Monitoring Activities and Summary of Bench-Scale Testing of Beal Mountain Leach Pad

Montana Bureau of Mines and Geology
1300 W. Park St. Butte, MT 59701

Prepared by: Nicholas J. Tucci

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INTRODUCTION

The Beal Mountain mining facility is located 22 miles southwest of Butte, MT in the Beaverhead-Deerlodge National Forest. The mine operated from 1988-1998, mining two small low-grade gold-silver deposits in open pits and recovering gold from a 70-acre cyanide heap-leach pad. In 1998, the operators of the mine went into bankruptcy, and shortly after, all bonding funds available for reclamation were exhausted. As a result, reclamation at the site is incomplete, and the United States Department of Agriculture-Forest Service (USDA-FS), in conjunction with the Montana Department of Environmental Quality (MDEQ), has assumed responsibility for final mine closure. In doing so, the USDA-FS placed the site under its Comprehensive Environmental Responsibility, Compensation, and Liability Act (CERCLA) authority, and determined that non-time-critical removal action process would be followed for mine closure. The goal for the site is to close the mine and allow for the area to return to its multiple use state (Maxim, 2004).

There are a number of areas of concern on the mine site which need to be addressed before the USDA-FS can meet its final reclamation goals for mine closure. One area, the leach pad, is a mining facility on the site that has continued to receive a considerable amount of water infiltration post-reclamation activities, and presents a water-quality issue of concern.

In 2002 and 2003, the leach pad was reclaimed using various low permeable geosynthetic and soil covers for the construction of a composite cap. After placement of the geocomposite covers, an 18-inch thick layer of sub-soil cover was constructed out of clayey and weathered quartzite, over which a 12-18-inch layer of cover soil was placed and seeded with native grasses and plants (Maxim, 2004).

The heap leach pad is a 70 acre facility located at the base of Beal's Hill (Figure 1). The USDA-FS has had to pump and treat the solution in the pad to prevent stability issues, and also prevent the water from spilling over the containment dikes and causing further spread of the contamination. Water has continued to collect in the leach pad sumps each spring and summer following reclamation, at a rate that would require solution contained in the pad to be pumped and treated every two years. Water-quality issues associated with the pad are numerous. Ammonia, arsenic, copper, cyanide, fluoride, nitrate, nitrite, selenium, and strontium are contaminants of concern for the heap leach pad solution (Maxim, 2005).

In October-2005 the Montana Bureau of Mines and Geology (MBMG) began assisting the USDA-FS with several issues related to the heap leach pad, in areas of both monitoring and research. Since that time, the MBMG has installed an array of monitoring equipment, performed a number of bench-scale water-quality experiments, assisted various other university and corporate researchers, and acted as a liaison between USDA-FS officials and Montana Tech faculty.

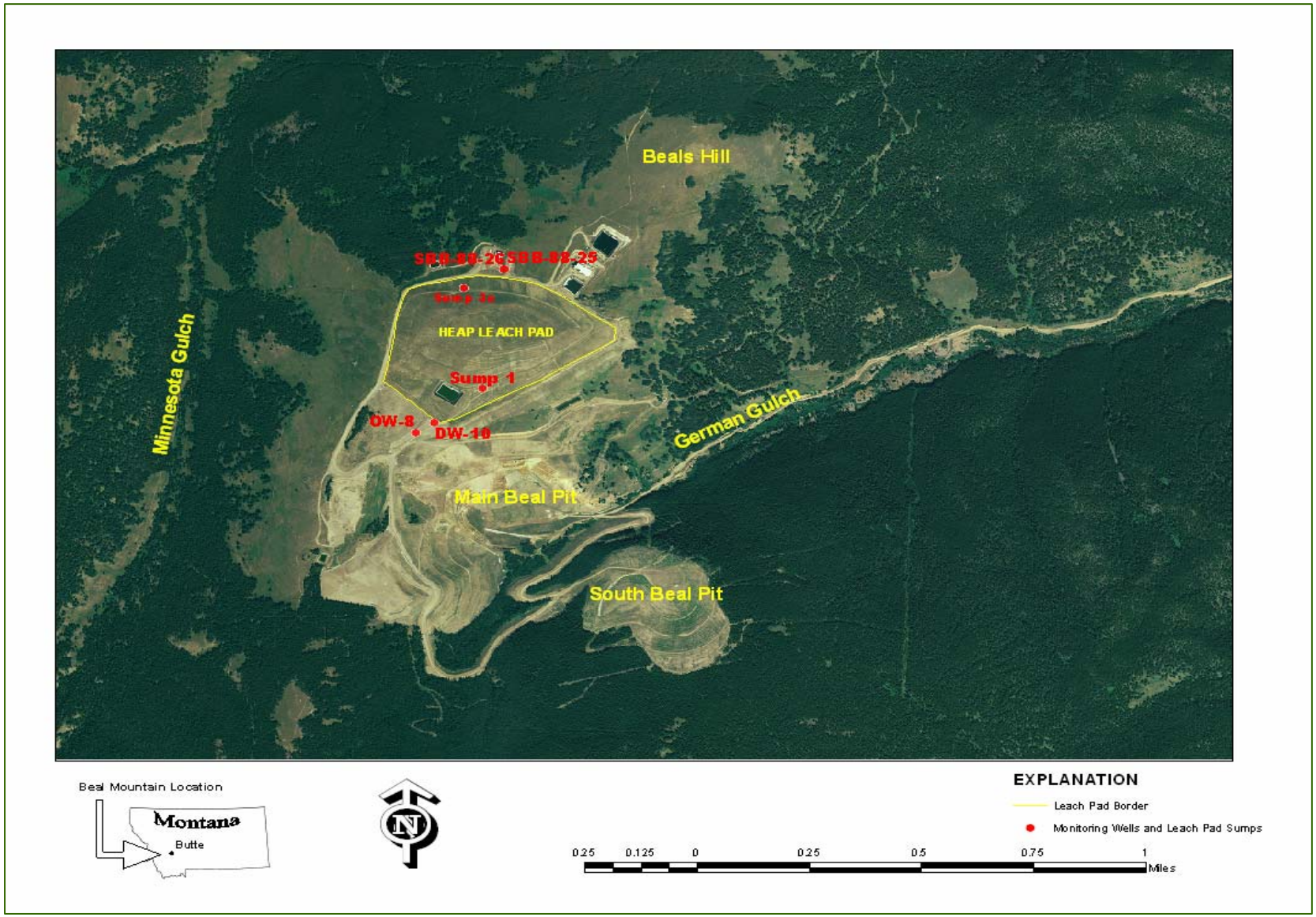

Figure 1: The Beal Mountain Site location, with mining facilities and MBMG monitoring sits.

PURPOSES AND SCOPE

In October of 2005, through a cooperative effort with the USDA-FS and Maxim Technologies, the MBMG started a data collection and interpretation effort to help address questions concerning unknown sources of recharge water to the heap leach pad located at the Beal Mountain Site. In achieving this goal, the scope of the MBMG activities was as follows:

1. establish a ground-water monitoring plan in selected wells located around the leach pad;
2. assess how water levels in wells respond to recharge events;
3. install in-situ monitoring equipment into pad sumps and surrounding observations wells to monitor physical parameters during recharge;
4. aid in the understanding of the complex dynamics involved in determining recharge to the heap leach pad; and,
5. Coordinate efforts between Montana Tech researchers as well as private industry, providing each group with necessary resources in achieving its own separate goals.

In addition to the monitoring plan, the MBMG undertook limited bench-scale analysis on the leach pad solution. The objective of these lab experiments was to determine the efficacy of wood fiber filters and five ion exchange resins at removing several contaminants of concern in the leachate solution.

Water-levels were measured in 26 wells (appendix 1). Most of these wells were either observation wells (OW) or dewatering wells (DW), but also included several dedicated nested wells, where levels could be monitored in both colluvium and bedrock aquifers. All of these wells have been monitored by Bruce Parker since mine closure and water-level records date back since that time (Parker, 2005). Five wells were equipped with continuous water-level recorders consisting of Solinst F-90 Transducers, and three wells were fitted with Hydrolab DS-4 multi-parameter Datasondes. Datasondes were installed to measure pH, Oxidation-reduction potential (ORP), specific conductance (SC), temperature, and dissolved oxygen (DO) parameters every two hours during recharge events.

Well hydrographs were used to determine where and how water levels surrounding the leach pad respond to precipitation events. Precipitation data were gathered from the Snotel site at Basin Creek, Montana (NCRS website).

WATER-LEVEL MONITORING

Water-levels were measured in 26 wells, including a sump located on the southern portion of the leach pad. Hydrographs were compiled using Solinst transducer data collected through the course of a year (Nov-05-Nov-06). Each transducer was calibrated to collect measurements of water-levels and temperature on an hourly basis. Two groups of nested wells were selected, wells SBB-88-25 and 26 are located north (up-gradient) of the leach pad, while wells OW-5 and 8 are located southwest (down-gradient) of the leach pad.

Leach Pad Sump 1

As of 21-Nov-06, water elevation in the leach pad was 7,482 feet. The low point of the south containment dike is 7,504-ft, at which point the dike could be breached and direct discharge to the surrounding environment can occur. Furthermore, slope stability analyses indicate that the crest of the leach pad dike has a relatively low factor of safety under worst-case conditions. The principal issue with respect to instability resulting from the clay/sill slide is the potential for movement of the slide with subsequent damage to the south containment leach pad dike. Failure of the containment dike could lead to a potential release of pad solution to the environment. Under worst-case conditions, a failure might occur in the leach pad dike that could breach the pad solution pool at an elevation of about 7,465 to 7,467 feet, which represents ~ 25 million gallons of pad solution (Maxim, 2005). It is currently recommended that pad solution be kept below 25 million gallons.

Wells Located to the North of the Leach Pad

Wells SBB-88-25 and 26 are two existing wells located on the north edge of the leach pad. The wells were completed at different depths. Figure 2 is a hydrograph of well SBB-88-25, which is completed in the colluvium at a depth of 32-ft. Figure 3 is a hydrograph of well SBB-88-26, completed in the bedrock at 73-ft. Drilling logs for these wells were obtained (Personal correspondence with Maxim Technologies and O' Keefe drilling) and are found in Appendix 2. Both wells are nested, and located in close proximity to one another up gradient of the leach pad and down gradient of Beal's Hill.

Water levels in both wells respond rapidly to spring recharge(Figure 4). Water-level increases in both wells respond almost simultaneously. Typically, water levels in wells are lowest in early spring, rise during spring runoff and fall rapidly in summer and fall. Temperatures decreases slightly during water-level increases suggesting that recharge is a result of colder snow melt. For both wells, recharge occurs very rapidly, and water levels increase (15-ft) steeply in a two week period. Recharge to SBB-88-25 is by rapid infiltration of rain and snowmelt into the overlying colluvium.

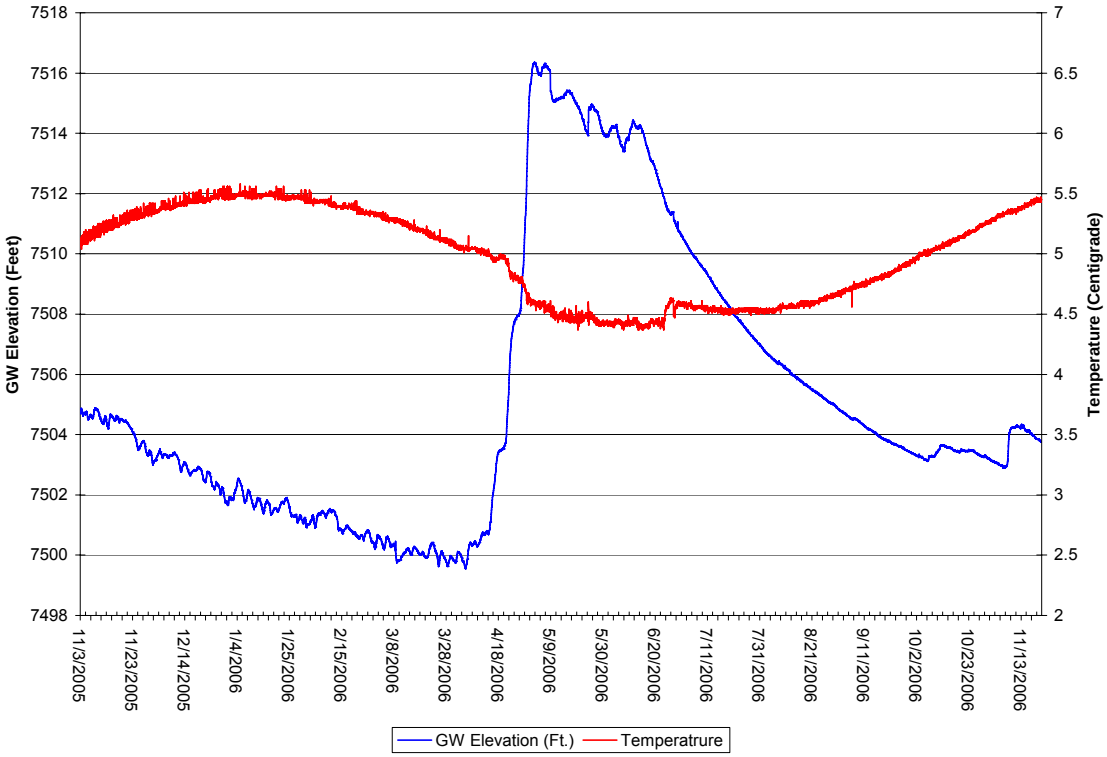

Figure 2. Well hydrograph for SBB-88-25 (Colluvium well), showing temperature data in centigrade.

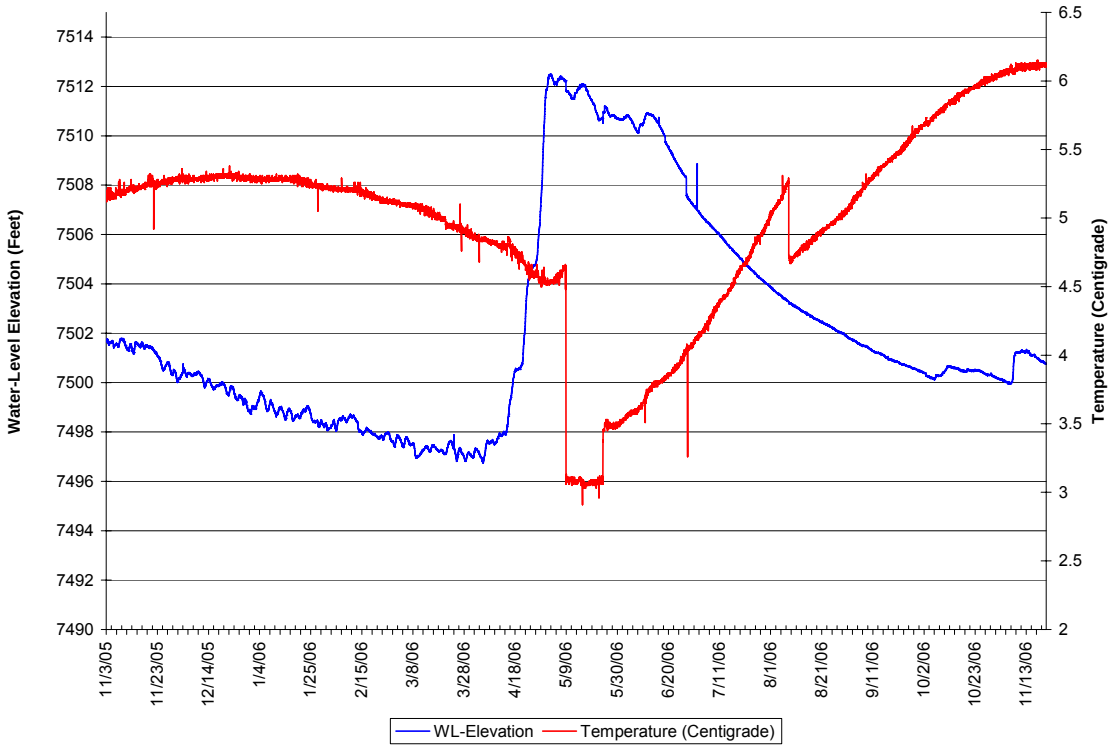

Figure 3. Well hydrograph for SBB-88-26 (bedrock well), showing temperature data in centigrade.

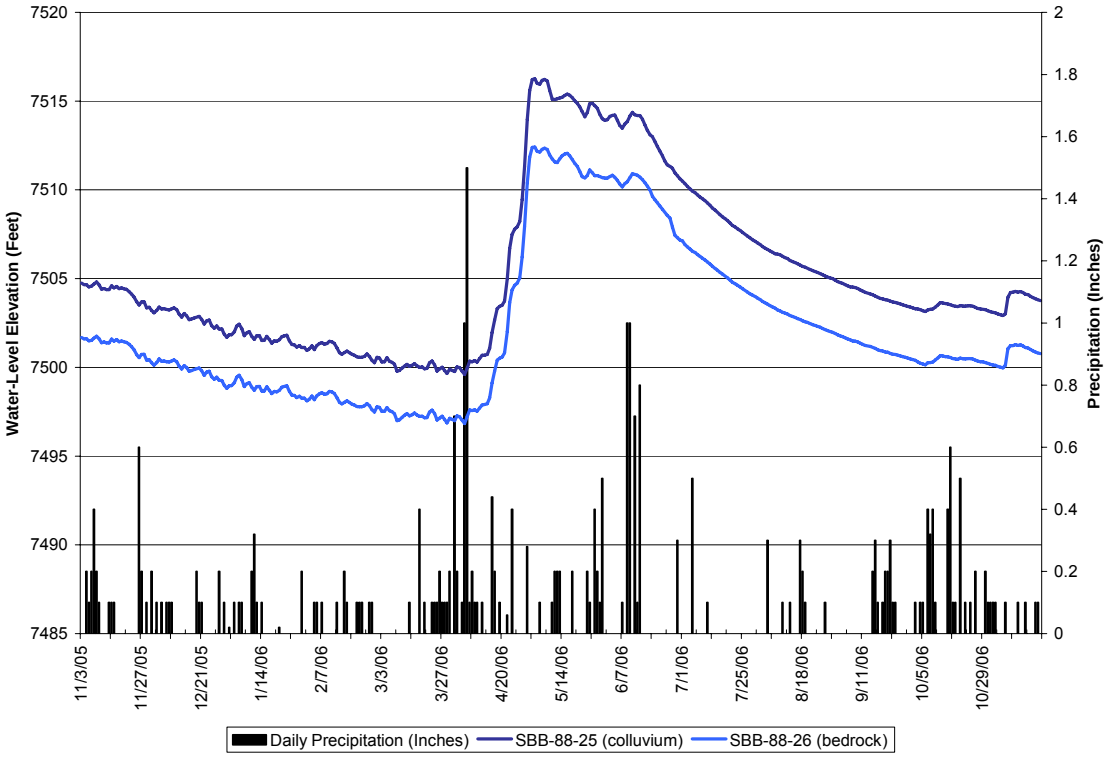

Figure 4. Nested well hydrographs for a colluvium/bedrock pair showing responses to daily precipitation (inches).

Two interesting observations are presented above, which can not be explained through analysis of current data. With respect to water-level response (figure 4), both colluvium and bedrock wells are almost identical, and this data suggests that both aquifers respond to rain and snow events simultaneously. Possible factors influencing this outcome are numerous; however, without the existence of surface-water gauging stations in the nearby area, an explanation of this observation is unable to be ascertained. Secondly, water levels for these two wells appeared to increase when the ground was still frozen. Peak water-level elevations for wells north of the leach pad were observed on 3-May-2006, while a field trip on 9-May-2006 revealed that the area north of the leach pads was still covered which thick layers of snow, indicating that the soil in that area still may be frozen and possibly impermeable. In fact, much of Beal's Hill was still blanketed with snow as well. Typically, infiltration into ground-water is minimal when the ground is still frozen. Again, additional monitoring of surface-water and investigation into surface-water/ground-water interaction is necessary in this area.

Wells Southwest of the Leach Pad

Several observation and dewatering wells are completed at various depths in the clay/silt slide area along the southwest corner of the leach pad. Driller logs for the two selected wells in this area could not be located; however total depths were measured to determine a shallow and a deep well pair. Two wells in this area, a shallow well and a deep well, were equipped with Solinst Transducers so water-levels could be monitored on an hourly basis for the duration of a year. Data gaps exist for both hydrograph generated for this area, as water-level fluctuations were much greater than anticipated, and raised above the range of the transducer. To combat this problem, existing transducers were replaced with those of higher range values.

Well OW-8 is a shallow well completed at ~ 85.5-ft below ground surface. Figure 5 represents the well's annual hydrograph, along with temperature data in centigrade. Recharge to this well was rapid and vast, receiving >52-ft of recharge in ~ two weeks. Temperature data shows no fluctuation during the first 30-ft of recharge, although some fluctuations were observed after the position of the transducer was moved.

Well OW-5 is a deep well completed at ~300-ft below ground surface. The hydrograph for this well is represented in figure 6, showing temperature data in centigrade. Well OW-5 exhibited the most impressive water-level increases, 67-ft in 3 weeks. Corresponding temperature data show little temperature variation during recharge, which may be a result of recharge occurring from the shallower aquifer. Too little is known of this area to ascertain.

Figure 7 is a hydrograph showing the response of the wells located to the southwest of the heap leach pad to daily precipitation. Both wells appear to recharge very rapidly, although the deeper well (OW-5) water-level response lags that of the shallow well (OW-8) by approximately 3 weeks. This lag time is not unusual, as well OW-5 is 100 ft. deeper than well OW-8. Temperature for both wells (figure 5 vs. figure 6), however, remained near 5°C, and did not fluctuate much throughout the year. Again, this observation cannot be explained using current data.

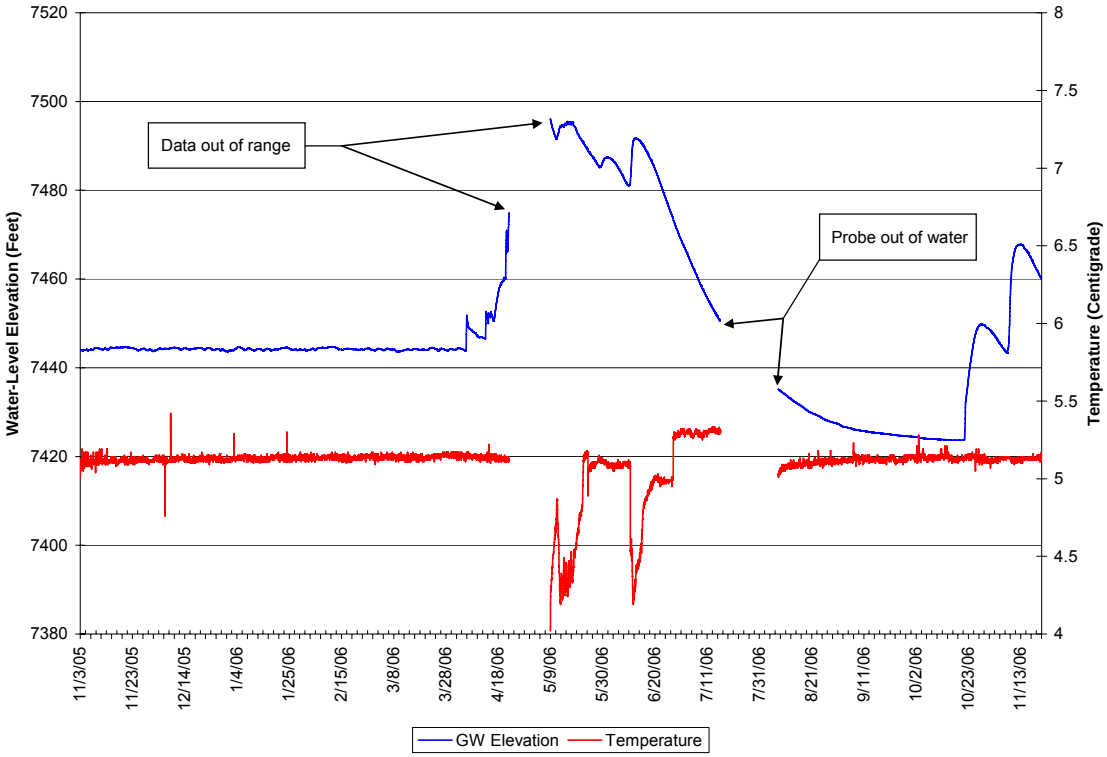

Figure 5. Well hydrograph for OW-8, showing temperature data in centigrade.

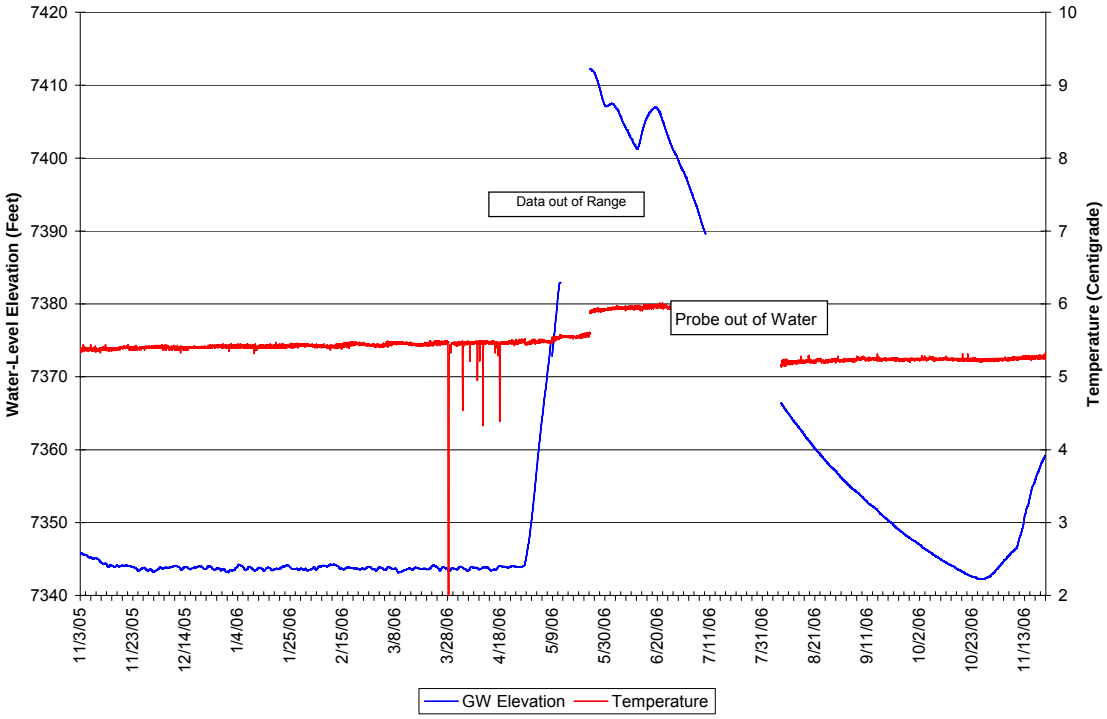

Figure 6. Well hydrograph for OW-5 with corresponding temperature data in centigrade.

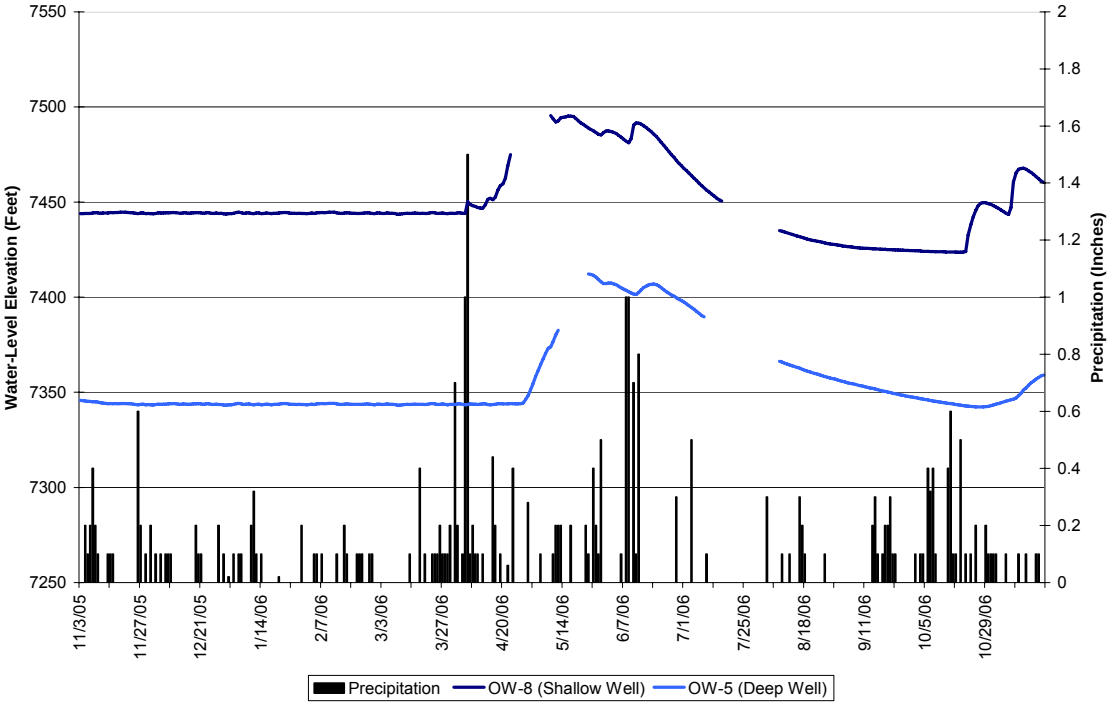

Figure 7: Hydrograph showing OW-8 and OW-5 response to daily precipitation

WATER QUALITY

Chemical Parameters

All MBMG water-quality data are given in Appendix 3 of this report. These data includes both dissolved and total recoverable analysis of spring 10a and the leach pad solution. Physical parameters, major anion and cation concentrations, and concentrations of dissolved and total metals are included in this appendix. Table 1 lists concentrations of contaminants that exceed one or more known water-quality standards.

Table 1: List of leach pad solution contaminants and water-quality standards.

Station	Dissolved concentrations									
	As	CN	NO_2	NO_3	NO_2 + NO_3	Se	Co	Cu	Sr	U
	ug/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L
Sump 1	**114**	**7.3**	**42**	**143**	**185**	**326**	**1,541**	**83**	**4,868**	**30**
Acute Aquatic Life Standards	340	0.02				20		50		
Chronic Aquatic Life Standards	150	0.005				5		29		
Human Health Standards	10 (MCL)	0.2 (MCL)	1 (MCL)	10 (MCL)	10 (MCL)	50 (MCL)		1300 (PP)	4,000 (HA)	30 (MCL)
EE/CA water-quality goals	20	0.2	1	10	10	50		1300	4,000	

Notes: 1. MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2. MCL = EPA maximum contaminant level.
3. PP = priority pollutant criteria.
4. HA = health advisory from EPA's "Drinking Water Standards and Health Advisories."

Since water quality in the leach pad is not suitable for discharge to either surface-water or ground-water, the water must be treated before it can be released to the environment. Recently, several existing technologies for treating mine water have being investigated by the MBMG. All EE/CA water-quality goals for discharge listed in table 1 have to be met before discharge to the surrounding environment is possible (Maxim 2005).

The leach pad solution at the Beal Mountain site is classified as a sodium-calcium-sulfate solution. A stiff diagram for the leach pad solution is provided in figure 8. Stiff diagrams are used to compare the ionic composition of water samples. The Stiff diagram is a polygon created from three horizontal axes extended on both sides of a vertical axis. Cations are plotted on the left side of the axis and anions are plotted on the right side, both in meq/L. A greater distance from the vertical axis represents a larger ionic concentration. The cation and anion concentrations are connected to form an asymmetric polygon known as a Stiff diagram, where the size is a relative indication of the dissolved-solids concentration. In this case, the major cations in solution are sodium and calcium, where the major anion is sulfate.

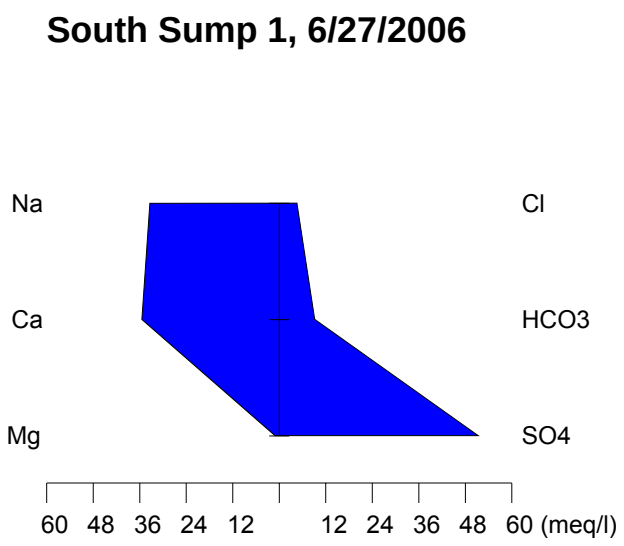

Figure 8: Stiff diagram for Beal Mountain leach pad solution.

Physical Parameters

In October-06, three Hydrolabs were installed at the Beal Mountain Site for a two week duration. Specifically, one Hydrolab was dedicated to monitor physical parameters on the north side of the pad, one was installed in a well to the south, and one was meant for heap leach sump #1. However, a treatability study being performed by Maxim Technologies at the time prevented access to Sump #1. As a result, the third Hydrolab was installed in spring 10a, in an attempt to determine if variations in physical parameters of the spring exist.

Hydrolabs were set up to collect readings on a 3 hr interval basis, and set up to monitor temperature (centigrade), pH, oxidation reduction potential (mV), specific conductance (us/cm), and dissolved oxygen (% saturation). Data for spring 10a and well SBB-88-25, a well to the north of the pad, are presented below. Malfunction in the Hydrolab dedicated to the well south of the pad prevented acquisition of data for that area.

Figures 9 and 10 are time series plots of pH, temperature, and specific conductivity for spring 10a. Minimal variation in physical parameters is observed for this spring during the two week time period. Initial fluctuations in temperature and specific conductance are due to low flow rates. Initially, flow rates were quite low (~1-2gpm), and provided just enough water to submerge the Hydrolabs to the top of the sensors. However, when Hydrolabs were extracted from the spring, flow rates had increased to ~5gpm, providing

higher water levels in the containment unit and accounting for the temperature decrease seen in figure 10. Higher water levels provided less interference from the ambient air temperature.

Figures 11, 12, and 13 show physical parameter time series plots for SBB-88-25, a well completed in the colluvium to the north of the pad. Again, little variation in physical parameters was observed in this well during the two weed time frame. A slight dip in ORP and DO followed by a subsequent rebound is shown in figure 12, which may be the effects of recharge from a rain event.

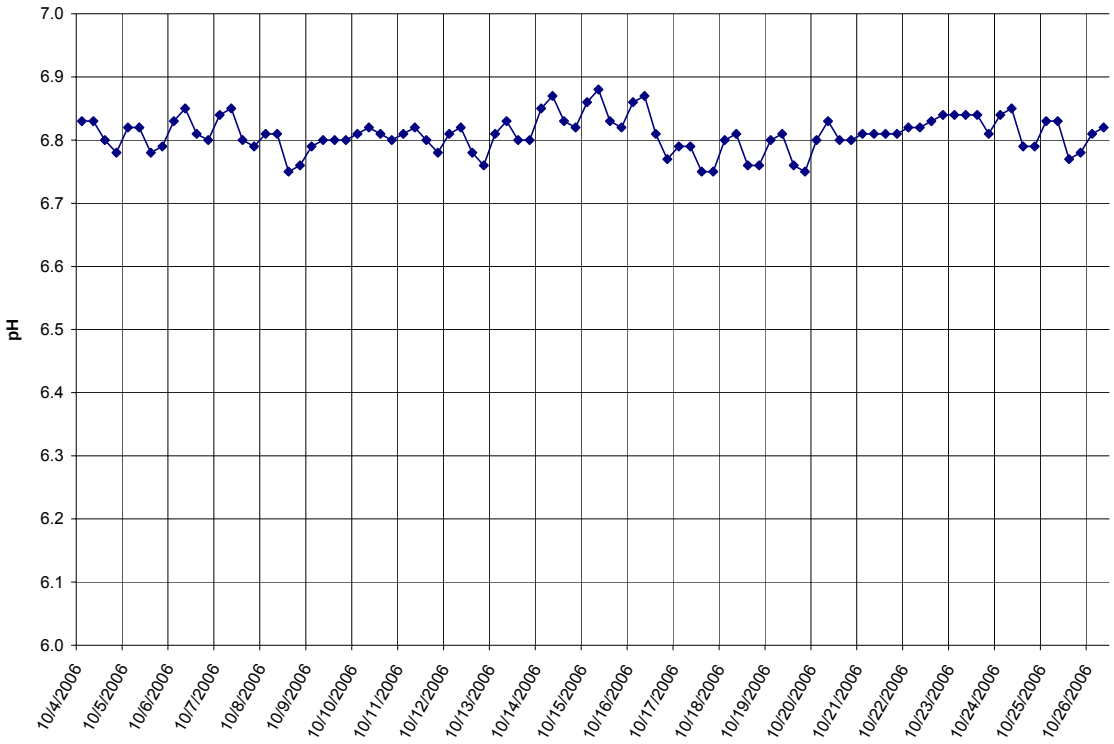

Figure 9: Spring 10a continuous pH reading.

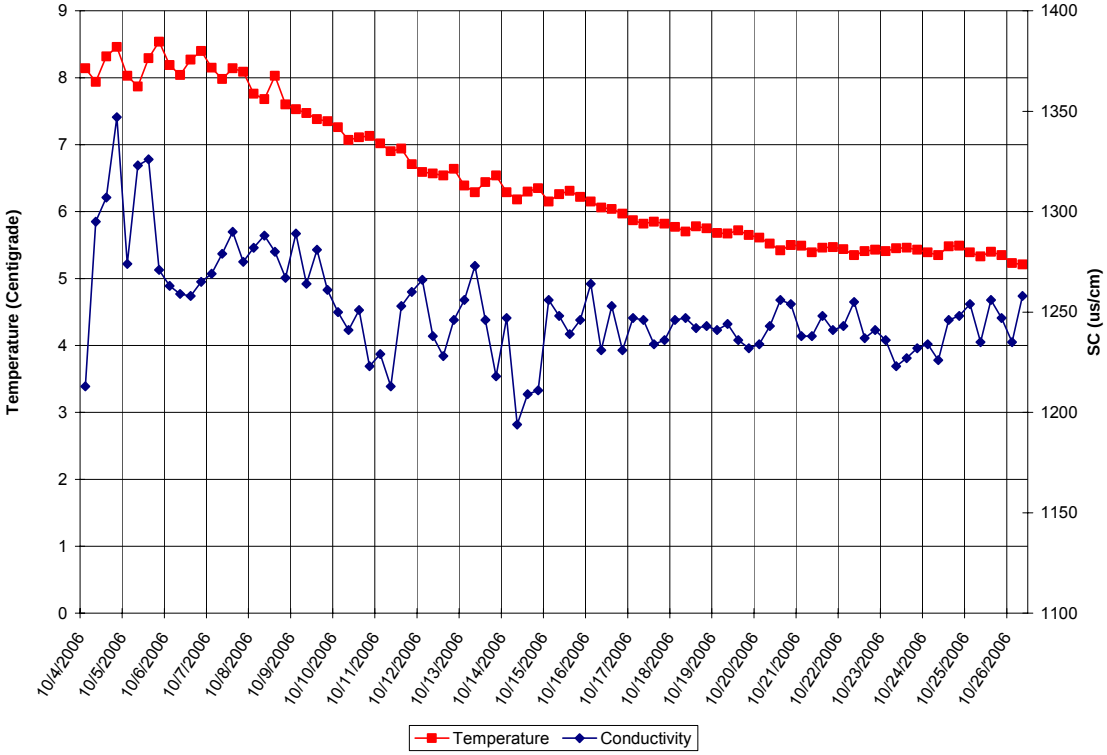

Figure 10: Time series profile of temperature for spring 10a.

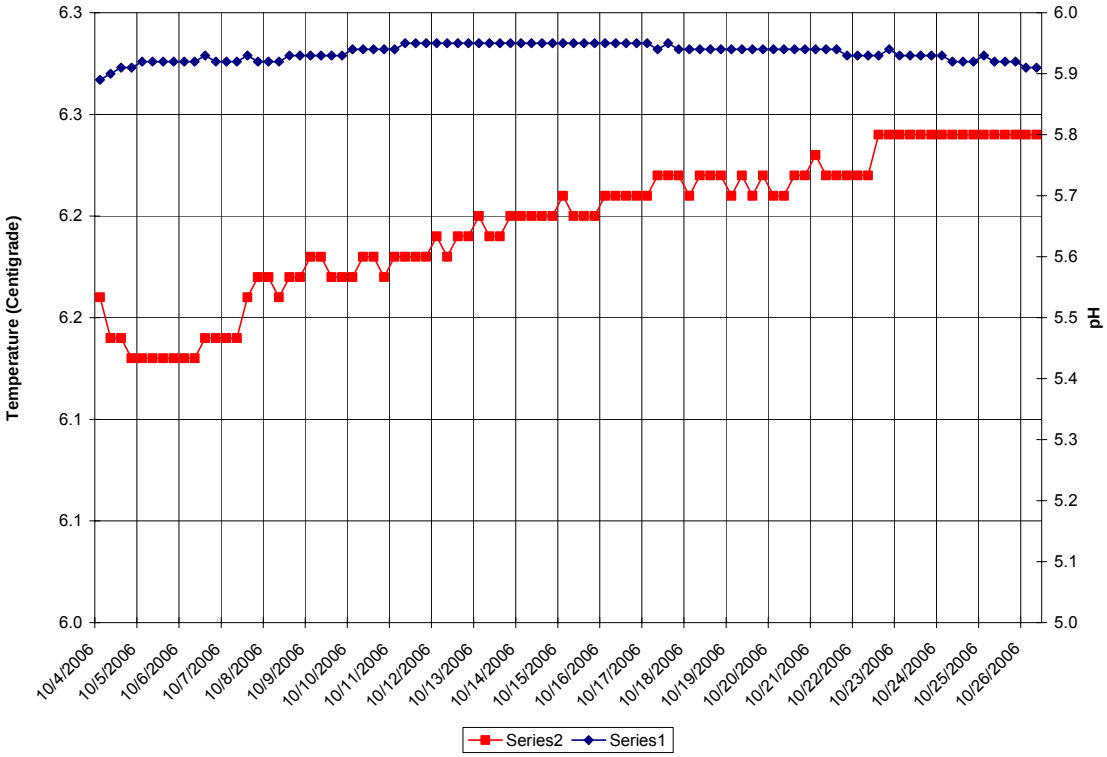

Figure 11: Time-series plot of pH and temperature for well SBB-88-25.

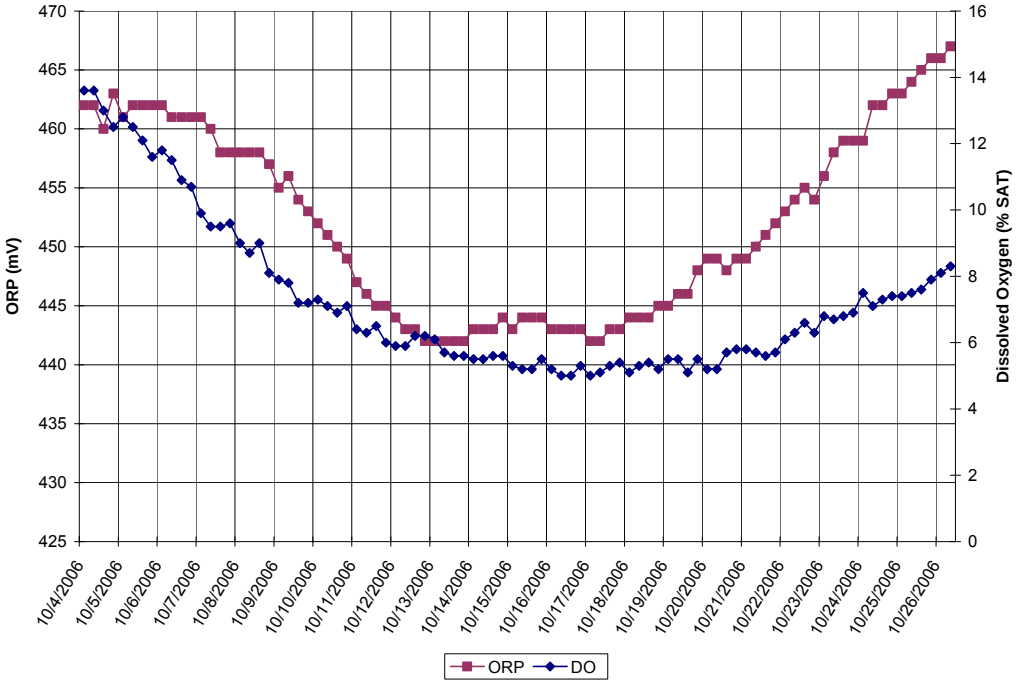

Figure 12: Time-series plot of oxidation-reduction potential (ORP) and dissolved oxygen (DO) for SBB-88-25.

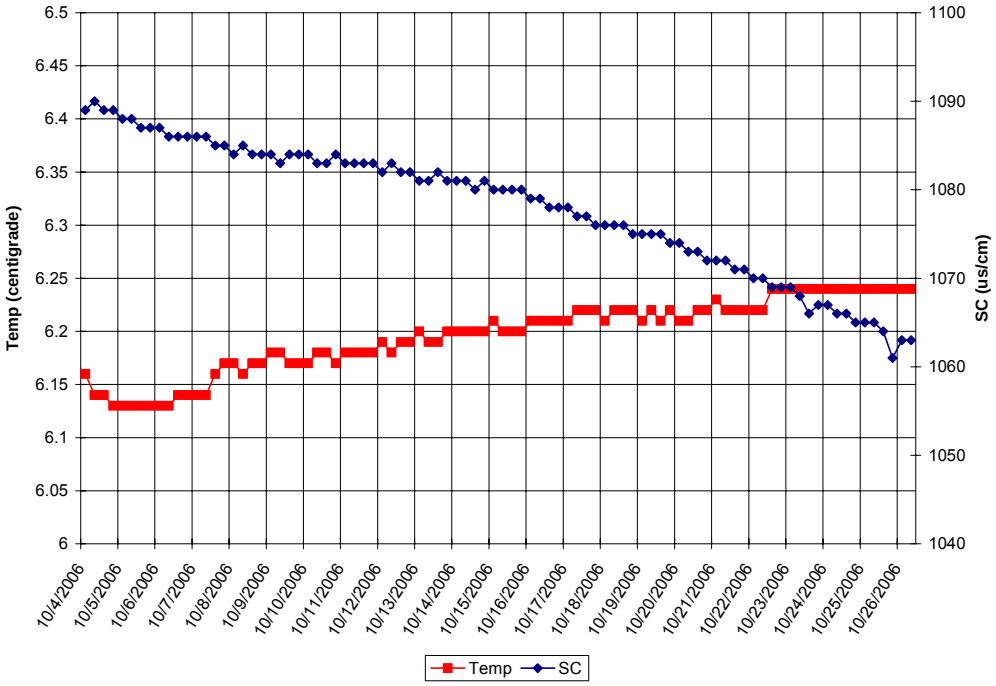

Figure 13: Temperature and SC time series plot for well SBB-88-25.

Three Hydrolabs were left in-situ to capture the spring run-off event for 2007. Currently, there is a Hydrolab in sump 1, well SBB-88-25, and well OW-8. Hopefully, the data received during this time can help give better insight to the conditions in and around the pad during snow melt.

ION EXCHANGE TECHNOLOGIES

In all, six ion exchange technologies were examined for their efficacy in removing contaminants of concern from the heap leachate. Four Purolite resins, one USDA-FS innovative technology, and one Dow experimental resin were tested in 400 mL batch experiments. Table 2 gives a brief description of each technology used.

Table 2: Brief description of ion exchange technologies

Technology	Description
Wood Fiber	Heat treated wood matrix combined to form a fibrous filter material
Purolite ArsenX	Hydrous iron oxide coated in a spherical polymer substrate
Purolite S-930	Macroporous Iminodiacetic chelating resin
Purolite C-106	Macroporous weak-acid cation exchange resin
Purolite A-500	Macroporous strongly basic type 1 anion exchange resin
Dow XY	Experimental hydrophobic quaternary amine resin

Controlled laboratory batch experiments were performed in 500 mL polyethylene sealable containers. Approximately 20 grams (g) of resin were allowed to equililibrate in 400 mL of pad solution for 24 hours. During equilibration, batch experiments were kept at room temperature (~25 centigrade) and mixed continuously in an agitator. During the experiment, 500 ml of Beal leachate solution was used as a control influent, and compared to the results of the other batch experiments.

Following equilibration, preserved filtered aliquots of each batch experiment were sent to the MBMG lab for dissolved metals analysis. Additionally, physical parameters of influent and effluent were monitored as well. Results are presented below.

Wood Fibers

The use of heat treated wood fibers for the remediation of acid mine drainage (AMD) was developed at the Forest Products Laboratory (FPL) in Madison, Wisconsin. Wood fibers are a sorption technology, and the small fibers of wood act as attachment sites for both cation and anion contaminants in AMD. Currently, this technology is being used in southern Ohio to clean adit seeps from abandoned coal mines. There are benefits in using this technology. The wood fiber for the filters can be processed from material that needs to be cut to improve forest health. The juniper fiber appears to be one of the most effective at removing contaminants (USDA-FS website, January 2007).

Prior to the experiment, two small sheets (~ 15 grams each) of wood fiber filter material were thoroughly rinsed with deionized water (DI) and left overnight to dry. The following day, the two sheets were suspended in leach pad water (in this case, 800 mL was used to fully submerge the filters), continuously mixed, and left to equilibrate at room temperature for 24 hours. When the experiment was terminated, physical parameters of both influent and effluent samples were measured (Table 3) and a filtered and preserved aliquot of batch solution was sent to the MBMG lab for dissolved metals analysis (Table 4).

Wood fiber filters did not seem to have a sufficient effect on the leach pad water. Concentrations of As, Cu, and Se showed significant reductions (70%, 83%, and 51% respectively), however effluent samples did not meet discharge goals set in the EE/CA. Dissolved sulfate increased by 51% (from 2,630 to 5,360 ppm) in the treated effluent samples, a change that cannot be accounted for. Moderate increases in dissolved concentrations of Ca, Na, and K were observed from influent to effluent as well. These increases can not be explained either. Additionally, the pH decreased from 6.54 to 5.61, a change believed to arise from the addition of organic acids.

Table 3: Physical parameters of wood fiber experiment.

Sample	Date	SpC	Temp	pH	ORP	DO
		uS/cm	^{o}C		mV	% Sat
Influent	10/18/2006	5,150	21.3	6.54	262	99.2
Wood fiber effluent	10/18/2006	5,210	22.7	5.61	285	95.2

Table 4: Dissolved metals analysis of wood fiber batch experiment.

Site	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Fe (mg/L)	Mn (mg/L)	SiO2 (mg/L)	Al (ug/L)	As (ug/L)	Co (ug/L)	Cu (ug/L)	Ni (ug/L)	Se (ug/L)	Sr (ug/L)	Zn (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	503	8.37	760	15.8	0.90	1.74	2.27	<300	100	1335	178	77.7	308	3,524	59	2,630	88
Wood fiber effluent	537	11.5	813	17.5	0.17	1.73	2.88	<300	<30	1427	82.8	74.5	152	3,639	165	5,360	89.5
% Decrease					**81.2**	0.6			**70.0**		**53.5**	4.1	**50.6**				
% Increase	6.3	27.2	6.5	9.7			21.2			6.4				3.2	64.2	50.9	1.7
Acute Aquatic Life Standards									340		50		20				
Chronic Aquatic Life Standards									150		29		5	4,000			
EE/CA goal for treated effluent									20		1,300		50	4,000			10
Human Health Standards									10		1,300		50				10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Purolite ArsenX Resin Technology

ArsenX is a nonoparticle-based selective resin designed to remove arsenic from waste-waster. This technology combines a unique chemistry based on hydrous iron oxide nanoparticles that have a very high affinity for arsenic with a durable, non-friable, spherical polymer substrate (www.purolite.com, 12/20/06). The ideal combination of selectivity and substrate stability means that ArsenX can not only remove arsenic, but other anions of similar chemistry (i.e. Selenium and nitrates).

Below are the results of the 24 hr batch experiment using ~20g of ArsnX as a resin, and 400 ml of Beal heap leachate. Table 5 shows physical parameters and table 6 are the dissolved metals analysis.

Table 5: Physical parameters for ArsenX Batch Experiment.

Sample	Date	SpC	Temp	pH	ORP	DO
		uS/cm	°C		mV	% Sat
Influent	10/18/2006	5,150	21.3	6.54	262	99.2
ArsenX Effluent	10/18/2006	5,070	21.1	6.33	284.9	97.1

Table 6: Dissolved metals analysis for ArsenX batch experiment.

Site	Fe (mg/L)	As (ug/L)	Cu (ug/L)	Se (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	0.90	100	178	308	2,630	88
ArsenX Effluent	0.05	38.2	<20	61.1	3,160	24.3
% Decrease	94.4	61.8	88.8	80.2		72.4
% Increase					16.8	
Acute Aquatic Life Standards		340	50	20		
Chronic Aquatic Life Standards		150	29	5		
EE/CA goal for treated effluent		20	1,300	50		10
Human Health Standards		10	1,300	50		10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Physical parameters did not seem to be effected by the ArsenX resin. Significant reductions were observed for As, Cu, Se, and NO_3, though EE/CA requirements for discharge were not met for these analytes. Selenium levels were decreased to 61 ppb, and it is believed that with further investigation, discharge requirements of 50 ppb can be met.

Purolite S-930 Technology

This ion exchange resin is a macroporous polystyrene based chelating resin, with iminodiacetic groups designed for the removal of cations of heavy metals from industrial effluents. Removal can be achieved both from weakly acidic and weakly basic solutions depending on the metals to be removed.

The iminodiacetic functional groups, neither the sodium or the hydrogen form, will chelate heavy metals by ion attraction to the dicarboxylic functionality and electron donation from the nitrogen. This is particularly suitable for the removal of heavy metals which are held according to the following order of selectivity:
Cu>>Ni>Zn≥Co>Fe>Mn>Ca.

Below are the results of the 24 hr batch experiment using ~20g of S-930 resin, and 400 ml of leach pad solution. Table 7 shows physical parameters and table 8 are the dissolved metals analysis.

Table 7: Physical parameter results for Purolite S-930 batch experiments.

Sample	Temp	SpC	pH	ORP	DO
	°C	uS/cm		mV	% Sat
Influent	21.3	5,150	6.54	262	99.2
S-930 effluent	19.1	5,880	6.35	235	99.2

Table 8: Dissolved metal analysis for S-930 batch experiment.

Site	Fe (mg/L)	Co (ug/L)	Cu (ug/L)	Ni (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	0.90	1,335	178	77.7	2,630	88
S-930 Effluent	<.05	<20	103	64	1,390	24.3
% Decrease	94.4	98.5	42.1	17.6	47.1	72.4
% Increase						
Acute Aquatic Life Standards			50			
Chronic Aquatic Life Standards			29			
EE/CA goal for treated effluent			1,300			10
Human Health Standards			1,300			10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Physical parameters were not effected by purolite S-930 resin. Large reductions however, were observed for Fe, Co, Cu, SO_4, and NO_3. Though promising, this technology does not seem adequate to treat Beal Mountain leach pad water.

Purolite C-106 Technology

C-106 is an acrylic-based macroporous weak-acid exchanger containing carboxylic groups. This resin has been designed for use under conditions where the marked swelling from the virtually un-ionized hydrogen form to the alkaline salt form in the equivalent gel resin might result in an unacceptable degree of mechanical breakdown. The resin is insoluble in acids, alkali's, and all common solvents.

Below are the results of the 24 hr batch experiment using ~20g of C-106 resin, and 400 ml of Beal heap leachate. Table 9 shows physical parameters and table 10 are the dissolved metals analysis.

Table 9: Physical parameter results for C-106 batch experiments.

Sample	Date	SpC	Temp	pH	ORP	DO
		uS/cm	°C		mV	% Sat
Influent	10/18/2006	5,150	21.3	6.54	262	99.2
C-106	10/18/2006	6,310	21.1	7.82	133	99.1

Table 10: Dissolved metals analysis for C-106 batch experiments.

Site	Fe (mg/L)	Co (ug/L)	Cu (ug/L)	Ni (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	0.90	1,335	178	77.7	2,630	88
C-106	0.12	1,297	53	68.8	2,595	63.2
% Decrease	86.7	2.8	70.2	11.5	1.3	28.2
% Increase						
Acute Aquatic Life Standards			50			
Chronic Aquatic Life Standards			29			
EE/CA goal for treated effluent			1,300			10
Human Health Standards			1,300			10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Both specific conductance and pH showed slight increases from influent to effluent samples, while ORP decreased slightly. Modest reductions in chemical parameters were observed, however, this technology does not appear sufficient to treat the leach pad solution.

Purolite A-500 Technology

Purolite A-500 is a premium quality strongly basic type I, macroporus anion exchange resin with an isoporous structure that contributes to its high capacity. Purolite A-500 will provide for optimum performance in deionization and as an organic trap.

Below are the results of the 24 hr batch experiment using ~20g of A-500 resin, and 400 ml of Beal heap leachate. Table 11 shows physical parameters and table 12 are the dissolved metals analysis.

Table 11: Physical parameter results for A-500 batch experiment.

Sample	Date	SpC	Temp	pH	ORP	DO
		uS/cm	°C		mV	% Sat
Influent	10/18/2006	5,150	21.3	6.54	262	99.2
A-500 Effluent	10/18/2006	2,820	20.8	6.6	137.1	99.9

Table 12: Dissolved metal analysis of A-500 batch experiment.

Site	Fe (mg/L)	As (ug/L)	Cu (ug/L)	Se (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	0.90	100	178	308	2,630	88
A-500	0.06	6.34	37.8	206	1,310	59.5
% Decrease	92.9	93.7	88.8	33.1	50.2	32.4
% Increase						
Acute Aquatic Life Standards		340	50	20		
Chronic Aquatic Life Standards		150	29	5		
EE/CA goal for treated effluent		20	1,300	50		10
Human Health Standards		10	1,300	50		10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Purolite A-500 resin proved to be a sufficient technology for arsenic removal (94% reduction), as EE/CA requirements for discharge were met in the effluent sample. Additionally, significant reductions in Fe and Cu (93% and 35% respectively), as well as sulfate (50% reduction).

Dow XY-91419 Resin Technology

This resin a large bead, gold selective strong base anion exchange resin for the recovery of gold from cyanidation leach solutions (manufactured under license from MINTEK). The resin is a developmental resin, manufactured under exclusive license from South Africa's premier mining technology house, MINTEK (www.dow.com). This resin is believed to be useful for the removal of nitrate, nitrite, and cyanide.

Below are the results of the 24 hr batch experiment using ~20g of XY-91419 resin, and 400 ml of Beal heap leachate. Table 13 shows physical parameters and table 14 are the dissolved metals analysis.

Table 13: Physical parameter results for XY technology.

Sample	Date	SpC	Temp	pH	ORP	DO
		uS/cm	°C		mV	% Sat
Influent	10/18/2006	5,150	21.3	6.54	262	99.2
XY Effluent	10/18/2006	5,390	20.8	3.86	377.2	96.5

Table 14: Dissolved metals analysis for XY technology.

Site	Fe (mg/L)	As (ug/L)	Cu (ug/L)	Se (ug/L)	SO_4 (mg/L)	NO_3 (mg/L)
Influent	0.90	100	178	308	2,630	88
XY Effluent	0.05	<30	325	88.6	2,355	6.2
% Decrease	94.4	70.0		71.2	10.5	93.0
% Increase			45.2			
Acute Aquatic Life Standards		340	50	20		
Chronic Aquatic Life Standards		150	29	5		
EE/CA goal for treated effluent		20	1,300	50		10
Human Health Standards		10	1,300	50		10

Notes: 1) MDEQ Circular WQB-7 human health and aquatic life standards (MDEQ, 2006).
2) Blue shaded cells represent exceedance of one or more water-quality standard. Standards based upon Circular WQB-7, Montana Numeric Water Quality Standards, February 2006 values.

Dow XY-91419 resin appears to be the best of the resins tested with respect to nitrate and nitrite removal. EE/CA requirements for discharge standards were met for both of these contaminants. Additionally, significant reductions for As and Se (70% and 71%) were observed as well. A significant decreases in pH (from 6.54 to 3.86) was observed, as a consequence of the presence of tertiary amines. Tertiary amines contain an extra proton, which when released into the surrounding environment decrease the pH of the solution. However, when properly washed with a base, this extra proton could be removed prior to use as a resin.

Adsorption Rates of Ion Exchange Resins

This section compares adsorption rates (k_{ads}) of all six technologies for Arsenic (As), copper (cu), selenium (Se), nitrate (NO_3), and sulfate (SO_4). Table 15 compares k_{ads} of all technologies for these contaminants. Appendix 4 is a list of equations used, and a table which shows all calculation of K_{ads}.

Table 15: Adsorption rates (k_{ads}) for all batch experiments.

Media	Contaminants Of Concern				
	As	Cu	Se	Nitrate	Sulfate
Wood	30	6	5	0	-3
ArsenX	38	103	53	34	-1
S-930				91	10
C-106				5	0
A-500	6	48	6	6	13
XY-91419	30	-5	29	157	1

Note: Yellow cells indicate highest adsorption rate for given technology.

It is worth noting that K_{ads} for target anion contaminants (As, Se, and nitrate) are much greater than K_{ads} for sulfate. Sulfate is the major anion in solution, and its relationship with respect to absorption rates, to that of other target anions is an important one. In most cases, K_{ads} for targets are much larger than for sulfate, indicating that target anions bind preferentially and the adsorbents would not be loaded to a great degree with non-target species.

SUMMARY AND CONCLUSION

Water-quality experiments, conducted by the MBMG on Beal mountain leach pad solution, showed a great deal of promise. During 24-hour batch experiments, many contaminants of concern for the USDA-FS were reduced below discharge standards set in the Engineering Evaluation/Cost Analysis Plan (2005). Arsenic concentration fell below discharge standards in the A-500 batch experiment; and based on literature research, it is believed that this resin is capable to remove cyanide as well. Nitrate and nitrite concentrations decreased below discharge standards (6.2 ppm for nitrate and ~1.0 ppm for nitrite) in the Dow XY-91419 batch experiment. Selenium did not meet discharge standards; however, results did show 80% reductions (from 308 ppb to 61 ppb) and it is believed that with further investigations a discharge standard of 50 ppb (EE/CA, 2005) is feasible.

Transducer and Hydrolab monitoring equipment were left in-situ for the upcoming 2007 spring snow-melt event. These devices were placed in and around the leach pad and set to take hourly measurements of water-levels, temperature, and a variety of other physical parameters. This data may prove useful to both the USDA-FS and Maxim technologies, a consulting firm responsible for remedial activities at the Beal Mountain Site.

RECOMMENDATIONS

1) Transducers should be left in-situ throughout the 2007 collecting season. This information provides valuable information concerning recharge of the heap leach pad and surrounding area.

2) Further investigation is needed concerning the efficacy of ion exchange resins. Specifically, column tests and field bench-scale tests should be conducted using one to several resins in series. Currently, three resins show a great deal of promise, if combined in series, and these technologies should be looked at in further detail.

3) Additional monitoring equipment could prove useful to the USDA-FS. Precipitation gauging stations and soil moisture probes are available for remote locations such as the Beal mountain site. The installation of this equipment would allow scientists to better understand the infiltration/recharge into the leach pad. Better understanding of the timing and sources of ground-water-recharge is necessary, and this monitoring equipment would aid in that understanding.

4) A water budget, defining quantities and sources of recharge to and discharge from the leach pad area can provide useful information. One of the biggest questions concerning the Beal Mountain Site is recharge to a capped heap leach pad, and defining the quantities of recharge and discharge is an important step in this understanding this phenomenon.

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APPENDIX 1: WATER LEVEL MEASUREMENTS IN GROUNDWATER WELLS

Wells Located Southwest of Leach Pad

Well	OW-4			OW-5 (DW-10) (Deep)			OW-7			OW-8 (Shallow)			OW-9		
	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ
		7505.48			**7510.87**			**7509.97**			**7509.55**			**Unknown**	
10/19/2004				164.7	7346.17					65.3	7444.3		48		
11/5/2004				165.8	7345.07	-1.1				73.9	7435.7	-8.6	49.7		1.7
11/28/2004				168.8	7342.07	-3				81.7	7427.9	-7.8	66		16.3
12/15/2004				171	7339.87	-2.2				83.7	7425.9	-2	87		21
12/31/2004	172.00	7333.48		172.6	7338.27	-1.6				84.7	7424.9	-1	97.4		10.4
1/20/2005				175.3	7335.57	-2.7				85	7424.6	-0.3	114.3		16.9
2/10/2005				177.6	7333.27	-2.3				85	7424.6	0	135.4		21.1
2/24/2005				178.9	7331.97	-1.3				85	7424.6	0	146.7		11.3
3/21/2005				180.6	7330.27	-1.7				85	7424.6	0	151.4		4.7
4/26/2005				163.6	7347.27	17				14.4	7495.2	70.6	112.4		-39
5/5/2005				146.3	7364.57	17.3				12	7497.6	2.4	18.4		-94
5/16/2005				112.2	7398.67	34.1				6.1	7503.5	5.9	18.7		0.3
5/23/2005				91.6	7419.27	20.6				12.7	7496.9	-6.6	14.9		-3.8
6/1/2005				96.6	7414.27	-5				23.4	7486.2	-10.7	20.6		5.7
6/9/2005				101.7	7409.17	-5.1				22.9	7486.7	0.5	22		1.4
6/21/2005				105.3	7405.57	-3.6				30.5	7479.1	-7.6	22.5		0.5
6/28/2005	110.80	7394.68	61.20	110.2	7400.67	-4.9				36.5	7473.05	48.15	26.5		4
10/28/2005				165.34	7345.53	-55.14				65.56	7443.99	-29.06			
5/9/2006				137.06	7373.81	28.28				13.51	7496.04	52.05			
5/24/2006	102.61	7402.87	8.19	98.63	7412.24	38.43									
8/8/2006	144.96	7360.52	-42.35	144.45	7366.42	-45.82	102.63	7407.34		73.97	7435.58	7435.58	42.9		16.4
9/7/2006				156.7	7354.17	-12.25				83.05	7426.5	-9.08			
10/3/2006	164.12	7341.36	-19.16	164.28	7346.59	-7.58	117.41	7392.56	-14.78	84.98	7424.57	-1.93	82.6		39.7
11/21/2006				151.56	7359.31	12.72				49.06	7460.49	35.92			

- Yellow cells represent wells with transducers in them
- Water-level measurements prior to 10/28/05 taken by Bruce Parker (Parker, 2005)

Well	97-1			95-3			DW-1			DW-2		
	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ
		7502.33			**7506.51**			**7497.51**			**7503.52**	
10/19/2004							165.7	7331.81		99.4	7404.1	
11/5/2004							169.8	7327.71	-4.1	102.7	7400.8	-3.3
11/28/2004							176	7321.51	-6.2	107.1	7396.4	-4.4
12/15/2004							180.5	7317.01	-4.5	109.6	7393.9	-2.5
12/31/2004	162.9	7339.43		249.7	7256.81		184	7313.51	-3.5	111.2	7392.3	-1.6
1/20/2005							190.3	7307.21	-6.3	114.2	7389.3	-3
2/10/2005							193.6	7303.91	-3.3	116.1	7387.4	-1.9
2/24/2005								7497.51	193.6	117.1	7386.4	-1
3/21/2005							194.4	7303.11	-194	117.9	7385.6	-0.8
4/26/2005							150.1	7347.41	44.3	84.1	7419.4	33.8
5/5/2005							123.5	7374.01	26.6	74.4	7429.1	9.7
5/16/2005							102.3	7395.21	21.2	58.5	7445	15.9
5/23/2005							98.8	7398.71	3.5	61.4	7442.1	-2.9
6/1/2005							107.9	7389.61	-9.1	73	7430.5	-11.6
6/9/2005							114.6	7382.91	-6.7	75.7	7427.8	-2.7
6/21/2005							119.2	7378.31	-4.6	80.4	7423.1	-4.7
6/28/2005	145.2	7357.13	17.7	225.2	7281.31	24.5	122.8	7374.71	-3.6	83.8	7419.7	-3.4
10/28/2005												
5/9/2006	156.4	7345.91	-11.2	255.3	7251.21	-30.1				71.68	7431.84	12.14
5/24/2006							109.4	7388.13	13.42	73.14	7430.38	-1.46
8/8/2006							155.2	7342.36	-45.8	105.8	7397.71	-32.67
9/7/2006												
10/3/2006							185.8	7311.76	-30.6	118.5	7385.02	-12.69
11/21/2006												

- Yellow cells represent wells with transducers in them.
- Water-level measurements prior to 10/28/05 taken by Bruce Parker (Parker, 2005).

Well	DW-3			DW-4			DW-5			DW-6		
	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ
		7502.14			**7501.15**			**7502.01**			**7507.75**	
10/19/2004	116.8	7385.34		200.2	7300.95		156.1	7345.91		161.8	7345.95	
11/5/2004	120	7382.14	-3.2	202.4	7298.75	-2.2	157.1	7344.91	-1	162.9	7344.85	-1.1
11/28/2004	124.3	7377.84	-4.3	204	7297.15	-1.6	160.3	7341.71	-3.2	165.9	7341.85	-3
12/15/2004	126.6	7375.54	-2.3	202.4	7298.75	1.6	162.5	7339.51	-2.2	168	7339.75	-2.1
12/31/2004	128.2	7373.94	-1.6	204	7297.15	-1.6	164	7338.01	-1.5	169.6	7338.15	-1.6
1/20/2005	131.2	7370.94	-3	207	7294.15	-3	166.8	7335.21	-2.8	172.3	7335.45	-2.7
2/10/2005	132.9	7369.24	-1.7	209.3	7291.85	-2.3	169.1	7332.91	-2.3	174.5	7333.25	-2.2
2/24/2005	133.8	7368.34	-0.9	211	7290.15	-1.7	170.3	7331.71	-1.2	175.6	7332.15	-1.1
3/21/2005	134.1	7368.04	-0.3	210.8	7290.35	0.2	172	7330.01	-1.7	177.5	7330.25	-1.9
4/26/2005	99.5	7402.64	34.6	197.8	7303.35	13	154.1	7347.91	17.9	160.6	7347.15	16.9
5/5/2005	90.7	7411.44	8.8	180.3	7320.85	17.5	137.1	7364.91	17	143.7	7364.05	16.9
5/16/2005	74.7	7427.44	16	156	7345.15	24.3	102.7	7399.31	34.4	109.5	7398.25	34.2
5/23/2005	76.7	7425.44	-2	141.1	7360.05	14.9	82.3	7419.71	20.4	89.4	7418.35	20.1
6/1/2005	88.6	7413.54	-11.9	143.5	7357.65	-2.4	87.8	7414.21	-5.5	94.5	7413.25	-5.1
6/9/2005	91.3	7410.84	-2.7	147.5	7353.65	-4	92.9	7409.11	-5.1	99.5	7408.25	-5
6/21/2005	95.9	7406.24	-4.6	151	7350.15	-3.5	96.6	7405.41	-3.7	103.1	7404.65	-3.6
6/28/2005	99.2	7402.94	-3.3	154	7347.15	-3	101.5	7400.51	-4.9	107.9	7399.85	-4.8
10/28/2005												
5/9/2006	84.36	7417.78	14.8	148.4	7352.78	5.63				134.6	7373.12	-26.73
5/24/2006	86.21	7415.93	-1.85	148.9	7352.24	0.54				96.32	7411.43	38.31
8/8/2006	119.4	7382.78	-35	175.7	7325.48	-26.8	89.52	7412.49	11.98	141.5	7366.22	-45.21
9/7/2006	61.11	7441.03	25.1				135.8	7366.18	-46.3			
10/3/2006	132.2	7369.92	-12.9	191.1	7310.04	-15.4	156.5	7345.48	-20.7	161.2	7346.57	-19.65
11/21/2006							155.7	7346.3	-0.87			

- Yellow cells represent wells with transducers in them.
- Water-level measurements prior to 10/28/05 taken by Bruce Parker (Parker, 2005).

Well	**DW-8**			**DW-9**		
	SWL	Elevation	Δ	SWL	Elevation	Δ
		7506.82			**7505.14**	
10/19/2004	174.8	7332.02		177.7	7327.44	
11/5/2004	176.1	7330.72	-1.3		7505.14	177.7
11/28/2004	177.5	7329.32	-1.4	180	7325.14	-180
12/15/2004	178.9	7327.92	-1.4	181.2	7323.94	-1.2
12/31/2004	179.6	7327.22	-0.7	181.8	7323.34	-0.6
1/20/2005	181.5	7325.32	-1.9	183.5	7321.64	-1.7
2/10/2005	182.9	7323.92	-1.4	184.9	7320.24	-1.4
2/24/2005	183.7	7323.12	-0.8	185.5	7319.64	-0.6
3/21/2005	184.4	7322.42	-0.7	186.3	7318.84	-0.8
4/26/2005	178.2	7328.62	6.2	178.9	7326.24	7.4
5/5/2005	165	7341.82	13.2	165.2	7339.94	13.7
5/16/2005	144.5	7362.32	20.5	142.7	7362.44	22.5
5/23/2005	130.1	7376.72	14.4	134.6	7370.54	8.1
6/1/2005	133.9	7372.92	-3.8	140.3	7364.84	-5.7
6/9/2005	138	7368.82	-4.1	144.1	7361.04	-3.8
6/21/2005	141.5	7365.32	-3.5	147.6	7357.54	-3.5
6/28/2005	144	7362.82	-2.5	150	7355.14	-2.4
10/28/2005						
5/9/2006	148.4	7358.45	-4.37			
5/24/2006	137.1	7369.75	11.3			
8/8/2006	161.9	7344.9	-24.9	69.17	7435.97	80.83
9/7/2006						
10/3/2006	173.5	7333.37	-11.5	177.6	7327.52	-108
11/21/2006						

- Yellow cells represent wells with transducers in them.
- Water-level measurements prior to 10/28/05 taken by Bruce Parker (Parker, 2005).

Wells North of Heap Leach Pad

Well	SBB-88-25			SBB-88-26			SBB-91-30			SBB-91-29			SBB-87-07			SBB-87-06		
	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ	SWL	Elevation	Δ
		7520			7516			Unknown			Unknown			Unknown			Unknown	
Date																		
6/30/2003	6.1	7513.9		7	7509		10.6						13.6			14.5		
11/13/2003	18.25	7501.75	-12.15	17.5	7498.5	-10.5							15.89		2.29	18.3		3.8
6/10/2004	13.35	7506.65	4.9	13.6	7502.4	3.9	10.4		-0				12.29		-3.6	15.5		-2.8
12/31/2004	19	7501	-5.65				12						14		1.71	18		2.5
6/28/2005						0												
10/28/2005	15.31	7504.69	3.69	14.34	7501.66	-0.74												
5/9/2006	6.41	7513.59	8.9	8.48	7507.52	5.86	10.19		-2				4.29		-9.71	10.44		-7.56
8/8/2006	13.57	7506.43	-7.16	12.78	7503.22	-4.3	11		0.8	13.51			15.57		11.28	17.76		7.32
9/7/2006	15.45	7504.55	-1.88	14.54	7501.46	-1.76	11.39		0.4	13.07		-0.44	16.1		0.53			
10/4/2006	16.7	7503.3	-1.25	15.72	7500.28	-1.18	11.4		0	13.08		0.01	16.06		-0.04	18.11		0.35
11/21/2006	16.31	7503.69	0.39	15.26	7500.74	0.46												

Heap Leach Pad Sump #1

Well	Leach Pad Sump # 1		
Date	SWL	Elevation	Δ
		7540	
5/24/2006	66.91	7473.09	
6/27/2006	62.18	7477.82	4.73
8/8/2006	60.45	7479.55	1.73
11/21/2006	57.85	7482.15	2.6

- Yellow cells represent wells with transducers in them.
- Water-level measurements prior to 10/28/05 taken by Bruce Parker (Parker, 2005).

APPENDIX 2: DRILLER LOGS FOR GROUND-WATER WELLS SURROUNDING HEAP LEACH PAD

Wells North of Pad

HYDROMETRICS

TEST HOLE LOG

Helena, MT

State: Montana County: Silver Bow Project: Beal Hole Name or Number: SBB-88-25

Legal Location: T 3N R 10W Sec. 31 Tract D Descriptive Location: 20 ft. east of SBB-88-26, north of plant are

Recorded by: JWB Date Hole Started: 8/11/88 Date Hole Completed: 8/11/88 Driller: George Drilling Company: Degerstrom

Drill Method: Air Rotary Drilling Fluids Used: Air Pilot Hole Diameter: 7-1/4 inches Reamed Hole Diameter: -------

Total Depth Drilled: 32 feet Total Depth Reamed: ------ Total Depth Cased Below G.S.: 32 feet Diameter and Type of Casing: 4-1/2 inch PVC

Weight or Gage of Casing: 160 psi Interval Perforated or Screened Below G.S.: 12-32 ft Target Aquifer: Colluvium Packer Type and Depth Below G.S.: 2 Neoprene packers at 7 and 12 ft.

	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?		X
E - Logs?		X

Method Perforated or Screened:

- ___ No casing in hole.
- ___ Open bottom only.
- ___ Slotted with Hill's Knife.
- ___ Slotted with a torch.
- ___ Screened by pulling casing.
- X Saw cut.
- ___ Other (specify)

Static Water Level: 18.1 feet Date: 8/15/88

Measuring Point Description/Elevation: Top of steel casing. MP Height Above (+) or Below G.S.: 1.35 feet

Well Annulus Completion Description: 6 feet of 8 inch steel casing (4.65 ft in ground). Bentonite from 0 to 7 feet.

Remarks:

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	4	SOIL. Weathered rock colluvial material.
4	13	CLAY. Medium stiff, reddish-brown, rock fragments (50%), hornfels.
13	20	BEDROCK. Weathered, hornfels, gray to dark gray coloration, fractured.
20	32	HORNFELS. Dark gray to black, some olive green coloration. Slightly fractured.

Elevation 7520.0

HYDROMETRICS

TEST HOLE LOG

Helena, MT

State: Montana County: Silver Bow Project: Beal Hole Name or Number: SBB-88-26

Legal Location: T 3N R 10W Sec. 31 Tract D Descriptive Location: 20 ft. west of SBB-88-27, north of plant area

Recorded by: JWB Date Hole Started: 8/11/88 Date Hole Completed: 8/11/88 Driller: George Drilling Company: Degerstrom

Drill Method: Air Rotary Drilling Fluids Used: Air Pilot Hole Diameter: 7-1/2 inches Reamed Hole Diameter: -------

Total Depth Drilled: 73 feet Total Depth Reamed: ------ Total Depth Cased Below G.S.: 64.25 ft Diameter and Type of Casing: 4-1/2 inch PVC

Weight or Gage of Casing: 160 psi Interval Perforated or Screened Below G.S.: 44-64 feet Target Aquifer: Bedrock Packer Type and Depth Below G.S.: 2 Neoprene packers at 30 and 36 ft.

	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?		X
E - Log?		X

Method Perforated or Screened:

- ___ No casing in hole.
- ___ Open bottom only.
- ___ Slotted with Hill's Knife.
- ___ Slotted with a torch.
- ___ Screened by pulling casing.
- X Saw cut.
- ___ Other (specify)

Static Water Level: 17.5 feet Date: 8/15/88

Measuring Point Description/Elevation: Top of steel casing. MP Height Above (+) or Below G.S.: 1.75 feet

Well Annulus Completion Description: 9 feet of 8 inch steel surface casing. Bentonite from 27 to 30 feet. Cuttings 5 to 27 feet. Bentonite 0 to 5 feet.

Remarks:

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	4	TOPSOIL. Weathered colluvium.
4	13	CLAY. Medium stiff, reddish-brown. Numerous rock fragments.
13	20	WEATHERED BEDROCK. Hornfels, dark gray to gray. Microxline to 1/8 mm. Fractured. Slight staining on fractures.
20	73	HORNFELS (QUARTZITE). Dark gray-black, intermixed with layers of light gray to olive green. Microxline. Staining on fractures. At 55 feet, 2 foot heavy clay zone, weathered granulated pieces of hornfels.

7516.00

HYDROMETRICS

TEST HOLE LOG

Helena, Mt.

State: Montana County: Silver Bow Project: Beal Hole Name or Number: SBB-88-20

Legal Location: T 2N R 10 W Sec. 5 Tract B Descriptive Location: Uphill from road above switchback 10 feet east of SBB-88-19

Recorded by: JWB Date Hole Started: 8/15/88 Date Hole Completed: 8/15/88 Driller: George Drilling Company: Degerstrom

Drill Method: Air Rotary Drilling Fluids Used: Air Pilot Hole Diameter: 8 inches Reamed Hole Diameter: -------

Total Depth Drilled: 60 feet Total Depth Reamed: ------ Total Depth Cased Below G.S.: 50.3 ft Diameter and Type of Casing: 4-1/2 inch PVC

Weight or Gage of Casing: 160 DSI Interval Perforated or Screened Below G.S.: 30.3-50.3 feet Target Aquifer: Bedrock Packer Type and Depth Below G.S.: 2 Neoprene packers at 17.8 & 23.8

	YES	NO
Well Developed?	X	
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?		X
E - Logs?		X

Static Water Level: 32.83 feet Date: 8/16/88

Measuring Point Description/Elevation: Top of steel casing. MP Height Above (+) or Below G.S.: 1.0 feet

Well Annulus Completion Description: 6.1 ft. steel (8") casing below ground surface. Bentonite at 17.8 to 11.8 ft. Cuttings 5 to 1.8 feet. Bentonite 5 to 6.5 feet.

Remarks: Developed by drill air compressor for 1 hour - making 20 gpm estimated.

Method Perforated or Screened:

- ____ No casing in hole.
- ____ Open bottom only.
- ____ Slotted with Mill's Knife.
- ____ Slotted with a torch.
- ____ Screened by pulling casing.
- X Saw cut.
- ____ Other (specify) ____

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	2	FILL.
2	4	TOPSOIL. Subsoil, brown clay.
4	12	CLAY. Brown, medium stiff, sticky. Fifty percent rock fragments, hornfels, olive green to gray and black coloration.
12	60	HORNFELS. Broken fragments, weathered, olive green to gray coloration. Clayey.
		At 23 feet about 50% clay. At 35 feet formations harden up. At 45 feet it is broken. At 50 feet, making water (approximately 15 gpm).

HYDROMETRICS

TEST HOLE LOG

Helena, MT.

State: MONTANA County: Silver Bow Project: Beal Hole Name or Number: SBB-87-06

Legal Location: T 3N R 10W Sec. 31 Tract DDA Descriptive Location: Minnesota Gulch side of Beal Ridge.

Recorded by: Blumer Date Hole Started: 10/13/87 Date Hole Completed: 10/14/87 Driller: Dan O'Keefe Drilling Company: O'Keefe Drilling

Drill Method: Rotary Drilling Fluids Used: Air Pilot Hole Diameter: 5-7/8 inch Reamed Hole Diameter: Not reamed

Total Depth Drilled: 150 ft. Total Depth Reamed: N/A Total Depth Cased Below G.S.: 120 ft. Diameter and Type of Casing: 4-inch I.D. PVC

Weight or Gage of Casing: 160 ft. Interval Perforated or Screened Below G.S.: 80 to 120 feet Target Aquifer: Bedrock Packer Type and Depth Below G.S.: 2 Neoprene 70 feet

	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?	X	
E - Logs?		X

Static Water Level: 18.1 feet Date: 10/18/87

Method Perforated or Screened:

- ___ No casing in hole.
- ___ Open bottom only.
- ___ Slotted with Mill's Knife.
- ___ Slotted with a torch.
- ___ Screened by pulling casing.
- X Saw cut
- ___ Other (specify)

Measuring Point Description/Elevation: Top of casing MP Height Above (+) or Below G.S.: + 1.33 feet

Well Annulus Completion Description: PVC = saw cut 3 ring cuts on 3 foot centers. Set 6-inch I.D. steel casing to 58 feet. Surface seal: 1 bucket of volclay tablets followed by one sack of bentonite crumbles and 100 gallons of bentonite slurry to surface.

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	3	SOIL HORIZON - Tan to light gray, clayey.
3	22	SAND - clayey, silty. Small lenses of gravel (1/2-inch) intermixed. At 20 feet (damp zone). Clay balls up with the sand.
22	35	GRAVEL - 1/2-inch, (large fragment layer (2-inch fragments) at 25 feet). Wet. Drill connection at 25 feet has water in hole. Blown out after connection.
35	55	SANDS (40%) - (unsorted particle size and SHALES (40%).intermixed, clayey, broken.
55	78	QUARTZITE - Broken, weathered, microcrystalline.
78	83	SAND - Coarse grained with pea-sized gravel layers (30%), yellow-brown. Sand does not seem well consolidated. ~~Sand is~~ quartzite fragments that appear to be fault gouge material.
83	115	QUARTZITE - Broken, microcrystalline, dark gray to black. Making a very small amount of water - less than 1/2 gpm. At 83 to 110 feet - fragment size is 1/2-inch or less. At 110 to 115 feet - fragment size up to 1-1/2-inches. Returns are not steady.
115	150	QUARTZITE - Broken, microcrystalline, dark gray to black (80%), reddish stained to tan color (20%). Fragment size up to 2 inches. At 125 feet, driller estimates 1-1/2 to 2 gpm.

HYDROMETRICS

TEST HOLE LOG

Helena, Mt.

State: MONTANA County: Silver Bow Project: Beal Hole Name or Number: SBB-87-07

Legal Location: T 3N R 10W Sec. 31 Tract DDA Descriptive Location: Minnesota Gulch side of Beal Ridge.

Recorded by: Blumer Date Hole Started: 10/12/87 Date Hole Completed: 10/13/87 Driller: Dan O'Keefe Drilling Company: O'Keefe Drilling

Drill Method: Rotary Drilling Fluids Used: Air Pilot Hole Diameter: 7-7/8 inch Reamed Hole Diameter: not reamed

Total Depth Drilled: 85 feet Total Depth Reamed: N/A Total Depth Cased Below G.S.: 38 feet Diameter and Type of Casing: 4-inch I.D. PVC

Weight or Gage of Casing: 40 PSI Interval Perforated or Screened Below G.S.: 18 to 38 feet Target Aquifer: Colluvium Packer Type and Depth Below G.S.: Neoprene at 14 feet

	YES	NO
Well Developed?		X
Well Test Pumped?		X
Water Samples Taken?		X
Material Samples Taken?	X	
E - Logs?		X

Method Perforated or Screened:

- ___ No casing in hole.
- ___ Open bottom only.
- ___ Slotted with Mill's Knife.
- ___ Slotted with a torch.
- ___ Screened by pulling casing.
- Y Saw cut
- ___ Other (specify)

Static Water Level: 15.5 feet Date: 10/14/87

Measuring Point Description/Elevation: Top of casing MP Height Above (+) or Below G.S.: 1.3 feet

Well Annulus Completion Description: PVC saw cut 3 rings on 3 ft. center. Surface seal: 1/4 bucket of volclay pellets and 30 gallons of bentonite slurry on top of packer. Backfilled to surface.
6-inch I.D. steel casing set to 5 feet.

From	To	DRILLING LOG Geological, Drilling, and Water Conditions and Sampling
0	5	BOULDERS - Up to .5 feet in diameter, matrix of silt - slightly clayey.
5	25	SAND - Yellow color, unsorted - some quartzite fragments 1-inch to 4-inches. Large Quartzite boulders to 6-inches in diameter, light green. Large, hard quartzite boulder at 15 to 18 feet.
25	30	QUARTZITE - Weathered bedrock ?, gritty, clayey. Light gray fragments. Wet - balls up fragments with clay. (Wet zone making a little water 0.1 gpm at 30 feet).
30	65	SAND - unsorted - clayey - sand balls up with clay. Sealed off upper water flow - Quartzite and weathered granite 1/2-inch fragments - scattered through sand zone (fault zone?).
65	70	QUARTZITE - Weathered fragments, dark gray.
70	85	SAND and PEA GRAVELS - unsorted particle size - clayey and silty (fault zone ?).
		At total depth, making less than 1/2 gpm when blown for 5 minutes with air compressor from drill. Caving zone at 40 feet.

Wells located to the southwest of the Pad

Well DW-3

Well No. OW95-4

Project Pegasus Gold

Location Beall Mt.

Engineer

Installed By O'Keefe Drilling

Date 10/17/95

Method of Installation Air Rotary, casing installed using Tubex bit to 160', 5½" hammer bit 160'-300'.

LOG OF BORING AND WELL

BORING

Depth In ft.	Description	H. Nu Reading
0		
	Gravels	
50	Gray Rock	
60	Red Rock	
100	Gray	
120	Gray - moisture	
130	Reddish Brown clay	
170	Gravels	
200	Limestone	
220		
	Gray Rock	
300'		

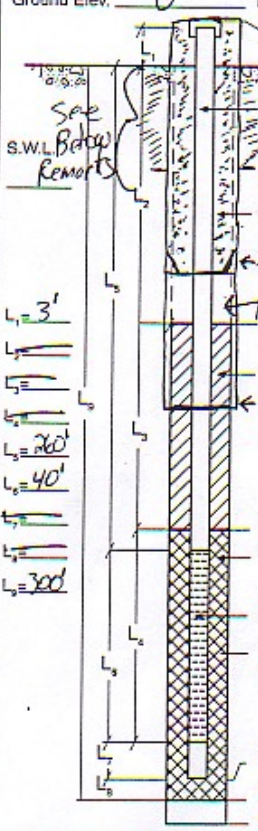
Materials used to construct well:
3 bags - 100 mesh sand
20 bags - concrete
1 bag - aqua-gel
1 - formation packer
12 bags - granular Bentonite
260' - riser
40' - screen

OBSERVATION WELL INFORMATION

Type of WELL Observation Well

Ground Elev. 0'

Top of Riser Elev. +3'



See Below Remarks

S.W.L.

L_1 = 3'
L_2 =
L_3 =
L_4 =
L_5 = 260'
L_6 = 40'
L_7 =
L_8 =
L_9 = 300'

Vented Cap

~~L.D. of Riser Pipe~~

Type of Pipe 4" flush joint

depth of grout 75'

Type of Backfill Around Riser Granular Bentonite +3-110'

formation packer - 110'

perforated 120'-140'

~~Top of Seal Elev.~~

~~Type of Seal Material~~

casing - 160'

~~Top of Filter Elev.~~

Type of Filter Material none

Size of Openings -0.02

~~Diameter of Screened Tip~~

Bottom of Well Elev. 300'

Bottom of Boring Elev. 300'

Diameter of Boring 6"-5½"

Remarks Initial Boring 0-160' casing 160'-200' open hole. Backfilled to 80' with pea-gravel, 75'-80' with 100 mesh ~~screen~~ sand, 20'-75' with concrete grout. upper casing perforated 4 rows 20'-70', 8 rows 75'-80'. Redrilled with 6" cone 0-160', 160'-300' with 5½" hammer

L-1 Flush MT/Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Rat Hole
L-9 Total Depth

Prepared by

Well DW-4

Well No. OW95-4

Project Pegasus Gold

Location Ball Mt.

Engineer

Installed By O'Keefe Drilling

Date 10/17/95

Method of Installation Air Rotary, casing installed using Tubex bit to 160', 5½" hammer bit 160'-300'.

LOG OF BORING AND WELL

BORING

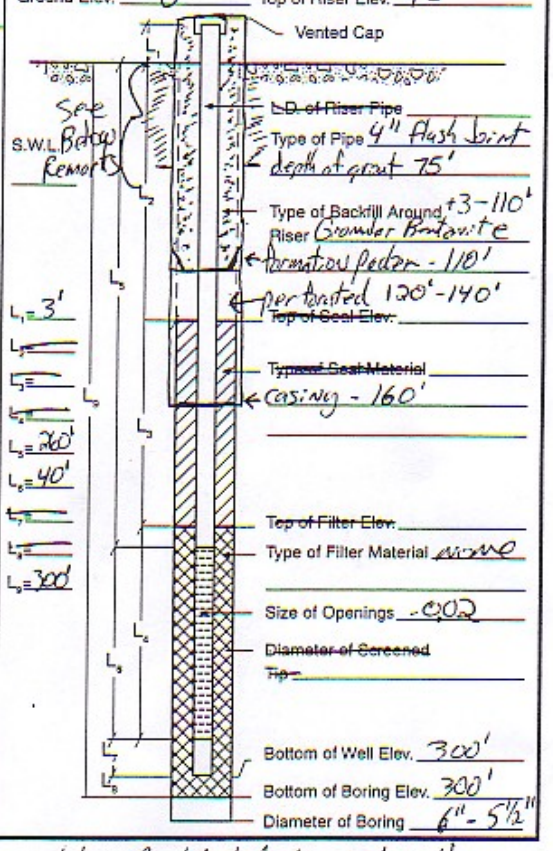
Depth in ft.	Description	H. Nu Reading
0		
	Gravels	
50	Gray Rock	
60	Red Rock	
100	Gray	
120	Gray - moisture	
130	Reddish Brown clay	
170	Gravels	
200	Limestone	
220		
	Gray Rock	
300'		
	materials used to construct well:	
	3 bags - 100 mesh sand	
	20 bags - concrete	
	1 bag - aqua-gel	
	1 - formation pellets	
	12 bags - granular Bentonite	
	260' - riser	
	40' - screen	

OBSERVATION WELL INFORMATION

Type of WELL Observation Well

Ground Elev. 0'

Top of Riser Elev. +3'



Remarks Initial Boring 0-160' casing 160'-300' open hole. Backfilled to 80' with pea-gravel, 75'-80' with 100 mesh sand, 20'-75' with concrete grout. Inner casing perforated 4 rows 20'-70', 3 rows 75'-80'. Redrilled with 6" core 0-160', 160'-300' with 5½" hammer

L-1 Flush Mt./Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Pot Hole
L-9 Total Depth

Prepared by

Well DW-5

Well No. OW45 - 3

Project Pegasus Gold

Location Beall MT

Engineer

Installed By O'Keefe Drilling

Date 10/18/95

Method of Installation Air Rotary, Casing installed using Tubex bit to 150', 5 1/2" hammer 150' - 300'.

LOG OF BORING AND WELL

BORING

Depth In ft.	Description	H. Nu Reading
0	Gravels	
20		
	Brown Gravels	
100	Brown Gravels	
130	Big Gravels, water	
140	Hard Gray Rock	
170	soft Clay	
200	Hard Red Clay	
230	Pea gravel & Clay	
	Gray Rock	
300		
	Materials used to construct well	
	3 bags - 100 mesh sand	
	18 bags - concrete	
	1 bag - aquagel	
	1 - formation packer	
	12 bags - granular Bentonite	
	260' - riser	
	40' - screen	

OBSERVATION WELL INFORMATION

Type of WELL Observation Well

Ground Elev. 0

Top of Riser Elev. +3'

Vented Cap

L.D. of Riser Pipe

Type of Pipe 4" flush joint

depth of grout - 75'

S.W.L. See Remarks Below

Type of Backfill Around Riser +3'-115' Granular Bentonite

formation packer 115'

perforated 120'-140'

Top of Seal Elev.

Type of Seal Material

casing - 150'

L_1 = 3'

L_2 =

L_3 =

L_4 =

L_5 = 260'

L_6 = 40'

L_7 =

L_8 =

L_9 = 300'

Top of Filter Elev.

Type of Filter Material none

Size of Openings .002

Diameter of Screened Tip

Bottom of Well Elev. 300'

Bottom of Boring Elev. 300'

Diameter of Boring 6" - 5 1/2"

Remarks Initial Boring 0-150' casing, 150'-300' open hole, perforated 20'-70' 4 rows, 75'-80' 8 rows. Backfilled to 80' with ~~100 mesh sand~~ pea gravel, 75'-80' with 100 mesh sand, 20'-75' with concrete grout. Redrilled with 6" cone 0-150', 150'-300' 5 1/2" hammer.

L-1 Flush MT/Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Rat Hole
L-9 Total Depth

Prepared by

Well DW-6

Well No. DW-6

Project Pegasus Gold

Location Beall Mt.

Engineer

Installed By O'Keefe Drilling

Date 10/10/95

Method of Installation Air Rotary, casing installed using Tubex bit to 140', 5½" hammer bit 140'-220'.

LOG OF BORING AND WELL

BORING

Depth in ft.	Description	H. Nu Reading
0		
	Gravels	
60	Red Rock	
80		
100	Gravels	
120	Red Rock	
135	Hard Rock	
140		
	Hard Rock	
200		
220		
	materials used:	
	3 bags - 100 mesh sand	
	20 bags - concrete	
	1 bag - gauge	
	1 ea - formation packer	
	12 bags - gran. bentonite	
	180' - riser	
	40' - screen	

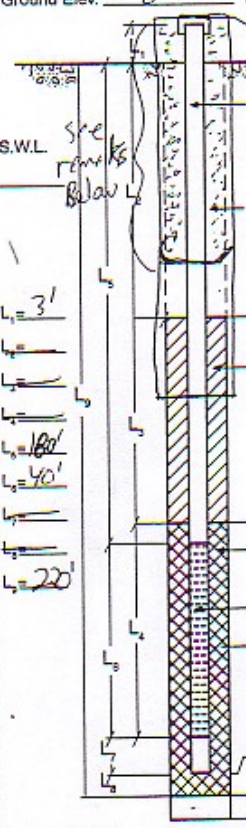
OBSERVATION WELL INFORMATION

Type of WELL Dewatering Well

Ground Elev. 0

Top of Riser Elev. +3'

S.W.L. See remarks below



~~L.D. of Riser Pipe~~

Type of Pipe 4" flush joint depth of grout 75'

Type of Backfill Around Riser +3-50' gran. bentonite formation packer -90' perforated 100'-120'

~~Top of Seal Elev.~~

~~Type of Seal Material~~ casing 140'

~~Top of Filter Elev.~~

Type of Filter Material none

Size of Openings .02

~~Diameter of Screened Tip~~

Bottom of Well Elev. 220'

Bottom of Boring Elev. 220'

Diameter of Boring 6"-5½"

L_1 = 3'
L_2 =
L_3 =
L_4 =
L_5 = 180'
L_6 = 40'
L_7 =
L_8 =
L_9 = 220'

Remarks Initial boring 0-140' casing, Backfilled to 80' with pea gravel, 75'-80' with 100 mesh sand, 20'-75' with concrete grout. Upper casing perforated 4 rows 20'-70', 8 rows 75'-80'. Redrilled with 6" core 0-140', 140'-220' with 5½" hammer.

L-1 Flush MT/Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Rat Hole
L-9 Total Depth

Prepared by

Well DW-08

Well No. DW95-2

Project Pegasus Gold

Location Beall MT.

Engineer

Installed By O'Keefe Drilling

Date 11/8/95

Method of Installation Air Rotary, casing installed using Tubex bit to 160', 5½" hammer bit 160-300'

LOG OF BORING AND WELL

BORING

Depth in ft.	Description	H. Nu Reading
0	Gravels	
40	Red Rock	
80	Gravels	
100	Red	
110	mixed	
120	Gray Rock	
160	Red Rock	
170		
200	Gray Rock (thick)	
300		

Materials used:
3 bags - 100 mesh sand
20 bags - Concrete
1 bag - quick seal
1 ea - formation packer
12 bags - granular Bentonite
260' - riser
40' - screen

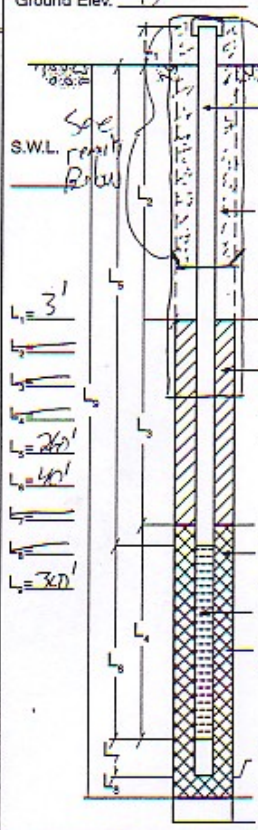
OBSERVATION WELL INFORMATION

Type of WELL Dewatering Well

Ground Elev. 0'

Top of Riser Elev. +3'

S.W.L. See remark below



L_1 = 3'
L_2 =
L_3 =
L_4 =
L_5 = 260'
L_6 = 40'
L_7 =
L_8 =
L_9 = 300'

Vented Cap

~~L.D. of Riser Pipe~~

Type of Pipe 4" flush joint depth of grout

Type of Backfill Around Riser granular Bentonite formation packer 90' ~~perfs~~ no perfs.

~~Top of Seal Elev.~~

~~Type of Seal Material~~ Casing 160'

~~Top of Filter Elev.~~

Type of Filter Material none

~~Size of Openings~~ .02

~~Diameter of Screened Tip~~

Bottom of Well Elev. 300'

Bottom of Boring Elev. 300'

Diameter of Boring 6"-5½"

Remarks Initial Boring 0-160' casing ~~[illegible]~~ Backfilled to 80' with pea-gravel 75'-80' with 100 mesh sand, 20'-75' with concrete grout. upper casing perforated 4 rows 20'-70', 8 rows 75'-80'. Redrilled with 6" core 0-160'; 160'-300' with 5½" hammer.

L-1 Flush MT/Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Fizz Hole
L-9 Total Depth

Prepared by

Well DW-09

Well No. DW-09-1

Project Pegasus Gold Location Beall Mt.

Engineer Installed By O'Keefe Drilling Date 10/25

Method of Installation Air Rotary, casing installed using Tubex bit to 220', 5½" hammer bit 220'-300'

LOG OF BORING AND WELL

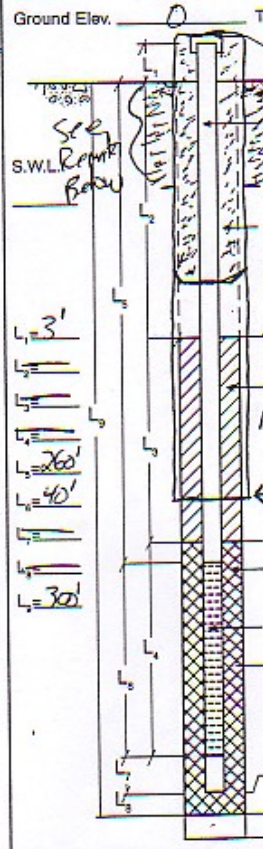
BORING

Depth in ft.	Description	H. Nu Reading
0	Gravels	
40	Broken up	
80	Hard Boulder	
100	Red Rock & Clay	
200	Water & Hard Gray	
220	Hard Rock (Gray) & H_2O	
300	Materials used to construct well: 3 bags - 100 mesh sand; 20 bags - concrete; 1 bag - aqua-gel; 1 - formation packer; 10 bags - granular Bentonite; 260' - riser; 40' - screen	

OBSERVATION WELL INFORMATION

Type of WELL Dewatering well

Ground Elev. 0 Top of Riser Elev. +3'



S.W.L.

~~L.D. of Riser Pipe~~

Type of Pipe 4" flush joint depth of grout 75'

Type of Backfill Around Riser Granular Bentonite +3-90' formation packer 90'

~~Top of Seal Elev.~~

~~Type of Seal Material~~ perforated 100'-140'

← casing - 220'

~~Top of Filter Elev.~~

Type of Filter Material none

Size of Openings .002

~~Diameter of Screened Tip~~

Bottom of Well Elev. 300'

Bottom of Boring Elev. 300'

Diameter of Boring 6"-5½"

L_1 = 3'
L_2 =
L_3 =
L_4 =
L_5 = 260'
L_6 = 40'
L_7 =
L_8 =
L_9 = 300'

Remarks Initial Boring 0-220' casing, 220'-300' open hole, Backfilled to 80' with pea gravel, 75'-80' with 100 mesh sand, 20-75' with concrete grout. upper casing perforated 4 rows 20'-70', 8 rows 75'-80', Redrilled with 6" cone 0'-220', 220-300 with 5½" hammer bit.

L-1 Flush MT/Well Protector
L-2 Surface to Bentonite Seal
L-3 Bentonite Seal
L-4 Filter Pack
L-5 Surface to Top of Screen
L-6 Screen
L-7 Sump
L-8 Rat Hole
L-9 Total Depth

Prepared by

APPENDIX 3: RAW WATER QUALITY DATA

Sampling Station					PHYSICAL PARAMETERS					
					FIELD				LAB	
	DATE	TIME	SWL	FLOW	pH	SC	TEMP	Eh	pH	SC
	(MM/DD/YR)	(HRS)	(FT)	(GPM)		(µs/cm)	(C)	(mv)		(µs/cm)
South Sump 1	**M: 999030**									
South Sump 1	05/31/05	17:00								
South Sump 1	5/24/2006	13:01	66.91	Bailed	7.77	5,000	9.97	425		
South Sump 1	6/27/2006	13:06	62.18	4.5	8.69	5,070	10.33	386	7.93	5,100
South Sump 1	8/8/2006	11:00	60.45	Bailed	7.87	4,730	10.7	360		
Spring 10A	**M:**									
Spring 10A	6/18/2003			10	7.3	814				
Spring 10A	7/10/2003				6.6	1,645	11.7	319		
Spring 10A	7/10/2003				6.32		10.8	344	6.95	1356
Spring 10A	9/28/2004			10.6	7.03					
Spring 10A	6/27/2006	14:10		20	7.33	1,079	8.92	404		
Spring 10A										
Acute Aquatic Life Standards Chronic Aquatic Life Standards Human Health Standards										

* Gray shaded row indicates total recoverable analysis.

Sampling Station	DATE	TIME	CHEMICAL PARAMETERS							
			HARDNESS	ALKALINITY	PERCENT MEQ/L					
			(mg/L)	(mg/L)	Ca	Mg	Na	HCO_3	CO_3	SO_4
South Sump 1	05/31/05	17:00								
South Sump 1	5/24/2006	13:01								
South Sump 1	6/27/2006	13:06	1,828	456.3	50.3	1.6	47.3	12.1	0.0	68.2
South Sump 1	8/8/2006	11:00								
Spring 10A	6/18/2003									
Spring 10A	7/10/2003		615.83		90.8					
Spring 10A	7/10/2003		600.47	165.43	90.6	6.2	2.5	24.4	0.0	74.2
Spring 10A	9/28/2004									
Spring 10A	6/27/2006	14:10								
Spring 10A										
Acute Aquatic Life Standards										
Chronic Aquatic Life Standards										
Human Health Standards										

* Gray shaded row indicates total recoverable analysis.

Sampling Station		MAJOR DISSOLVED CATIONS AND ANIONS														
	DATE	Ca	Mg	Na	K	Fe	Mn	SiO_2	HCO_3	CO_3	Cl	SO_4	NO_3-N	NO_2-N	F	CN-
	(MM/DD/YR)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)	(mg/L)
South Sump 1	**M: 999030**															
South Sump 1	05/31/05											2540	114	42.7		7.3
South Sump 1	5/24/2006															
South Sump 1	6/27/2006	710	13.5	767	15.9	0.995	0.158	14.4	556.3	0	162	2,463	143	42.4	<2.5	
Spring 10A	**M:**															
Spring 10A	6/18/2003					0.01						416	2.9			
Spring 10A	7/10/2003	231	9.48	6.96	2.56	0.029	0.006									
Spring 10A	7/10/2003	225	9.39	7.13	2.45	0.012	0.004	8.2	201.7	0	<2.5	482	2.48	<.25	<.25	<.005
Spring 10A	9/28/2004											686	2.11			
Spring 10A	6/27/2006															
Spring 10A																
Acute Aquatic Life Standards																0.02
Chronic Aquatic Life Standards																0.005
Human Health Standards												250 (SDWS)	10 (MCL)	1 (MCL)	4 (MCL)	0.2 (MCL)

- Gray shaded row indicates total recoverable analysis.
- Blue shaded area indicates exceedance of one or more water-quality standard.

Sampling Station		DISSOLVED METAL CONCENTRATION																		
	DATE	Al	Ag	As	B	Ba	Be	Cd	Co	Cr	Cu	Hg	Li	Mo	Ni	Pb	Se	Sr	U	Zn
	(MM/DD/YR)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
South Sump 1	**M: 999030**																			
South Sump 1	05/31/05							0.4			93						317			10
South Sump 1	5/24/2006																			
South Sump 1	6/27/2006	<100	<10	114	<300	<20	<20	<10	1,541	<20	83.2	NR	<10	107	81.8	<20	326	4,868	30	<20
Spring 10A	**M:**																			
Spring 10A	6/18/2003			3							1						173			
Spring 10A	7/10/2003			8.69			<2	<1	<2	<2	3.52		1.58	<10	5.42	<2	234	956	7.68	66.8
Spring 10A	7/10/2003	<30	<1	8.66	<30	12.9	<2	<1	<2	<2	2.17		3.23	<10	3.64	<2	229	967	7.51	32.6
Spring 10A	9/28/2004																275			
Spring 10A	6/27/2006																			
Spring 10A																				
Acute Aquatic Life Standards		750	37	340				19	?	1773	50			?	1515	280	20	4000		379
Chronic Aquatic Life Standards		87		150				6	?	231	29			?	168	11	5	4000		382
Human Health Standards				10			4	5			1300				100	15	50		30	

- Gray shaded row indicates total recoverable analysis.
- Blue shaded area indicates exceedance of one or more water-quality standard.

APPENDIX 4: CALCULATION OF ADSORPTION RATES (K_{ads})

K_{ADS} = [Analyte on resin] / [Analyte in solution]

Where, [Analyte in solution] = [analyte on resin] x (volume of solution/volume of media)

SULFATE							
Media	[SO42-] in soln	Bulk Density of media	Mass of Media	Volume of media	Volume of Solution	[SO42-] on resin	Kads
	mg/L	g/mL	g	ml	mL	mg/L	
BM Leach Pad	2630						
A-500	1265	0.646	20.02	30.99	400	17618	13.9
A-500	1310	0.646	20.02	30.99	400	17037	13.0
XY	2355	0.595	20.02	33.65	400	3269	1.4
Arsenx	2545	0.655	20.07	30.64	400	1110	0.4
Arsenx	3160	0.655	20.07	30.64	400	-6919	-2.2
S-930	1475	0.622	20.01	32.17	400	14361	9.7
S-930 dup	1390	0.622	20.01	32.17	400	15418	11.1
C-106	2595	0.667	20.07	30.09	400	465	0.2
Wood	5360	0.398	29.87	75.05	400	-14550	-2.7

NITRATE							
Media	[NO3-] in soln	Bulk Density of media	Mass of Media	Volume of media	Volume of Solution	[SO42-] on resin	Kads
	mg/L	g/mL	g	ml	mL	mg/L	
BM Leach Pad	88						
A-500	59.5	0.646	20.02	30.99	400	368	6.2
XY	6.2	0.595	20.02	33.65	400	972	156.8
Arsenx	24.3	0.655	20.07	30.64	400	832	34.2
S-930	11	0.622	20.01	32.17	400	957	87.0
S-930 dup	10.1	0.622	20.01	32.17	400	969	95.9
C-106	63.5	0.667	20.07	30.09	400	326	5.1
Wood	89.5	0.398	29.87	75.05	400	-8	-0.1

SELENIUM							
Media	[Se] in soln	Bulk Density of media	Mass of Media	Volume of media	Volume of Solution	[Se] on resin	Kads
	ug/L	g/mL	g	ml	mL	ug/L	
BM Leach Pad	308						
A-500	206	0.646	20.02	30.99	400	1317	6.4
XY	88.6	0.595	20.02	33.65	400	2608	29.4
Arsenx	61.1	0.655	20.07	30.64	400	3223	52.8
S-930		0.622	20.01	32.17	400	3830	
C-106		0.667	20.07	30.09	400	4094	
Wood	152	0.398	29.87	75.05	400	831	5.5

COPPER							
Media	[Cu] in soln	Bulk Density of media	Mass of Media	Volume of media	Volume of Solution	[Cu] on resin	Kads
	ug/L	g/mL	g	ml	mL	ug/L	
BM Leach Pad	178						
A-500	37.8	0.646	20.02	30.99	400	1810	47.9
XY	325	0.595	20.02	33.65	400	-1748	-5.4
Arsenx	20	0.655	20.07	30.64	400	2063	103.1
S-930	103	0.622	20.01	32.17	400	933	
C-106	53	0.667	20.07	30.09	400	1662	
Wood	82.8	0.398	29.87	75.05	400	507	6.1

ARSENIC							
Media	[As] in soln	Bulk Density of media	Mass of Media	Volume of media	Volume of Solution	[As] on resin	Kads
	ug/L	g/mL	g	ml	mL	ug/L	
BM Leach Pad	100						
A-500	6.34	0.646	20.02	30.99	400	1209	190.7
XY	30	0.595	20.02	33.65	400	832	27.7
Arsenx	38.2	0.655	20.07	30.64	400	807	21.1
S-930		0.622	20.01	32.17	400	1243	
C-106		0.667	20.07	30.09	400	1329	
Wood	30	0.398	29.87	75.05	400	373	12.4