum (which pre-dates other vertical survey systems). The pond elevation was then converted to NAVD88 (by compensating 54.4 feet), in order to evenly compare this site with the domestic groundwater elevations. Again, there may be some inherent error in the surveying and elevation compensation, but this should closely approximate the elevation of the YDTP during the time period of this study.

Table 6.2.2.2 List of locations used to measure groundwater elevations. All measurements are given in feet, and elevations are compensated to match NAVD88. "211BDBT*" indicates assumed lithology (see text).

GWIC ID	SITE NAME	GROUND ELEV.	WELL DEPTH	LITHOLOGY	SWL	WATER ELEV.
227189	METESH	6,435	320	211BDBT	32.12	6,404
199357	BRADLEY	6,535	80	211BDBT	5.75	6,530
153761	NEARY, J	6,310	180	211BDBT	55.60	6,256
197462	COTTON	6,440	450	211BDBT	39.93	6,402
268805	NEARY, M	6,290	240	211BDBT*	46.35	6,246
269001	SULLIVAN	6,430	140	211BDBT*	79.50	6,352
196757	DAILY- NEW	6,430	273	211BDBT	61.57	6,370
124175	SMITH	6,690	412	211BDBT	117.85	6,574
158789	JOHNSTON	6,560	222	211BDBT	54.51	6,507
206013	VARNAVAS- OFF	6,260	260	211BDBT	22.65	6,239
153525	VARNAVAS- USED	6,260	180	211BDBT	18.17	6,244
269126	CALLAHAN	6,685	320	211BDBT*	36.26	6,650
183655	REILLY	6,490	60	211BDBT	41.08	6,451
139260	YDTP- SURFACE	-	-	-	-	6,256

Every site location and water elevation in Table 6.2.2.2 was then mapped using ArcGIS software, and contour lines showing the potentiometric surface were created using the Inverse-Distance Weighted method (shown in Figure 6-5). Instead of using other methods, this approach was preferred because it allowed better adherence to controlled point values, particularly near the YDTP. In order to acknowledge the surface water boundary, many data points were created along the YDTP shoreline, to provide a more accurate approximation of groundwater flow around the pond.

Figure 6-5 shows groundwater elevations using 40 feet contour lines, with shades of red/orange for the higher elevations and shades of green for lower elevations. In this map, it is clear that there is a significant vertical gradient in groundwater flow, especially to the north and northwest of the YDTP. In this area (and across the entire MBRGA), the groundwater elevation seems to closely follow the ground surface topography. Directly north of the YDTP, the ground surface drops from a high point of almost 6700 feet, down to the pond's shore (near 6256 feet) in only half a mile. This topographically high area extends along the western edge of the YDTP, creating a watershed boundary between the Bull Run Gulch and historic Silver Bow Creek drainages (shown in blue in Figure 6-5).

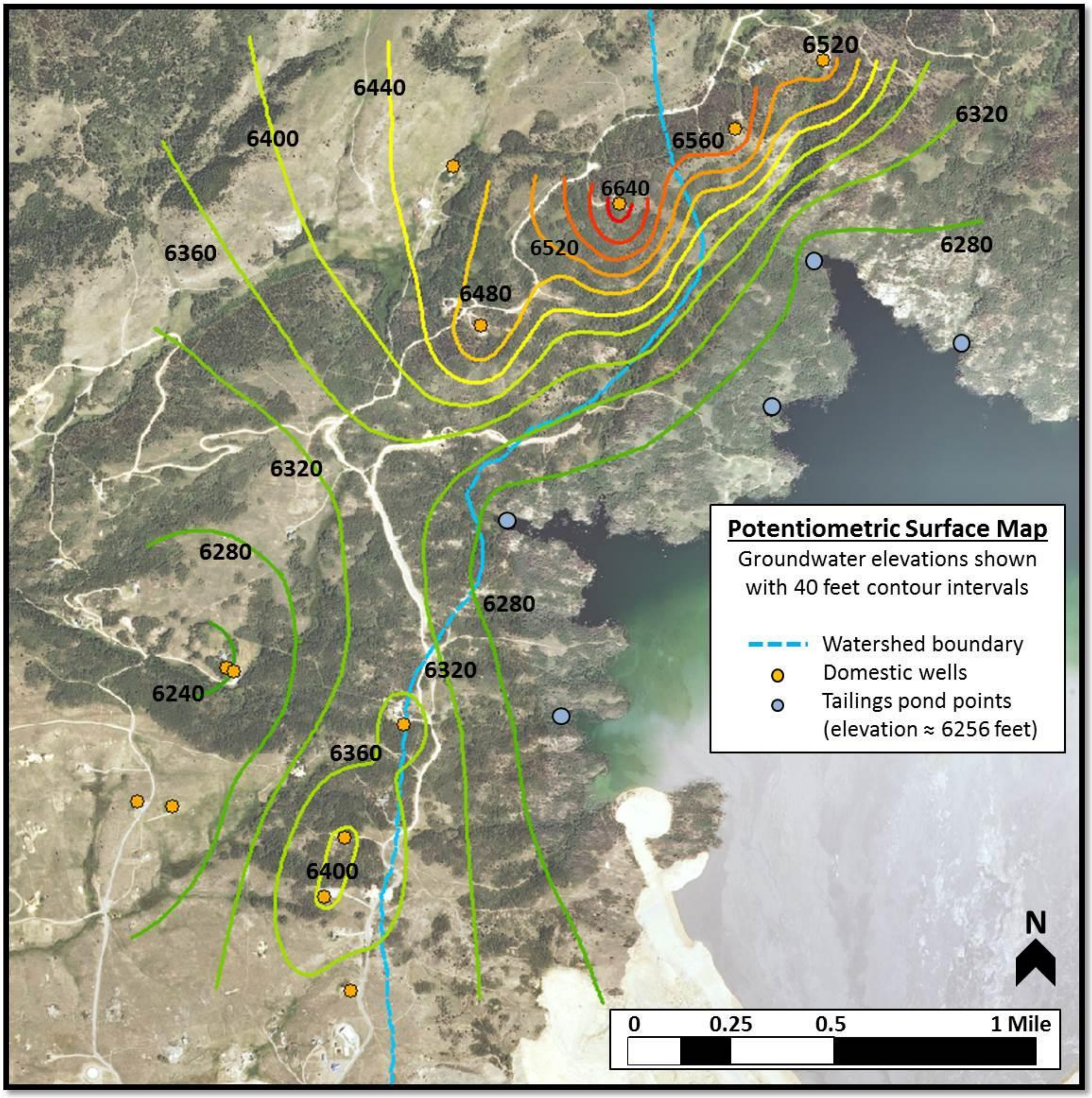

Figure 6-5 Potentiometric surface map for MBRGA

Roughly following this watershed boundary, some groundwater appears to flow toward the YDTP, with a change in water elevation of > 300 feet on the north side. At the head of the historic Silver Bow Creek drainage, the ground surface elevation surrounding Moulton Reservoir is > 7,000 feet. From this high area, it is likely that groundwater flows through the drainage from north to south, toward the YDTP. However, this northern area could not be included in the groundwater map, due to a lack of data (i.e. sealed wells and unavailable owners). Along the western side of the YDTP (on Moulton Reservoir Road), most of the domestic wells have groundwater elevations > 6,300 feet. Some groundwater appears to flow toward the YDTP, but there also appears to be flow to the west through the Bull Run Gulch drainage. Again, data-gaps (especially around the large bend in the road) are preventing a complete picture of this flow system.

Based upon the available groundwater data, it appears that groundwater flows toward the YDTP from the north and portions of the west, roughly following the topographic highs (i.e. watershed boundary). At this point in time, it does not appear that water from the YDTP is migrated out of the drainage, into regional groundwater given the vertical gradients. However, a more complete potentiometric surface map could be created if more information is available, particularly to the north (below Moulton Reservoir) and to the west of the YDTP, along Moulton Reservoir Road. Recently, MR drilled monitoring wells in the area around the perimeter of the pond, but the lithology and groundwater elevations for these wells are not available to MBMG. As the YDTP expands in the future, it will be important to use these new monitoring wells and incorporate more domestic wells into a monitoring program, if this hydrologic system is to be more accurately modeled.

Section 6.2.3 Water Quality Results

Although the domestic wells in the MBRGA are not included or regulated as part of the BABCGWA boundary, it is helpful to view the water quality results by comparing them to the same COC drinking water standards (established by Circular DEQ-7). Table 6.2.3.1 shows the drinking water standards for the five main COC and compares them to the 2012 MBRGA domestic well results. Complete water quality results from each site are summarized in a table in Appendix A.

Table 6.2.3.1 A comparison of the DEQ-7 MCLs (for the 5 BABCGWA COC) to the MBRGA 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*	*1,300*	*15*	*2,000*
199357	BRADLEY	10/23/2012	3.03	<0.100 U	6.05	<0.040 U	15.97
227189	METESH	10/23/2012	10.85	<0.100 U	3.30	<0.040 U	0.750 J
145971	MCCLOSKEY	10/24/2012	1.25	<0.100 U	156.10	<0.040 U	2.76
153761	NEARY, J.	10/24/2012	4.01	<0.100 U	33.13	<0.040 U	7.18
268805	NEARY, M.	10/25/2012	14.99	<0.100 U	2.36	<0.040 U	7.82
197462	COTTON	10/25/2012	2.55	<0.100 U	2.37	<0.040 U	7.46
263277	RULE	10/29/2012	163.99	<0.100 U	1.86	<0.040 U	10.20
269001	SULLIVAN	11/1/2012	3.10	<0.100 U	0.91	<0.040 U	19.05
163566	ZIELER	11/1/2012	4.67	<0.100 U	1.10	<0.040 U	1.20
196757	DAILY- NEW	11/2/2012	38.32	<0.100 U	3.01	<0.040 U	9.85
124175	SMITH	11/7/2012	8.25	<0.100 U	1.88	<0.040 U	4.21
158789	JOHNSTON	11/7/2012	21.53	<0.100 U	7.73	<0.040 U	14.20
153525	VARNAVAS- USED	11/14/2012	1.60	<0.100 U	<0.100 U	<0.040 U	3.62
269126	CALLAHAN	11/14/2012	2.31	<0.100 U	2.18	<0.040 U	9.13
183655	REILLY	11/26/2012	8.28	<0.100 U	1.48	<0.060 U	19.55
50991	KELLY	11/28/2012	5.52	<0.100 U	14.29	0.260 J	4.13
139260	YDTP- SURFACE	12/4/2012	6.93	<0.250 U	9.51	<0.150 U	<1.000 U

After the MBMG laboratory analyzed the samples and reported the 2012 results, each well-owner was sent a letter which described the sampling objectives for the project and included a complete analytical report of their sample and comparison to the DEQ-7 standards. Out of these five COC, the only MCL exceedances that occurred in the MBRGA samples were for arsenic, with five wells exceeding the standard of 10.0 µg/L (Metesh at 10.85 µg/L; M. Neary at 14.99 µg/L, Rule at 163.99 µg/L, Daily at 38.32 µg/L, and Johnston at 21.53 µg/L). At the time of sampling, some of these well-owners indicated that their wells had been tested in the past, and they were aware of high arsenic concentrations in their water (some were filtering their water with reverse-osmosis systems). In these locations, the YDTP cannot be considered as a source for arsenic, considering that its arsenic concentration was only 6.93 µg/L.

In addition to those five exceedances for arsenic, there were also 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 site are given in Table 6.2.3.2.

Table 6.2.3.2 A comparison of the DEQ-7 MCLs and SMCLs to the MBRGA 2012 exceedances.

Gwic Id	Site Name	Exceeded Analyte	2012 Result	MCL	SMCL
153761	NEARY, J.	NO_3	11.08 mg/L	10 mg/L	-
268805	NEARY, M.	U	112.54 μg/L	30 μg/L	-
197462	COTTON	U	36.31 μg/L	30 μg/L	-
263277	RULE	Mn	0.069 mg/L	-	0.05 mg/L
163566	ZIELER	Sb	6.32 μg/L	6 μg/L	-
196757	DAILY- NEW	U	40.18 μg/L	30 μg/L	-
124175	SMITH	U	92.28 μg/L	30 μg/L	-
158789	JOHNSTON	U	84.17 μg/L	30 μg/L	-
153525	VARNAVAS- USED	Mn	0.13 mg/L	-	0.05 mg/L
50991	KELLY	Al	102.94 μg/L	-	50 - 200 μg/L
139260	YDTP- SURFACE	SO_4	1,191.00 mg/l	-	250 mg/L

Although there is no regulatory action needed for the domestic wells in the MBRGA, the well-owners were notified of these MCL and SMCL exceedances, so that they could voluntarily treat/filter their water appropriately. The YDTP only exceeded one drinking water SMCL (for sulfate), but it also greatly exceeded the irrigation standard for molybdenum (1,456.26 μg/L vs. std. of 5 μg/L). There is not an established drinking water standard for molybdenum.

After comparing the water chemistry results for the YDTP to the domestic wells, it seems clear that there is little to no influence from the pond on domestic water quality at this time. For example, sulfate is a good tracer in this setting, with a high concentration in the YDTP (1,191.00 mg/L), but much lower concentrations in the domestic wells (range from 24.07 – 164.60 mg/L). If tailings water was impacting the domestic wells, one might expect to see elevated sulfate in those wells. Similarly, the molybdenum concentrations in the domestic wells range from below detection (<0.10 μg/L) to 10.09 μg/L, while the YDTP has a very high molybdenum concentration (1,456.26 μg/L). The same logic can be applied to the exceedances that occurred in the domestic samples, but not in the YDTP sample. In addition to the arsenic concentrations that were discussed previously, uranium is a common exceedance for the domestic wells (see Table 6.2.3.2). However, the uranium concentration in the YDTP was below detection (<0.25 μg/L). This trend is present with other metals as well (e.g. Cu and Zn), as seen in the water quality data in Appendix A.

Given that the domestic wells are completed in the altered granite of the Boulder Batholith, it is likely that the elevated uranium and arsenic concentrations (and other metals) are coming from the aquifer, rather than the YDTP. Through previous studies, the MBMG collected water samples from other wells and mine shafts in the Boulder Batholith in the Butte area. Those sites also exhibit elevated metals concentrations, particularly uranium (e.g. from GWIC database; #257528 U=135.79 μg/L, #163567 U=35.5 μg/L). It seems likely the mineralized fracture zones in the local granite contribute easily mobilized metals, while also acting as the preferred pathways for groundwater flow.

Section 6.2.4 Stable Isotope Results

The stable isotopes of hydrogen and oxygen in the water molecule are widely used as tracers of hydrogeological processes like precipitation, groundwater recharge, groundwater-surface water interaction, evaporation, etc. The analysis of these isotopes typically involves measuring the ratio of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ in a sample using mass spectrometry, and then comparing those results to a known, empirical standard. This final comparison results in an isotopic ratio that is often reported in delta notation ($\delta^{18}O$ and $\delta^{2}H/\delta D$), in units of one-per-thousand or "per mille" (‰). The composition of precipitation has been studied extensively around the world, and has been shown to vary in a systematic fashion. The majority of global precipitation fits a trend-line called the "Global Meteoric Water Line" (GMWL), which mathematically describes the relationship between $\delta^{18}O$ and δD as: $\delta D = 8.17*(\delta^{18}O) + 10.35$ (Rozanski and others, 1993). However, the relationship between these isotopes can vary greatly depending on the geographic location and elevation of the precipitation event. Therefore, it is often beneficial to use a locally or regionally-derived equation to describe this isotopic relationship, called the "Local Meteoric Water Line" (LMWL). In 2006, the first LMWL for Butte, MT was developed from numerous precipitation samples collected in the area by Gammons and others. This LMWL differs slightly from the GMWL, as it describes the relationship with the following equation: $\delta D = 7.31*(\delta^{18}O) - 7.50$. Water samples that have isotopic signatures which fall near this trend-line are considered to be meteoric in origin, whereas significant deviations from this relationship might indicate that the water has undergone non-equilibrium evaporation, mixing with other sources, equilibrium exchange, or other fractionation reactions, to alter the isotopic signature. (Information taken from Clark and Fritz, 1997; Gammons and others, 2006).

Samples for stable isotope analysis were collected from the 16 wells listed in Table 6.2.2.1, as well as the YDTP. The resulting data is listed in Table 6.2.4, and plotted on a graph against the Butte LMWL in Figure 6-6.

Table 6.2.4 List of stable isotope data from the MBRGA and the Butte LMWL

GWIC ID	Sample Name	Sample Date	$\delta^{18}O-H_2O$ ‰	$\delta D-H_2O$ ‰
227189	METESH	10/23/2012	-18.84	-151.1
199357	BRADLEY	10/23/2012	-18.74	-148.8
145971	MCCLOSKEY	10/24/2012	-18.64	-147.0
153761	NEARY, J.	10/24/2012	-18.44	-149.7
197462	COTTON	10/25/2012	-18.34	-147.8
268805	NEARY, M.	10/25/2012	-18.58	-149.6
263277	RULE	10/29/2012	-18.32	-147.0
163566	ZIELER	11/1/2012	-17.79	-142.6
269001	SULLIVAN	11/1/2012	-17.62	-142.7
196757	DAILY- NEW	11/2/2012	-18.40	-147.3
124175	SMITH	11/7/2012	-18.56	-147.5
158789	JOHNSTON	11/7/2012	-18.98	-150.7
153525	VARNAVAS- USED	11/14/2012	-18.62	-150.1
269126	CALLAHAN	11/14/2012	-18.41	-146.8
183655	REILLY	11/26/2012	-19.04	-150.2
50991	KELLY	11/28/2012	-18.70	-147.5
139260	YDTP- SURFACE	12/4/2012	-13.22	-117.6
Butte Local Meteoric Water Line (Gammons, and others)			**-22.00**	**-168.3**
$\delta D = 7.31*(\delta^{18}O) - 7.50$			**-10.00**	**-80.6**

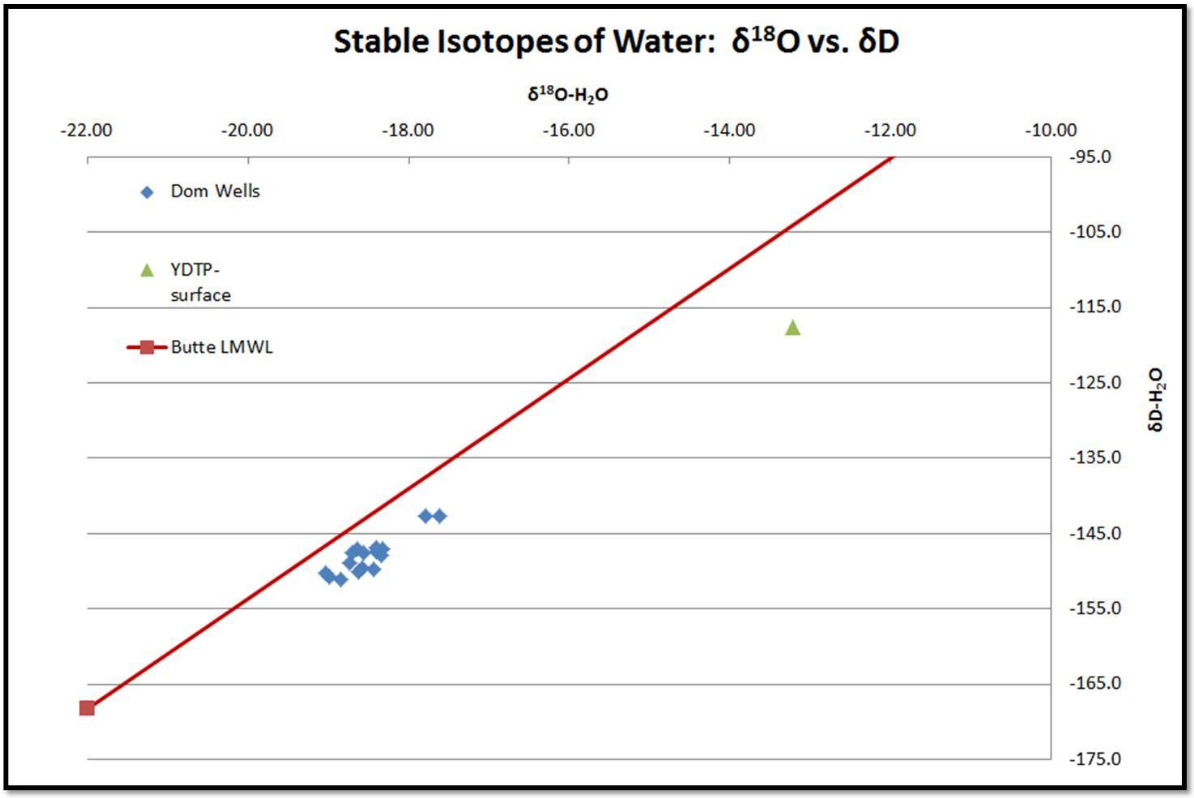

Figure 6-6 Graph showing the stable isotope composition of water samples collected from domestic wells and the YDTP. The Butte LMWL (Gammons and others, 2006) is shown for reference.

Figure 6-6 shows two distinct groups of water types, based on the stable isotope composition of water. Although two points are slightly outside the main group, the domestic well data are clustered near each other, with $\delta^{18}O$ values ranging from -19.04 to -17.62‰ and δD values from -151.10 to -142.60‰ (avg: $\delta^{18}O$ = -18.5‰; δD = -147.9‰). These data deviate slightly from the theoretical LMWL values, with an average $\delta^{18}O$ shift of 0.71‰, and an average δD shift of -5.16‰. However, these data points are clustered relatively close to the LMWL, and suggest that the groundwater in the domestic wells is meteoric in origin and has experienced minimal fractionation.

In contrast, the water sample from the YDTP has a $\delta^{18}O$ value of -13.22‰ and δD value of -117.6‰. While the original source and transport/usage timeline of the YDTP water is not entirely clear, these data deviate much more from the theoretical LMWL values, with the $\delta^{18}O$ value shifted 1.84‰, and the δD value shifted -13.46‰ away from the LMWL. This degree of deviation is typical of waters that have experienced some amount of fractionation through non-equilibrium evaporation, where the $\delta^{18}O$ and δD values are isotopically enriched (i.e. more positive δ values). This means that during the course of evaporation, the water molecules with "lighter" isotopic compositions ($^{16}O > {}^{18}O$,

$^1H > {}^2H$) require less energy for vaporization, and therefore evaporate preferentially more quickly than the molecules with "heavier" compositions. The isotopic composition of the water remaining in the pond is then shifted away from the original meteoric signature, toward the heavier (more positive) values.

These data are similar to the meteoric water samples and evaporated water samples that were collected around Butte through previous investigations (Pellicori and others, 2005; Gammons and others, 2006). The most highly evaporated samples that were collected came from the YDTP, with $\delta^{18}O$ between -8 and -5‰; δD between -90 and -50‰. However, the pond was inactive and had no outlet for the years prior to their samples, so the effects from evaporation were even greater at that time. Through their evaporation modeling, it was determined that the original isotopic signature for this water must be similar to the average composition of recharge water around Butte ($\delta^{18}O$ = -18.2‰; δD = -141.0‰) and their resulting YDTP samples were likely 50-60% evaporated. This source water signature is similar to the average isotopic values measured for the MBRGA domestic wells in this study ($\delta^{18}O$ = -18.5‰; δD = -147.9‰). Using the evaporative fractionation model found in Gammons and others (2006), it appears that the YDTP sample collected in this study is 20-25% evaporated (assuming 0.7 relative humidity).

The stable isotope data confirms the previous hypotheses that the YDTP is not currently impacting domestic well water supplies. If mixing took place between regional groundwater and YDTP water, then the isotopic signature for the domestic wells would be somewhere between the two end-members (i.e. meteoric recharge and the evaporated YDTP). As the water level continues to rise in the pond in the future, stable isotopes could be a useful diagnostic tool to determine if there is any outward influence from the YDTP.

SECTION 7.0 REVIEW OF THE BERKELEY PIT MODEL

The Berkeley Pit water-level model was updated based upon actual 2012 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 2012.

Based upon the 2012 model update, it was projected that the critical water level (CWL) of 5,410 ft will be reached at the Anselmo Mine in **July 2023**, 3 months (0.25 years) later than predicted in the 2011 model (April 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 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 2012; the consistent filling rate and operational activities led to the minor adjustment in filling-rate projection. The pit contained 42.5 billion gallons of water at the end of 2012; 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, a review of the HSB treatment plant design and operation would begin in July 2019. Any necessary upgrades would have to be completed by July 2021, figure 7-1.

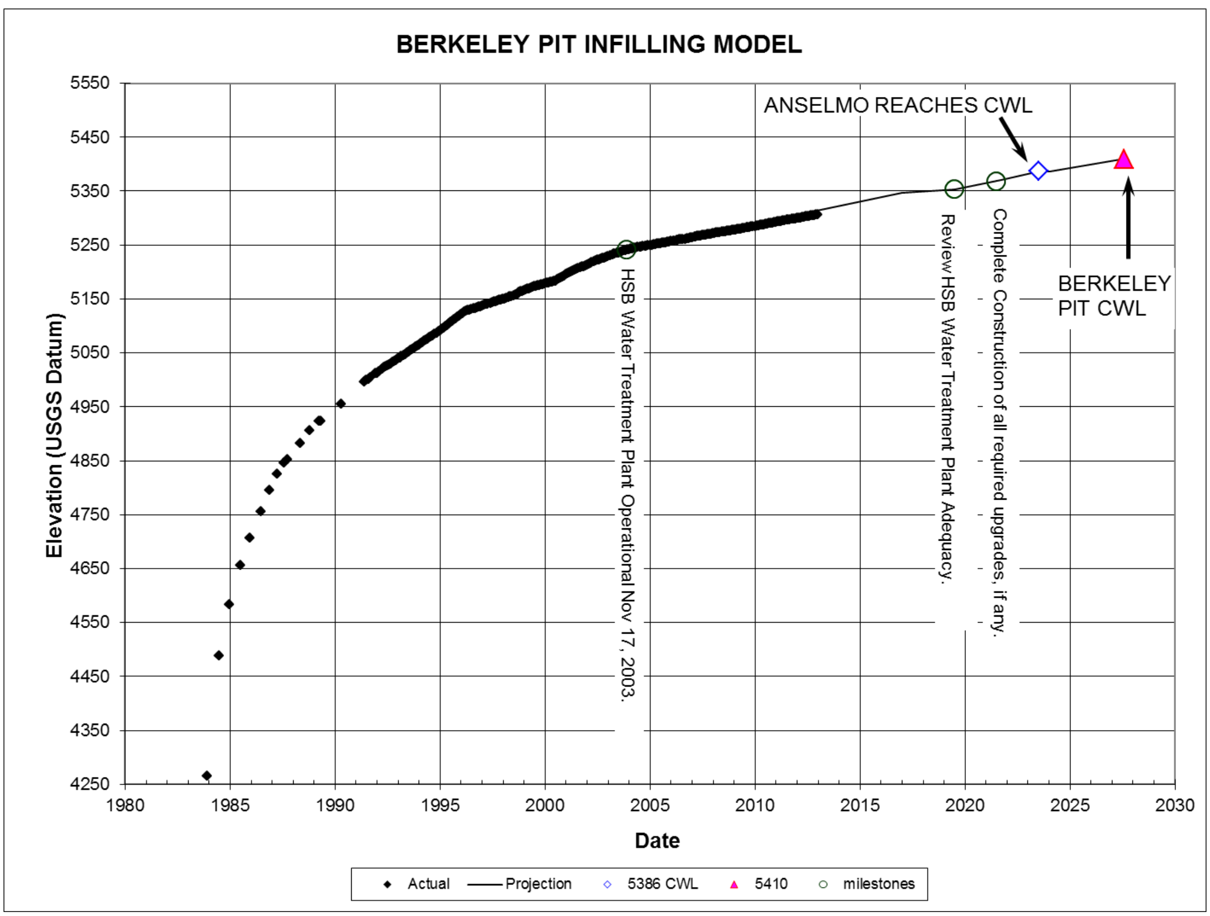

Figure 7-1. Figure showing projected Berkeley Pit filling rate and dates of treatment review and upgrades.

SECTION 8.0 CONCLUSIONS AND SUMMARY

Water-level trends in the alluvial monitoring system within the active mine area were similar to those of 2007-2010, with water levels decreasing in a majority of the wells north of the Pittsmont Dump. This reverses the trend observed from 2004 and earlier and from 2006 through 2009 of water levels increasing 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 activities 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 two-to three-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. This adds more support for the relationship between operational changes and water-level changes in the vicinity of the active mine area. Water-level changes were also noted in several alluvial wells as a result of BPSOU activities. All of these changes were short-lived, with water-levels returning to normal after dewatering and construction activities were completed.

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 mines' 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 2012 (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 April 2023 to July 2023, or three months later than that predicted in 2011. The CWL date is assumed to be the date the 5,410-foot elevation would be reached at the Anselmo Mine. The Anselmo Mine is the anticipated compliance point in order to keep the Berkeley Pit the lowest point in the East Camp bedrock-mine system. This will ensure that all water in the historic underground mine system will continue to flow towards the Berkeley Pit.

The pumping of groundwater in the West Camp System continues to control water levels in this system. No changes in pumping operations were noted during 2012. Water levels increased up to seven feet throughout this system and water levels are about 11 ft below the maximum-allowable level.

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

In several cases, chemistry data from the East Camp mines show a strong departure from 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 contaminants of concern. Water quality of domestic wells north of Walkerville showed that a majority of the wells have good water quality; however, several sites were found to have elevated concentrations of such things as arsenic 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 2012 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.

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The continued cooperation of Montana Resources and British Petroleum/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 land owners who allowed sampling of their domestic wells is recognized and appreciated.

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Errors and omissions remain the authors' responsibility.

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