TETRA TECH

Technical Memorandum

To:	Mary Beth Marks	From:	Kirk Miller, Jim Maus, Scott Jungwirth
Company:	US Forest Service	Date:	March 20, 2015
Project #:	114-560368A		
Re:	Yearly Operations Summary – 2014 Beal Year 7 RO Water Treatment Season		
CC:	Dale Reckley		

Tetra Tech is pleased to submit this *Yearly Operations Summary – 2014 Reverse Osmosis (RO) Water Treatment Season* for the Beal Mountain Mine located 16 miles west southwest of Butte, Montana, in Silver Bow County (**Figure 1, Appendix A**). This yearly report is required as a deliverable for Task 5 of the Beal Mountain Mine Year 7 Work Order, (contract #GS-10F-0268K/AG-0343-C-13-0001). Data reported includes water volumes treated through the RO Treatment System, heap leach solution level monitoring, and heap leach laboratory and field solution chemistry analytical results.

TOTAL LEACH PAD SOLUTION VOLUME TREATED BY RO

The RO System startup began on August 5, 2014. The system began treating water on Friday, August 9, 2014. At startup the total volume treated meter was 142,001,056 gallons, and at the end of the season on November 3, 2014, the meter reading was 156,713,472 gallons. The original contract had called for the RO System to treat 10.5 million gallons of water. The actual treatment volume for the 2014 season was 14,712,416 gallons.

The volume of treated water was monitored and recorded using the computer software data logger. The Year 7 final treated volume was approximately 831,384 gallons more than the previous year. The treatment volumes for years 2009 – 2014 are summarized in **Table 1**.

Table 1: Yearly Treatment Summary

Year	Total Days	Total Gallons Treated	Average Treatment Rate (gpd)
2009	119	25,377,606	213,257
2010	130	33,638,532	258,758
2011	147	32,136,432	218,615
2012	119	24,959,896	209,747
2013	79	13,881,032	175,709
2014	86	14,712,416	171,075

<u>Leach Pad Solution Levels</u>

Leach pad solution levels were measured in July 2014 (before treatment began), and the calculated solution volumes on the leach pad were as follows:

- July 8, 2014 Sump 1 depth to solution = 63.35 feet, which equates to 30.26 million

gallons
- July 3, 2014 Sump 3A depth to solution = 58.03 feet

Leach pad solution levels were measured on November 24, 2014, (3 weeks after treatment ended) and the calculated volumes of the leach pad were as follows:
- Sump 1 depth to solution = 77.4 feet, which corresponds to 8.19 million gallons
- Sump 3A depth to solution = 58.69 feet

The RO treatment system was shut down for the season on November 3, 2014. Therefore, any cone of influence within Sump 1 should have dissipated by the time of measurement on November 24, 2014.

Heap leach levels have been recorded manually or by pressure transducers located in Sump 1 and Sump 3A since 2003 as shown in **Figure 1**.

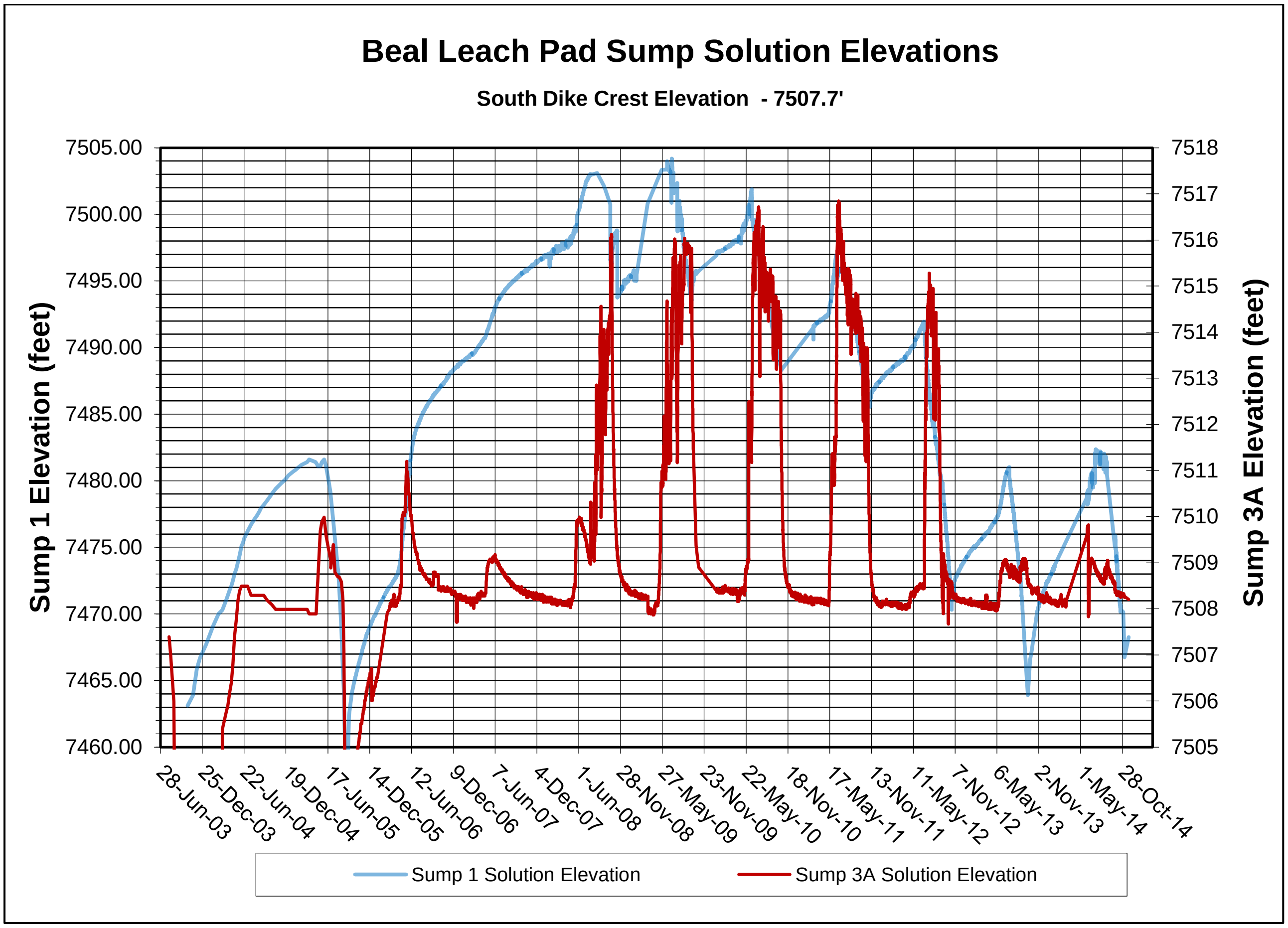

Figure 1: Heap Leach Elevations as Recorded Manually and by Pressure Transducers

Figure 2 presents solution elevations and calculated volumes using data from Sump 1.

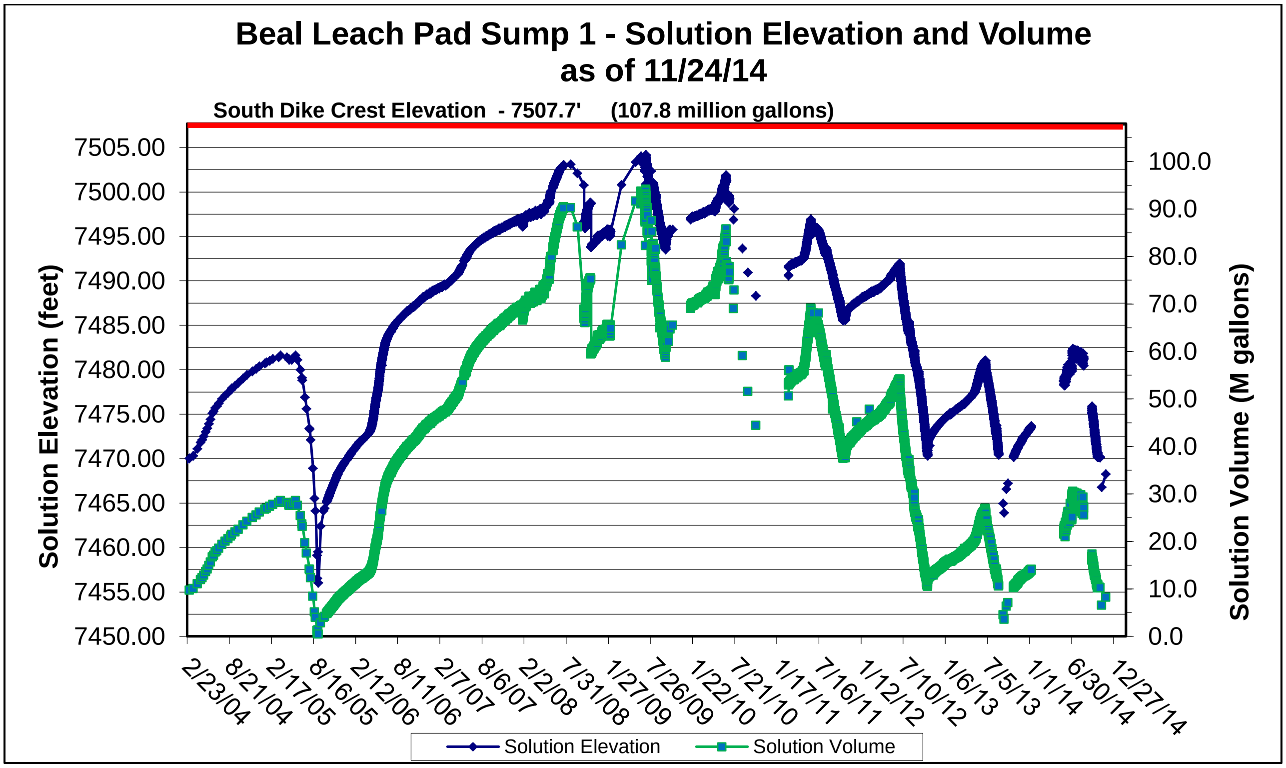

Figure 2: Solution Elevations and Calculated Volumes Using Data from Sump 1

Leach Pad Drain Down

Figure 2 exhibits a pattern of annual solution accumulation equal to an average of approximately 21 million gallons per year. Most of the annual increases have occurred during the spring runoff period (May through July). However, even during winter's "frozen" conditions the leach pad continues to accumulate solution volume. At this time it is unknown whether the accumulation observed during frozen conditions is due to external groundwater entering the leach pad, equilibration of solution from the elevated north pool to the lower south pool, drain-down of previously saturated material, or a combination of these factors.

Table 2 summarizes the leach pad winter accumulation (or drain-down) rate for historical data beginning in 2006. The leach pad solution accumulation rate decreased from the winter of 2010/2011 to the winters of 2011/2012 and 2012/2013, then increased for the winter of 2013/2014. The average accumulation rate on the leach pad from 2006 – 2014 is 30.9 gallons per minute (gpm). Additionally, the 2014 accumulation rate was calculated to be 32.5 gpm, which is 31% greater than the 2013 accumulation rate. Since the water treatment system discharges the reject water back into the leach pad via the Injection Well, a considerable amount of water is expected to accumulate back into the sump this winter. The exact time it takes for the reject water to return to the sump has not been determined. This accumulation should be seen much earlier than before since the reject discharge has been rerouted to the Injection Well (IW-1) rather than to Sump-3A, which is farther away from Sump-1 and would be expected to take a longer time to flow to Sump-1.

Table 2: Water Accumulation Rate on Leach Pad - Winter Period

Date	Total Volume Change (million gallons)	Days Elapsed	Gallons Per Minute
Jan 2006 – March 2006	+3.6	88	28.4
Dec 2006 – March 2007	+5.5	120	31.8
Dec 2007 – March 2008	+4.5	122	25.6
Dec 2008 – Feb 2009	+3.3	67	34.2
Oct 2009 – April 2010	+7.1	167	29.5
Oct 2010 – March 2011	+9.7	162	41.6
Dec 2011 – March 2012	+4.0	94	29.6
Nov 2012 – March 2013	+5.4	151	24.8
Nov 2013 – Jan 2014	+3.3	71	32.5
Average			30.9

Treatment System Daily Inspection Reports

Copies of the Daily Operation Logs for the 2014 treatment season are attached in **Appendix B**.

TREATEMENT SYSTEM CHEMISTRY RESULTS

Analysis of RO water was conducted using both field and laboratory analysis methods. Results of these programs are summarized below.

Treatment System Field Chemistry Results

Water chemistry was tested in the RO Plant laboratory during the 2014 treatment season using field meters and field test kits. Analyses were completed once a month rather than bi-weekly as indicated in the sampling and analysis plan due to an oversight by the operator. Samples were collected from four locations along the treatment flow path, which are referred to as Raw Water, After Filters, 1st Stage Permeate, and 2nd Stage Permeate. The results were recorded and used to analyze the system performance to implement any necessary adjustments to the treatment process. The four monitoring locations are arranged as follows: (1) the Raw Water monitoring point is located where the influent water enters the treatment building; (2) After Filters is collected after the influent water is filtered through the multi-media filters; (3) the treated water (i.e. permeate) is monitored after the 1st Stage and 2nd Stage of the RO. A summary of treatment system field parameters is presented in **Table 3**.

Table 3: 2014 RO Treatment System Summary of Field Parameters

	Raw Water	After Filters (Greensands)	1st Stage Permeate	2nd Stage Permeate
Temperature (°F)	53.2 – 57	53.0 – 60.0	53.4 - 64.2	53.0 - 64.4
Turbidity (NTU)	0.54 – 1.17	0.63 - 0.96	--	--
Conductivity (uS/cm2)	8,740 –	8,360 –	161.1 – 668	30.3 – 66.2
pH	7.69 - 9.18	8.05 - 8.29	--	8.68 - 10.11
Cyanide (mg/L)	0.034 - >0.264	--	0.027 - 0.037	0.016 - 0.029
Manganese (mg/L)	0.300 – 1.123	0.254 - 0.398	0 - 0.06	0.000 - 0.009
Nitrate (mg/L)	>5.5	--	--	0 – 2.2
Nitrite(mg/L)	>0.550	--	--	0.043 - 0.202
Ammonia (mg/L)	>3.34	--	1.06 – 1.75	0.37 – 1.42
Chlorine (mg/L) (pre-sodium)	--	0.08 - 0.78	--	--
Chlorine (mg/L) (post-sodium)	--	0.02 - 0.2	0.00 - 0.07	--

Treatment System Laboratory Chemistry Results

The 2012 Water Treatment Sampling and Analysis Plan (WTSAP) was reviewed and updated in 2013 according to current water treatment operations and the changing heap leach chemistry (Tetra Tech, 2013).

Task 5 of the Beal Mountain Mine Year 7 Proposal contains the sample schedule for monitoring the water treatment plant (Tetra Tech, 2014). The influent (raw water) and the effluent (2nd stage permeate) were sampled for lab analysis on a bi-weekly basis. These samples were tested for field parameters (Table 3 of 2013 WTSAP) and also taken to Energy Laboratory in Helena, Montana, for laboratory water chemistry analysis (Table 5 of 2013 WTSAP). Monthly sampling of the RO influent, effluent, and reject (2nd stage concentrate) water was also conducted, and samples were analyzed according to Table 6 of the 2013 WTSAP. Additionally, the 2013 WTSAP required that two sample sets associated with the discharge of treated water to a tributary of German Gulch be analyzed according to Table 7 of the 2013 WTSAP. The sample sets were collected from locations referred to as Direct Discharge – End of Rock (DD-ER) and surface water station (STA-3A). DD-ER is located south of the leach pad, northeast of the main pit highwall and just southwest of former Pump Station 5. This location is used for the direct discharge from the treatment system and is located at the south end of the riprap channel that was constructed to divert excess water away from the main pit highwall. The Year 7 Work Plan called for the addition of selenium to the parameter list for DD-ER. This change was not made to the proper table in the 2013 WTSAP; hence, these analyses were not conducted. STA-3A is located farther down German Gulch and southwest of the main Beal access gate and Pump Station 4. The locations of the two direct discharge stations are shown on **Figure 2** (**Appendix A**).

Graphical results of key parameters for influent, effluent, reject, and direct discharge samples are attached as **Figure 3** through **Figure 12**. The analytical results are summarized below.

<u>Cyanide (CN)</u>

During the 2014 season, raw water (influent) entered the treatment system with an average CN concentration of 5.6 milligrams per liter (mg/L) and a maximum of 7.5 mg/L during the October sampling event. The 2nd stage permeate (effluent) water only retained an average CN concentration of 0.025 mg/L when leaving the system, while the concentrate (reject) solution exited the RO system with an average CN concentration of 11.5 mg/L. The 2nd stage permeate water undergoes secondary treatment by aeration in the Fresh Water Pond to further reduce CN concentrations prior to being discharged. Cyanide levels observed at DD-ER and STA-3A were below the reporting limit of 0.005 mg/L for all samples. **Figure 3** shows the cyanide reduction for each sample collection date in 2014. **Figure 4** presents the total cyanide concentration in the influent, and **Figure 5** displays the total cyanide concentrations for the effluent. **Figure 6** shows the total cyanide concentrations in the reject.

Figure 7 displays the total cyanide concentration in DD-ER and STA-3A along with the MDEQ Aquatic Life Standards for cyanide.

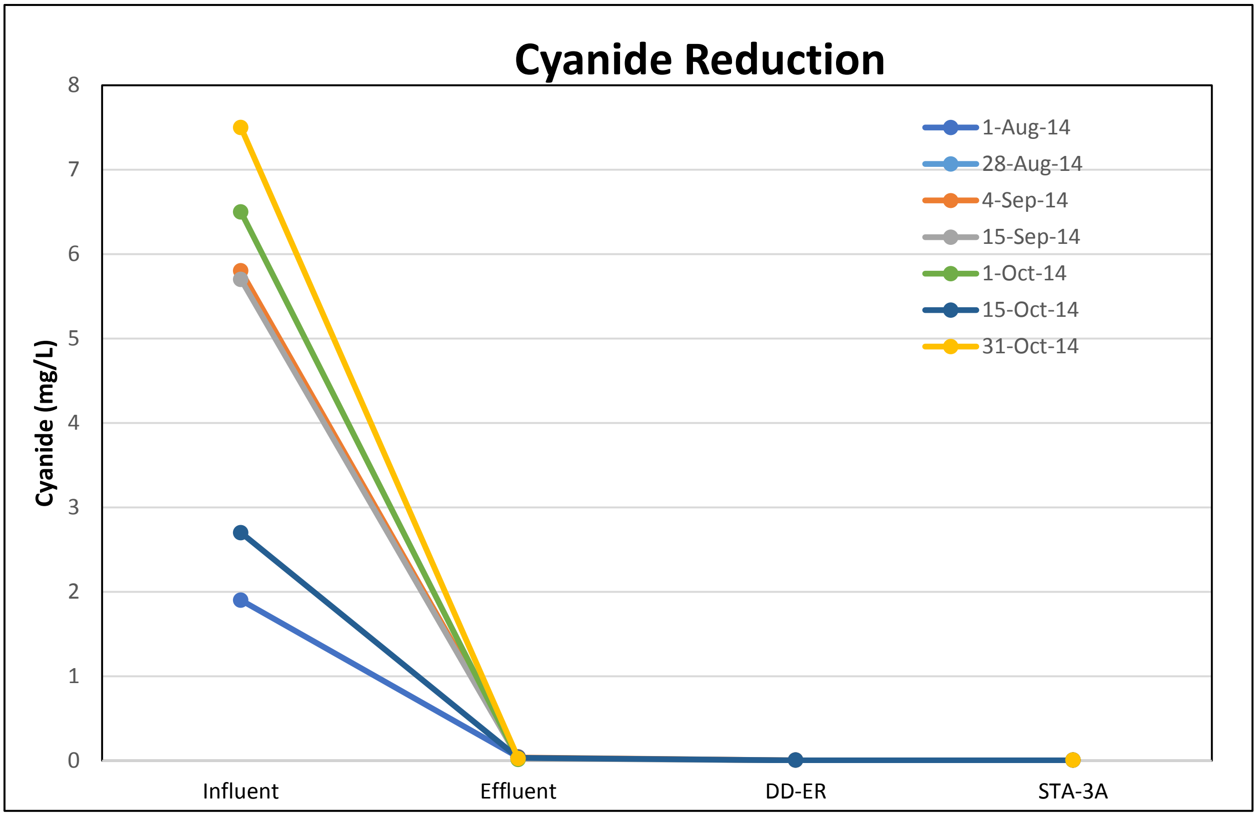

Figure 3: Cyanide Reduction through the Treatment Process

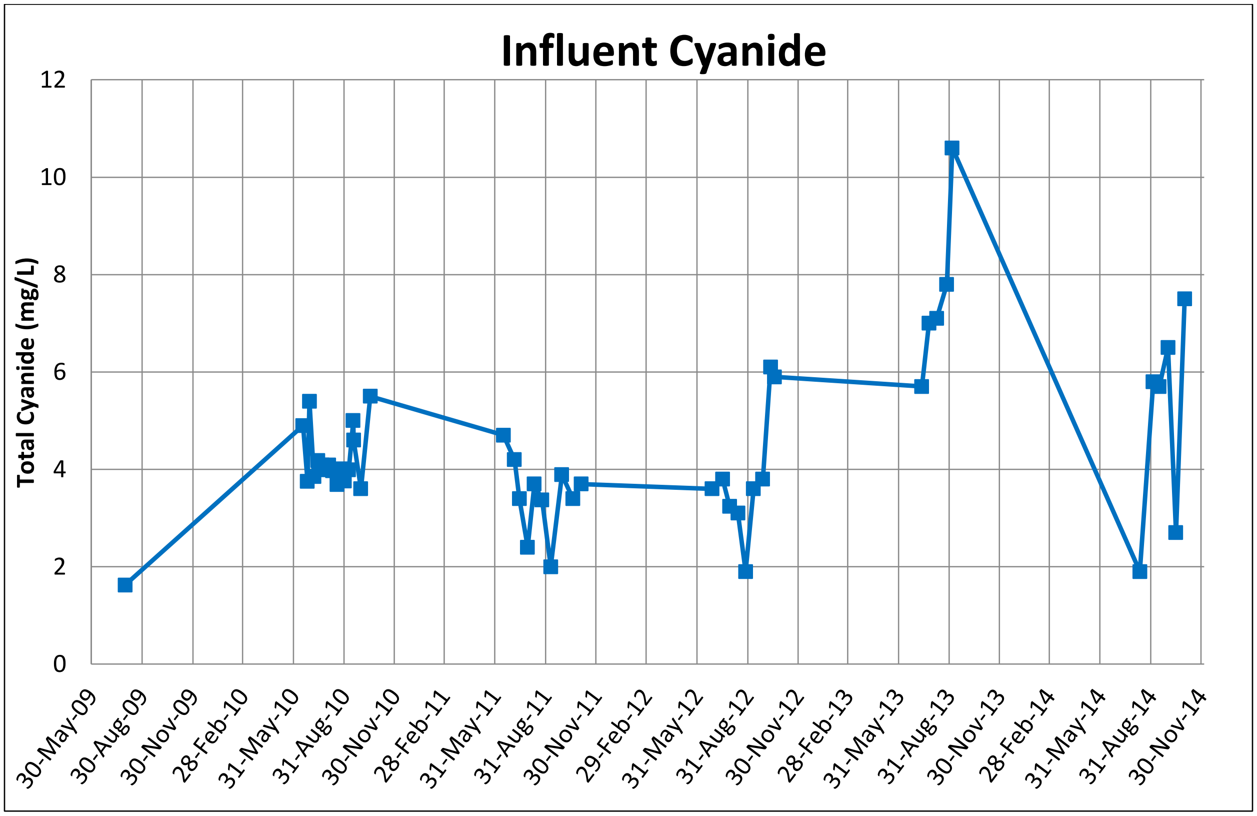

Figure 4: Total Cyanide (CN) in Influent

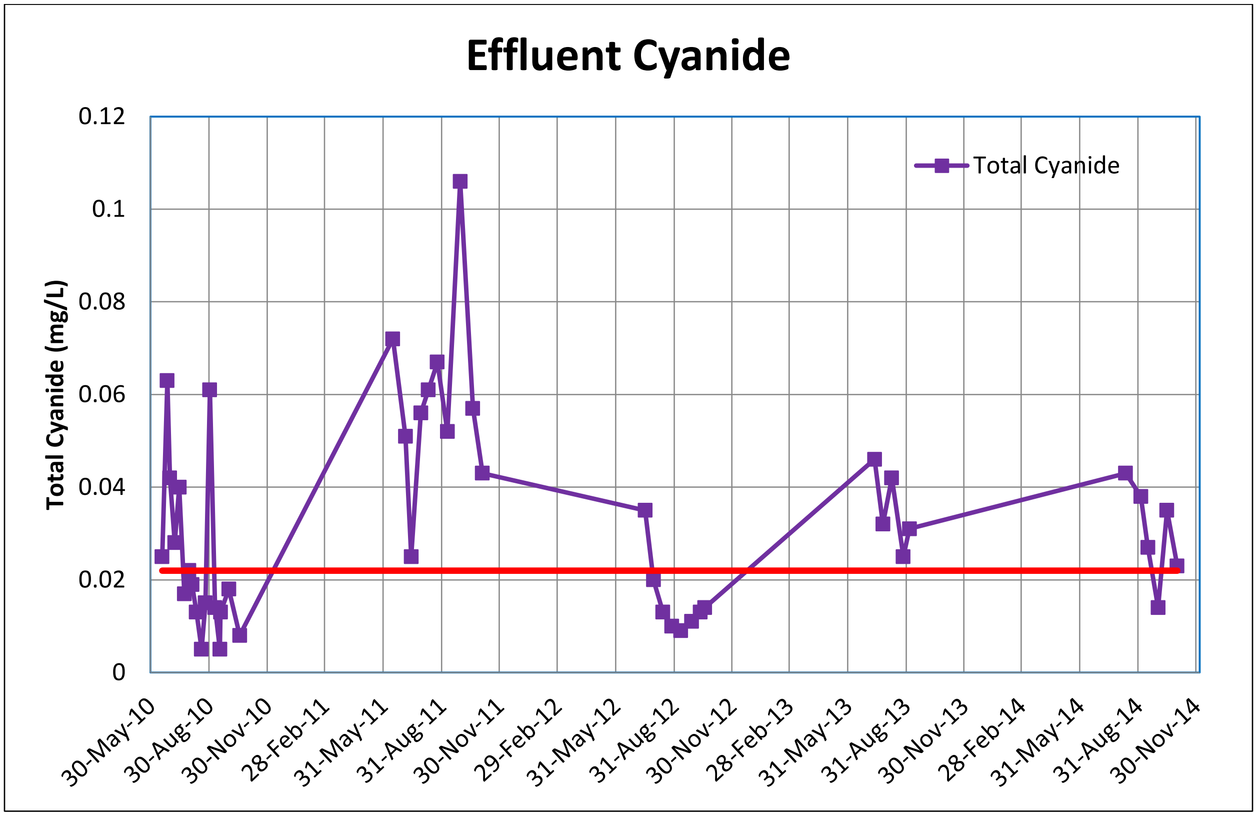

Figure 5: Total Cyanide (CN) in Effluent

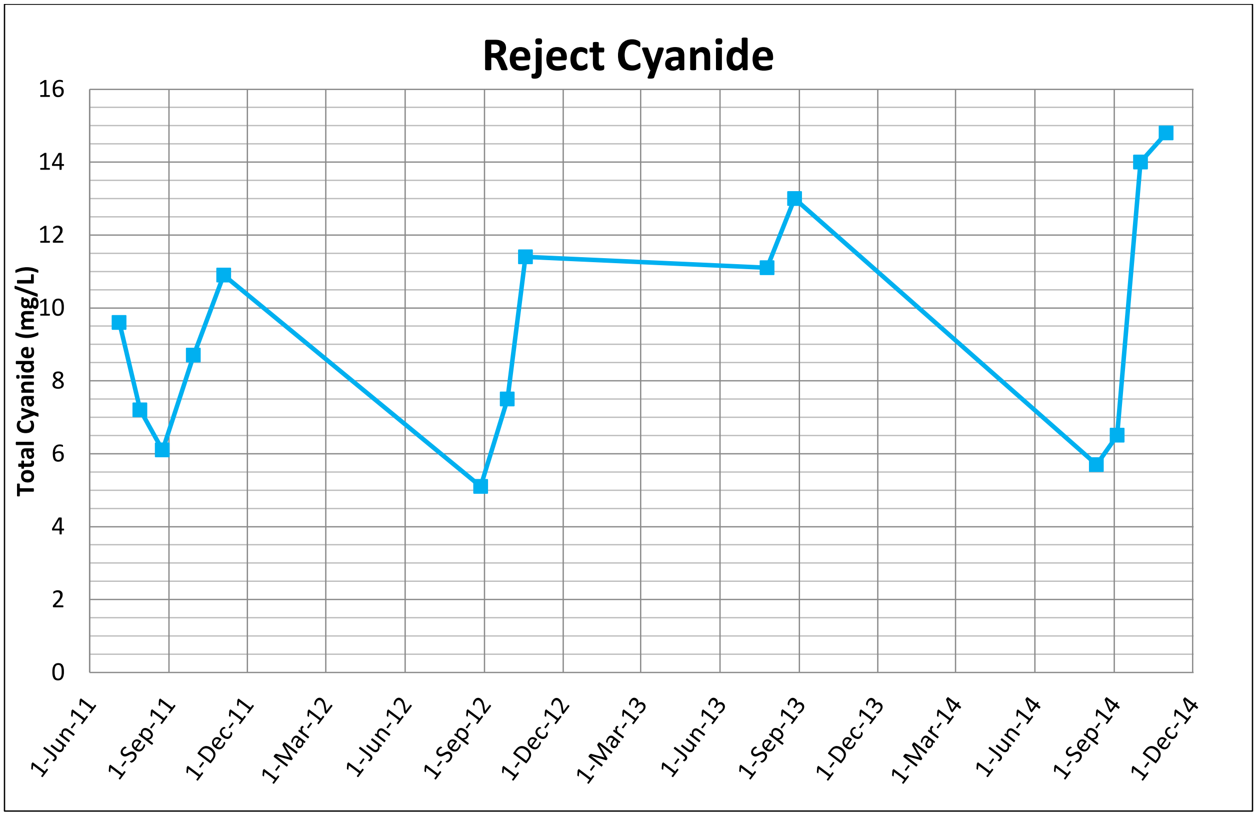

Figure 6: Total Cyanide (CN) in Reject

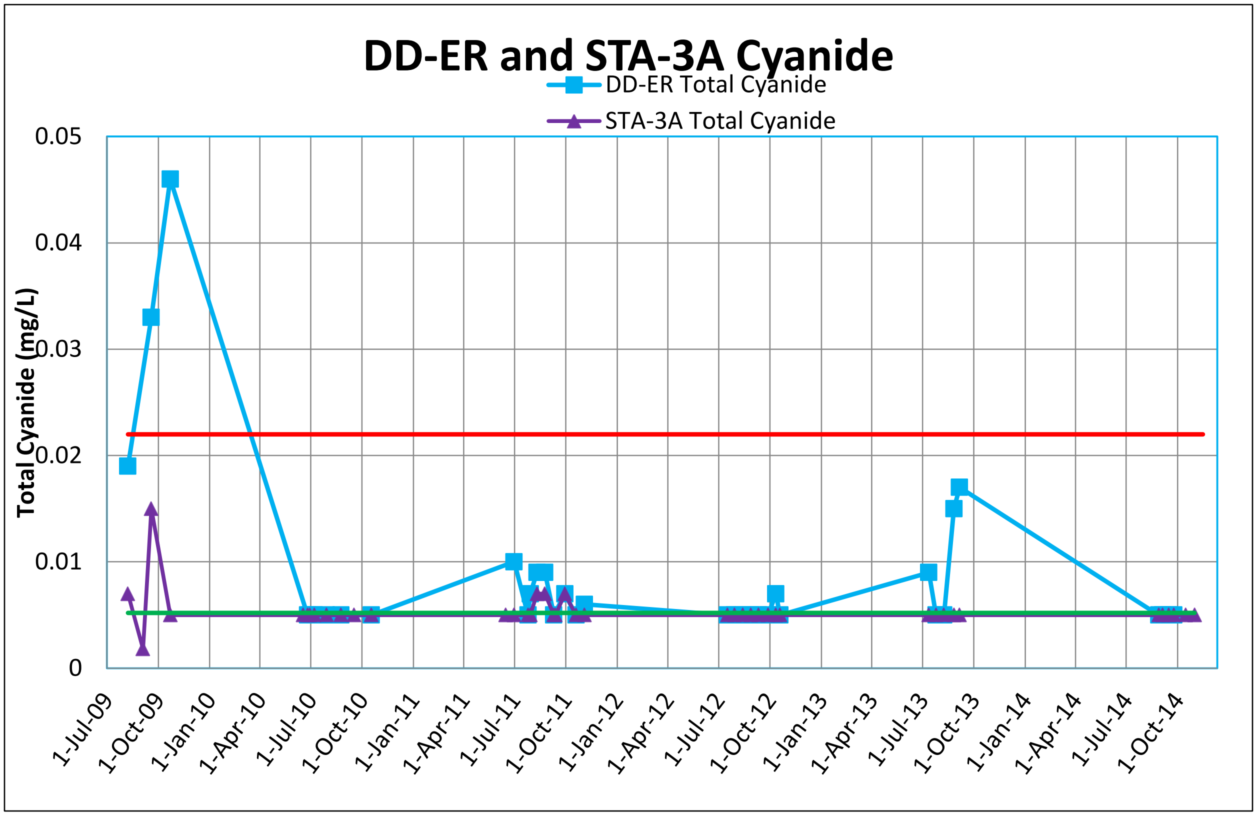

Figure 7: Total Cyanide (CN) in DD-ER and STA-3A

Ammonia

Influent ammonia concentrations began the treatment season around 14.0 mg/L and steadily increased to 25 mg/L throughout the 2014 season. Ammonia concentrations remained relatively consistent in the effluent (i.e., water exiting the RO system) through September and then increased in October to 2.3 mg/L, which is still well below the aquatic life chronic standard of 3.58 mg/L. However, this trend was not observed downstream at the monitoring station along German Gulch, STA-3A. The ammonia levels at STA-3A were below the method detection limit of 0.05 mg/L and well below the chronic aquatic life standard of 3.58 mg/L for all biweekly samples during 2014. The aquatic life standards for ammonia are determined by a formula provided by DEQ Circular 7 (i.e., State water quality standards) (MDEQ 2012), wherein temperature and pH of the receiving stream are used to calculate a site specific ammonia standard. This formula also varies depending upon whether salmonids are present in the receiving stream. For the purpose of comparison, it is assumed salmonids are present in German Gulch immediately downstream of STA-3A. A graphical summary of the ammonia laboratory results from the past few years for the various sampling locations are presented below in **Figure 8** and **Figure 9**.

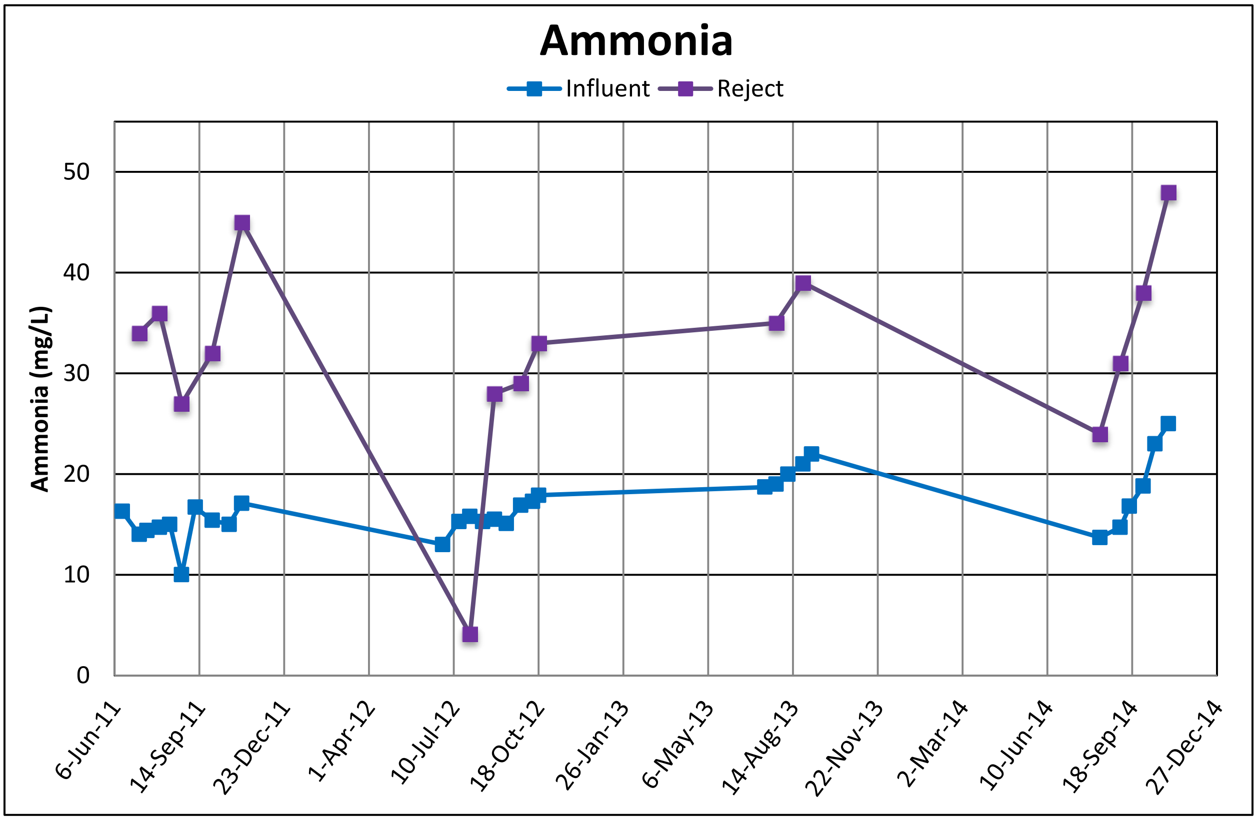

Figure 8: Ammonia Concentrations in Influent and Reject

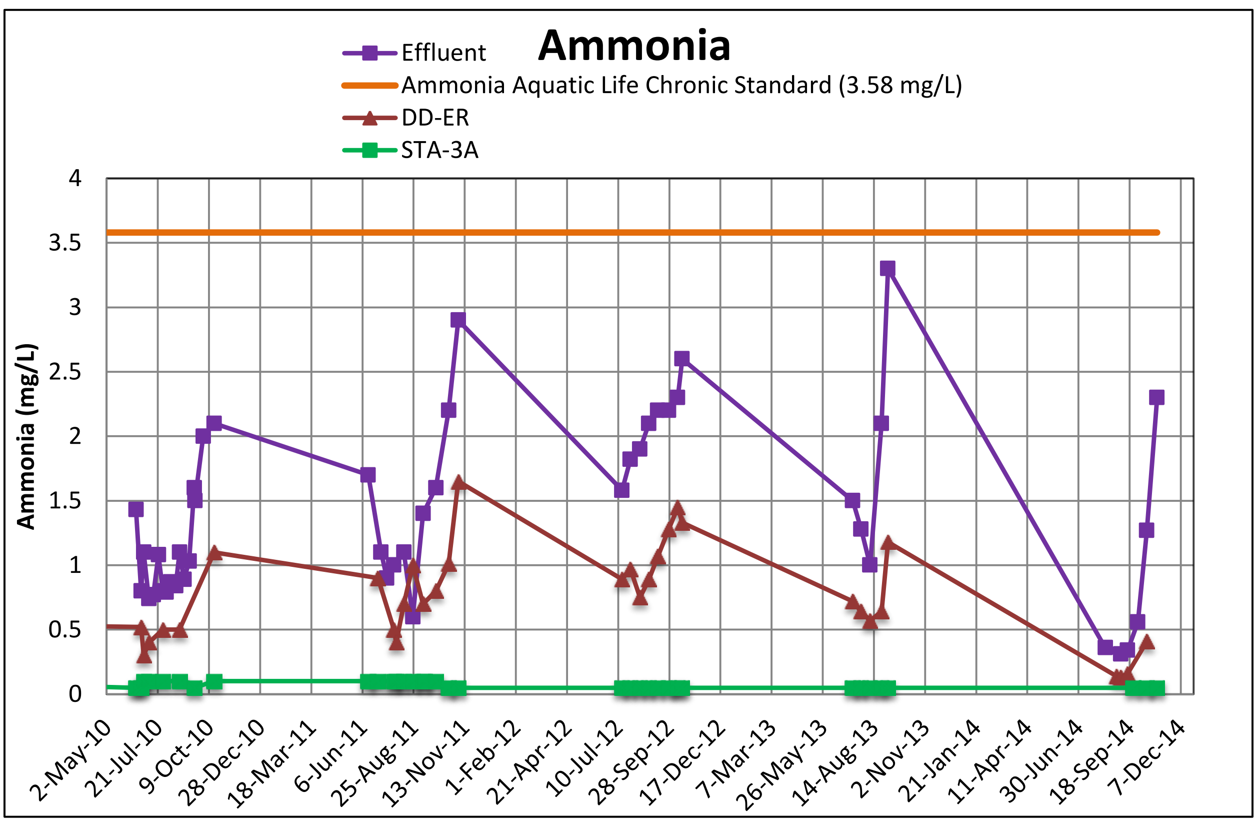

Figure 9: Ammonia Concentrations in Effluent, DD-ER and STA-3A

Metals

Throughout the 2014 treatment season, metals, such as arsenic, selenium and strontium steadily increased in the influent as displayed in **Figure 10**. Influent arsenic concentrations increased from 0.204 mg/L to 0.348 mg/L during the 2014 treatment season. Influent selenium concentrations increased from 0.14 mg/L to 0.315 mg/L, while influent strontium concentrations increased from 4.24 mg/L to 7.27 mg/L. Based on historical data, it is observed that metal concentrations in the influent generally increase throughout the water treatment season. This trend occurred in 2014, as the concentrations of metals in the reject water increased throughout the 2014 treatment season as shown in **Figure 12.** The increase in metal concentrations in the influent and reject water is likely caused by the discharge of the reject water back into the heap leach pad.

As mentioned above, samples collected from the direct discharge stations DD-ER and STA-3A were not analyzed for total recoverable selenium in 2014 due to the oversight of revising Table 7 per Task 5 of the Year 7 Beal Mountain Mine water treatment work order. However, according to the site wide monitoring program, STA-3A has been analyzed semi-annually for metals that include arsenic and selenium. The 2014 Water Resources Monitoring Summary reports that selenium concentrations were at or below chronic aquatic life standards during operation of the water treatment system in 2014. The summary also states that arsenic concentrations at STA-3A were approximately equal to the Human Health Standard and were below the chronic aquatic life standard for the May and September monitoring events in 2014 (Tetra Tech, 2015).

Near the end of the 2014 treatment season, selenium concentrations in the effluent water were observed at a maximum level of 0.005 mg/L as shown in **Figure 11**. This is equal to the MDEQ Chronic Aquatic Life Standard and below the Acute Aquatic Life Standard of 0.020 mg/L (MDEQ, 2012). Effluent selenium concentrations from September 2014 are significantly lower than concentrations in September 2013. A considerable drop in effluent strontium concentrations was observed between November 2011 and July 2012 due to a change in the laboratory reporting limit for strontium, which changed from 0.1 mg/L to 0.01 mg/L.

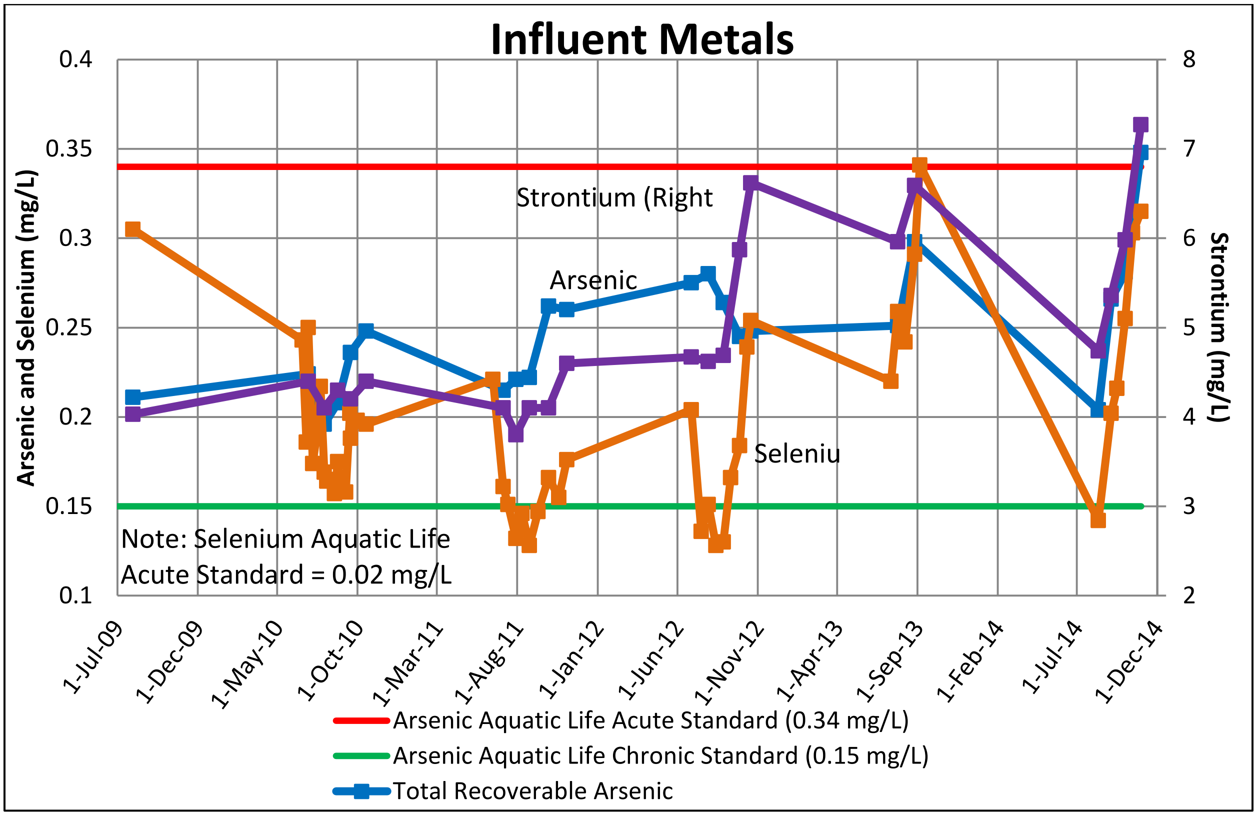

Figure 10: Influent Metal Concentrations

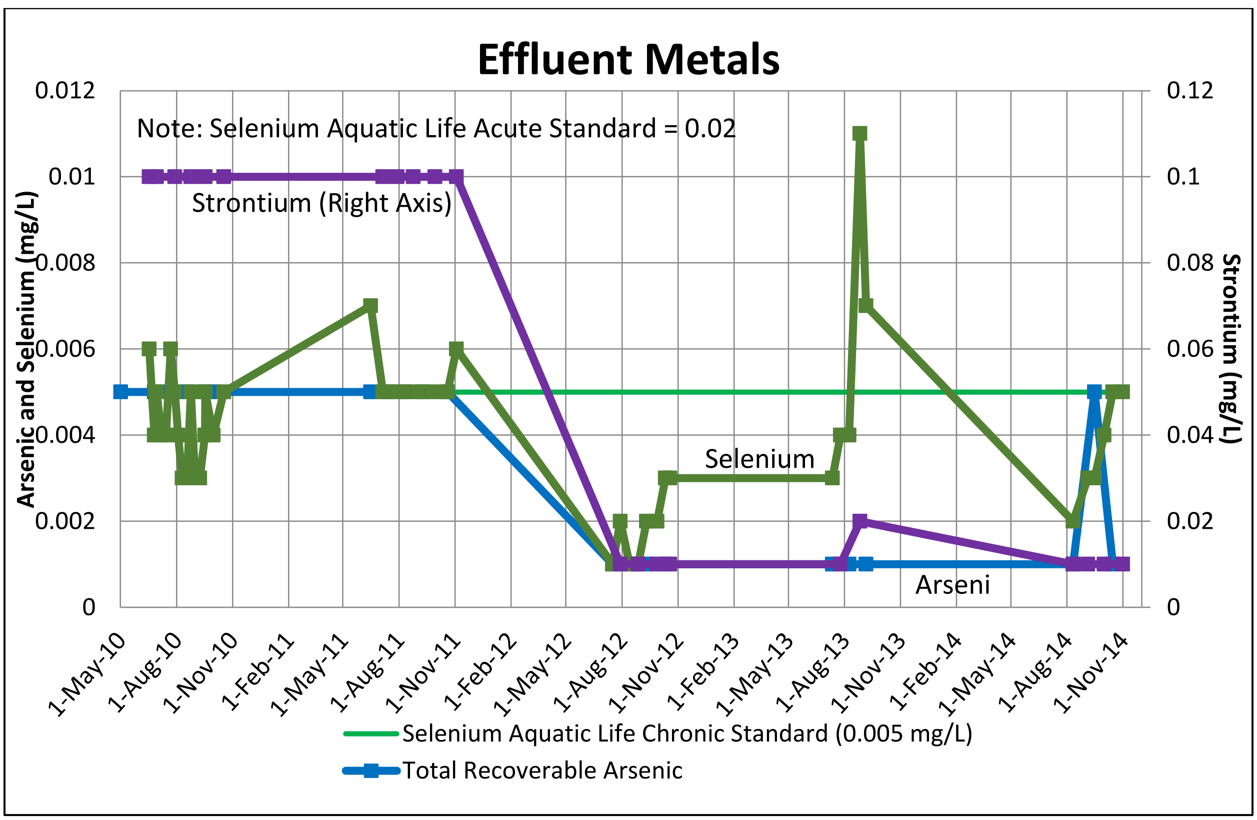

Figure 11: Effluent Metal Concentrations

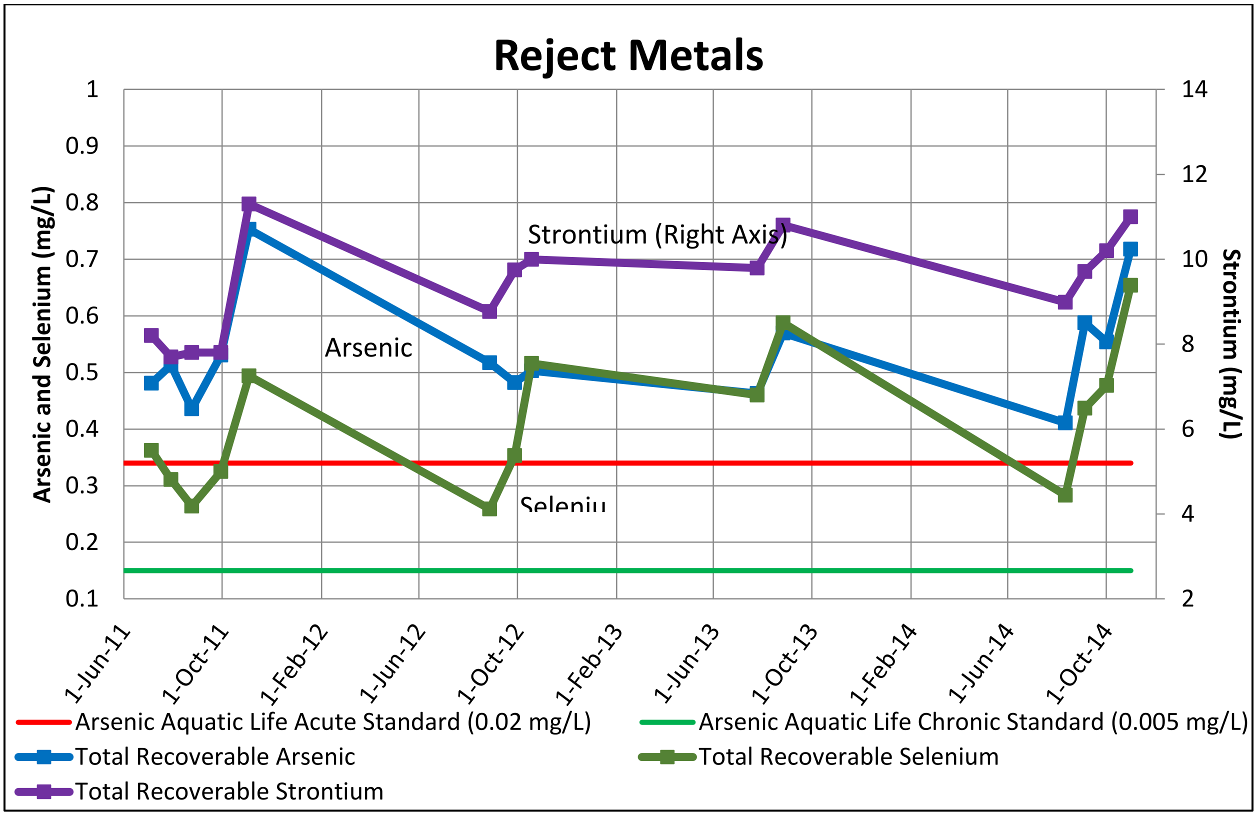

Figure 12: Reject Metal Concentrations

Leach Pad Geochemical Modeling

After the completion of the 2012 treatment season, geochemical modeling was performed for the leach pad water (Tetra Tech, 2013). The goal of the modeling was to use the previous volume and laboratory analytic data to predict which contaminants of concern would limit the amount of water that could be removed from the leach pad before the RO effluent concentrations would exceed DEQ discharge standards. The other purpose of the modeling was to evaluate whether additional pre-treatment procedures would need to be implemented due to increasing concentrations of key contaminants.

For the 2014 treatment season, the modeling projected that the Beal Mountain treatment facility would be able to extract up to 15 million gallons of treated leach pad water resulting in approximately 7.5 million gallons of water remaining in the leach pad without running into major issues with scaling or with contaminants other than ammonia exceeding the discharge standards. The effluent selenium concentration was projected to be close to the limit of 0.005 mg/L in October 2014. The model assumed a recharge of approximately 16 million gallons and the total volume of the leach pad would be approximately 26.5 million gallons. The model also assumed that the RO recovery would remain at approximately 60%. Under these assumptions, selenium was found to be the contaminant that would likely exceed its discharge limit if 16 million gallons or less accumulation occurred and more than 20 million gallons of treated water was discharged in 2014.

The leach pad accumulation from shut down in 2013 (September) to startup in 2014 (August) was approximately 26.7 MG (well above the 16 million gallons of recharge used in the model). The total treated gallons was only 14.7 million gallons (over 5 million gallons less than used in the model). Based on these differences between the 2014 model and 2014 actual, the model would likely not predict selenium discharge limits being exceeded during 2014 since there was more accumulation than predicted and lower treatment volumes. It should be noted that the volume taken on by the leach pad is calculated, and inconsistencies have been observed with the rating table used in these calculations (Tetra Tech, 2013).

Tables 4, 5 and **6** compare predicted to actual concentrations for five constituents. Ammonia, cyanide, and selenium were the only contaminants predicted to become a concern due to elevated levels according to Tetra Tech's modeling. The actual end of season influent cyanide results were slightly greater than the model projections. The end of season effluent cyanide results were slightly greater than the model prediction. The actual influent ammonia concentration at the start of the season was slightly lower than the predicted value; however, the end of season influent and effluent results were lower than the model predictions. Influent selenium concentration results near the end of the season were very similar to predicted. According to the model projections, the concentration of effluent selenium would be close to the limit of 0.005 mg/L when there was approximately 6.5 million gallons of water remaining in the leach pad. At the end of the season, a depth to water measurement was taken on November 6, 2014, and used to calculate a volume of 6.57 million gallons in the leach pad. This shows that, as the residual water volume approached the 6.5 million gallon mark, the selenium levels began to exceed the limit as projected by the model. Unfortunately, due to apparent inconsistencies between the rating table and measured volume of water removed from the leach pad, it was unknown exactly how much water was left in the leach pad near the end of the 2014 treatment season.

Table 4: June 2014 Influent Predicted vs. Actual Concentrations

Contaminant of Concern	Predicted Concentration June 2014	Actual Concentration Aug. 2014
Arsenic (mg/L)	0.206	0.204
Cyanide, Total (mg/L)	3.0	5.7 (Sept. 11)
Selenium (mg/L)	0.160	0.142
Ammonia (mg/L)	15.0	13.7
Strontium (mg/L)	3.8	4.74

Table 5: October 2014 Influent Predicted vs. Actual Concentrations

Contaminant of Concern	Predicted Concentration Oct. 2014	Actual Concentration Oct. 2014
Arsenic (mg/L)	0.617	0.35
Cyanide, Total (mg/L)	9.0	7.5
Selenium (mg/L)	0.478	0.315
Ammonia (mg/L)	43	25
Strontium (mg/L)	9.1	7.27

Table 6: October 2014 Effluent Predicted vs. Actual Concentrations

Contaminant of Concern	Predicted Concentration Oct. 2014	Actual Concentration Oct. 2014
Arsenic (mg/L)	0.002	0.001
Cyanide, Total (mg/L)	0	0.023
Selenium (mg/L)	0.0049	0.005
Ammonia (mg/L)	5	2.3
Strontium (mg/L)	0	0.01

ISSUES/CONCERNS/REMEDIES FROM THE 2014 TREATMENT YEAR

Treatment Rate

The RO production rate in 2014 was lower than previous seasons due to the increasing concentrations of contaminants in the influent and the reuse of membranes from previous seasons. A decrease in the treatment rate was observed at the end of the treatment season due to a reduction in flow through the membranes caused by the accumulation of scale and contaminants throughout the 2014 season. A summary of the starting and ending treatment rates from the last four seasons is presented in **Table 7**. Effluent flow rates for the 2014 treatment season are shown in **Figure 13**. In full operation, the 2014 treatment rate started the season at 141 gpm and gradually decreased until October 3, 2014. A decrease in treatment flow rate to 127 gpm was observed between October 10 and 14, 2014, due to suspected membrane fouling. Due to the shortened treatment season, a mid-season cleaning was not performed. Cleaning was performed at the end of the treatment season on November 4, 2014.

Table 7: RO Treatment Rates

Treatment Season	Starting Treatment Rate (gpm)	Ending Treatment Rate (gpm)
2010	185	183
2011	164	130
2012	171	161
2013	132*	114
2014	141	126

Note: * Starting treatment rate once system was running at full capacity.

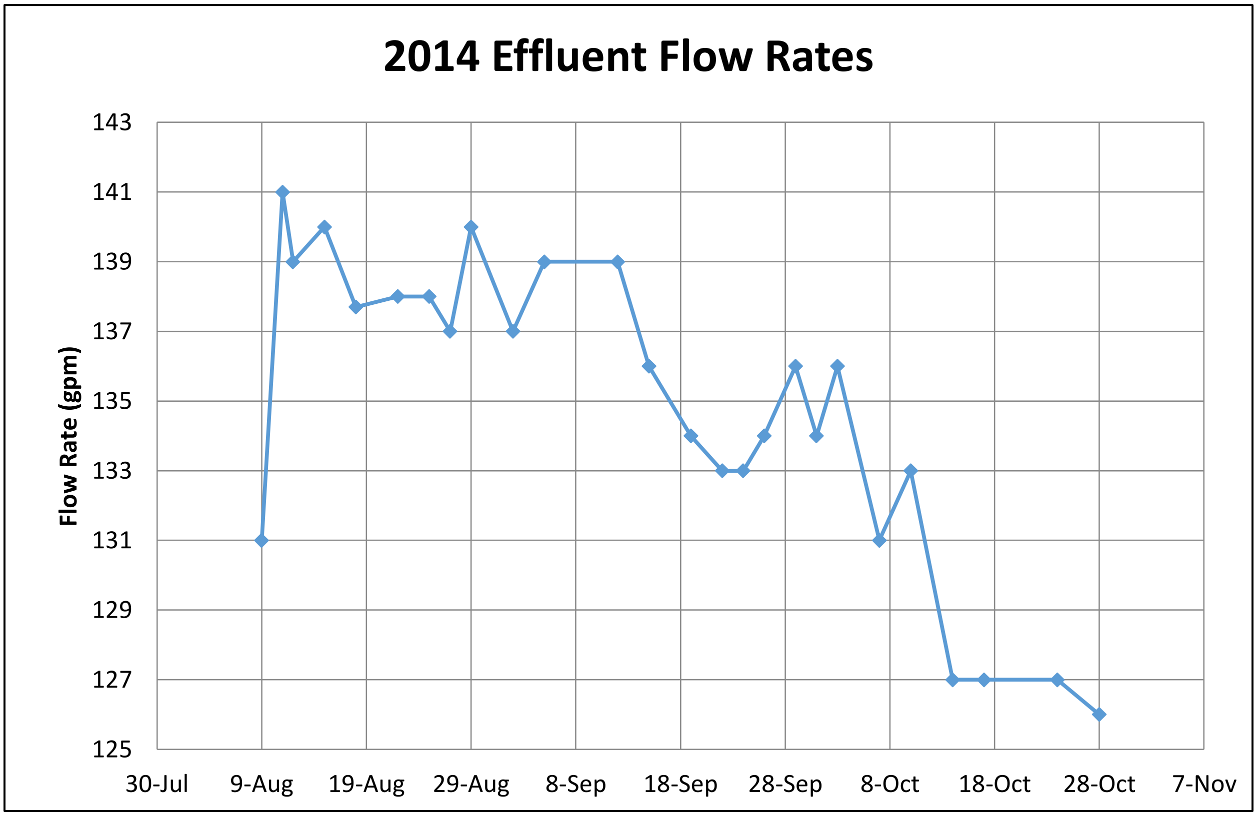

Figure 13: 2014 Effluent Flow Rates

The last four years have seen decreases in the treatment rate during the season due to gradual scaling of the membranes. As the concentrations of salt and contaminants increase in the leach pad due to reductions in water volume, a decrease in the treatment rate has been observed.

According to **Table 1**, a 2.6% decrease in the treatment rate occurred in 2014. This is less than may be expected, given the continually decreasing quality of the influent. The replacement of 18 membranes prior to the 2014 treatment season may have allowed treatment rates to stay relatively stable through the season.

System Availability

Four unscheduled shut downs were experienced during the 2014 season. The first one occurred on August 20, 2014, and was due to an issue with communications, which was repaired by switching fiber optic connections. The second unscheduled shut down occurred on September 6, 2014, and was due to a failure of the pump motor in Sump-1. This motor was replaced on September 12, 2014. The third system shut down occurred when Beal Mountain lost power on September 16, 2014. The final shut down occurred on September 26, 2014, due to failure of the 1st pass motor lead, which was repaired on September 27, 2014. The system availability from the last few years is as follows:

- 2009 - online 76% of the time
- 2010 - online 96% of the time
- 2011 - online 97% of the time
- 2012 - online 97% of the time
- 2013 - online 94% of the time
- 2014 - online 91% of the time

Scaling and Membranes

During the 2013 shutdown, some membranes were noticeably heavier than the previous year. After a visual and physical inspection, these membranes were determined to be unusable. A total of 18 membranes were disposed of during the 2013 shutdown, and all the remaining membranes were allowed to drain before being packaged and transported to a heated garage bay where they were stored for the winter. Prior to startup in 2014, 18 new first pass membranes were purchased to replace discarded membranes. The weights of the remaining membranes removed from the system were compared to the weights of the membranes discarded from previous seasons and it was decided that testing was not necessary prior to the 2014 season.

During the 2014 end of season shutdown, there was evidence of calcium sulfate deposits on all of the first pass first array membranes. A decrease in effluent flow rate (approximately 6 gpm) occurred between October 11 and October 14, 2014. Review of system performance for this period indicates: (1) the aniti-scalent did not run dry, thus, this condition could not have contributed to membrane fouling; (2) during this period plant feed decreased approximately 3 gpm, which was likely due to the decrease in solution heads over the pump in Sump-1, (3) on October 10 the system was adjusted to allow an additional 3 gpm of plant feed to bypass treatment and return to the Leach Pad as Reject. Further review of interstage pressures indicate a gradual and continuous pressure increase for the week before and after this period, which suggests a gradual and continuous fouling of the membranes throughout the season. The rate of membrane fouling and subsequent reduction in flow may have increased slightly late in the treatment season due to the increased concentrations of contaminants and salts in the leach pad. This trend was also observed in the 2013 season. At the end of the 2014 season, approximately 23 membranes were set aside for further evaluation. Based on weight, 19 of these membranes were marked as bad and 4 were labeled as questionable. It is recommended that a select few of the stored membranes be sent in for testing to determine the approximate condition of the remaining membranes and how many need to be replaced.

Water Quality

Analysis of 2014 influent (raw water) cyanide concentrations indicate 2014 concentrations were similar to or less than concentrations in 2013 (**Figure 4)** and cyanide concentrations in the reject (concentrate returned to leach pad) water increased in 2014 relative to 2013 (**Figure 6)**.

Although the effluent water left the system with cyanide levels slightly above standards, the treated water was aerated in the clean water pond and the samples collected from the direct discharge location DD-ER (direct discharge-end of rock) remained below the Acute Aquatic Life Standard of 0.022 mg/L. The cyanide concentrations for STA-3A remained under the detection limit for cyanide for the duration of the season.

Throughout the 2014 treatment season, an increase in ammonia levels was observed at all sampling locations except STA-3A, which remained under the detection limit for the duration of the season. The influent, effluent, and DD-ER all reported increases during 2014 season. Ammonia concentrations in the influent water began the season at 13.7 milligrams per liter (mg/L) and ended the year at 25.0 mg/L. The effluent began the season at 0.36 mg/L and ended at 2.3 mg/L. The DD-ER began the season at 0.14 mg/L and ended at 0.41 mg/L. All of the samples collected downstream of the treatment plant were below the Chronic Aquatic Life Standard for ammonia in surface water, which is 3.58 mg/L. In order to lower ammonia levels earlier in the discharge process, the clean water pond was kept at a higher level to allow more aeration of the water prior to discharge. The discharged water is also aerated as it flows down the direct discharge ditch toward German Gulch.

The concentration of metals in the influent also continued to increase. Arsenic levels in the influent water began the season at 0.204 mg/L and ended at 0.35 mg/L. Strontium concentrations began the year at 4.74 mg/L and finished the year at 7.27 mg/L. During 2014 arsenic and strontium began the season slightly lower, but ended the season slightly greater, than 2013 concentrations. The most significant increase for the season was seen in selenium levels, which started the year at 0.142 mg/L and finished at 0.315 mg/L. During 2014 selenium began and ended the season less than 2013 values. This seasonally increasing trend was anticipated due to the return of the reject water back into the heap leach pad. The rate at which these and other metals increase in concentration, along with the load of dissolved salts (TDS) may require the design and implementation of additional pre-treatment processes for future treatment seasons.

<u>Heap Leach Pad Water Volume</u>

The annual water accumulation rates on the heap leach have seen a decline since the completion of the Heap Leach Cap Repair project in August 2011. The leach pad solution volume increased approximately 26.7 MG from shut down in 2013 to startup in 2014. Projections suggest that the leach pad solution volume will likely increase approximately 16 million gallons during the winter of 2014-2015. The geochemical modeling projected that the leach pad can be treated down to a level of approximately 7 million gallons remaining on the pad before the selenium effluent concentration would be close to exceeding the chronic aquatic life standard concentration of 0.005 mg/L. Elevated TDS concentrations at solution volumes less than 7 million gallons are likely to lower selenium removal efficiencies. The 2014 treatment season ended with a leach pad volume of approximately 6.57 million gallons. However, the selenium concentrations were equal to the chronic aquatic life standard in the effluent samples around this time.

The RO treatment plant will need to continue operating to account for the water taken on when the system is not in operation. The system will, however, either need to be operated for much shorter periods of time or with extended periods of time between operating seasons. Since the heap leach volume needs to stay above 7 million gallons due to the RO treatability restraints, it would be most feasible to allow the leach pad volume to increase to a volume greater than the previous contract amount so a full season of treatment can occur. If recent patterns continue, the leach pad solution volume will increase to approximately 25 to 30 million gallons between November 2014 and July 2015. According to the existing rating table, the addition of this anticipated water to the water that was remaining on the pad at the end of 2014, would result in a value that would limit the treatment volume for next year's treatment season to approximately 14 million gallons. If the system was operated for a full season (May through October) every other year, it may be possible to treat close to 28 million gallons assuming the system takes on approximately 16 million gallons each year. Another option would be to operate the system every five or six years to treat the water that has accumulated in the heap leach. This would allow for a full treatment season, due to an increased heap leach volume, and possibly increased treatment rates with the dilution of salt and other contaminant concentrations.

The geochemical modeling performed after the 2012 treatment season has proved to be very useful for better understanding the concentrations of contaminant levels with the decreasing leach pad volume. One of the major reasons geochemical modeling was performed was to evaluate whether pretreatment would be needed for the RO plant to continue treating water. The results of the modeling showed that, as long as the leach pad volume was kept above 7 million gallons and the recharge is below 25 million gallons annually, the selenium concentration and gypsum saturation would be at a level that could be handled by the RO plant and no additional pretreatment would be needed. However, based on late season observations, membrane fouling becomes a concern due to increased contaminant concentrations and increased scaling. This trend was observed during the 2013 season when the leach pad volume dropped to a minimum of 3.6 million gallons and the selenium concentrations in the effluent were detected at levels exceeding the chronic aquatic life standard for selenium, demonstrating that the RO was not able to adequately remove selenium under those conditions. This trend was also observed during the 2014 season. As the leach pad volume decreased, the selenium concentrations and amount of scaling increased. If the leach pad volume is below approximately 7 million gallons, a pretreatment option will likely need to be added to decrease the concentration of contaminates and salts, which contribute to membrane scaling, prior to entering the RO system. Another option would be to treat pad solution to a volume of 12 to 13 MG remaining on the leach pad. Below the 12 to 13 MG volume is when 2014 treatment flow rates significantly decreased.

During 2012, treatment system flow meters indicated approximately 25 million gallons were removed from the leach pad. A review of **Figure 2** (which is based on the rating table) suggests that the solution volume in the leach pad dropped approximately 45 million gallons during the 2012 treatment season. Then in 2013, the treatment flow meters showed that just less than 14 million gallons of water were treated by the RO system and in 2014, a total of 14.7 million gallons of water was treated. Referring back to **Figure 2**, it is revealed that the leach pad volume decreased by approximately 23 million gallons during the 2013 treatment season and decreased by 23.6 million gallons in 2014.

Figure 2 and the associated rating table were developed by using data during 2002 and 2005 when the leach pad was dewatered. During these events, depth to solution was periodically measured from top of steel casing in Sump 1, and a corresponding solution elevation was calculated. At the same time, the volume of water removed was recorded. These changes in volume and corresponding elevations are believed to be the foundation for the available rating table. In order to accommodate solution levels (and therefore volumes) greater than observed (7,481 feet or 30 million gallons), a model was developed by Tetra Tech in 2006 using Eagle Point software, available leach pad design drawings, and an assumed porosity to calculate the available pore volume for one foot elevation increments. Unfortunately this table has proven to be inaccurate at the lower leach pad elevations. Three possible reasons for the table inaccuracies are as follows:

- First, both the 2002 and 2005 dewatering events occurred prior to any leach pad cap repairs and occurred in the spring when influx of ambient water was the highest. Therefore, a greater volume of solution needed to be pumped out in order to obtain the same elevation change, which resulted in over estimating the volume change per foot.
- Second, there are no As-Built drawings of the leach pad to accurately define the final leach pad configuration.

- Finally, there are no site-specific data defining leach pad material porosity, and the porosity has likely been reduced from 2002 to present by precipitation of salts from the reject water injected into the leach pad.

References:

MDEQ 2012. Circular DEQ-7 Montana Numeric Water Quality Standards, Montana Department of Environmental Quality, Helena, MT, October 2012.

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Tetra Tech 2013. Final – Beal Mountain Mine Heap Leach Pad and Treatment Chemical Modeling. Tetra Tech, Helena, MT, March 13, 2013.

Tetra Tech 2014. Reverse Osmosis (RO) Year Seven Water Treatment and Monitoring Proposal, Tetra Tech, Helena, MT, May 9, 2014.

Tetra Tech 2015. 2014 Draft Water Resources Monitoring Summary, Tetra Tech, Helena, MT, January 2015.

APPENDIX A
FIGURES

APPENDIX B
DAILY OPERATION LOGS