Tucson Office
3031 West Ina Road
Tucson, AZ 85741
Tel 520.297.7723 Fax 520.297.7723
www.tetratech.com

Technical Memorandum

To:	Kathy Arnold	**From:**	Amy Hudson, REM
Company:	Rosemont Copper Company	**Date:**	January 14, 2010
Re:	Heap Leach Facility Infiltration, Seepage, and Fate and Transport Modeling/Treatment Options	**Doc #:**	042/09-320864-5.3
CC:	David Krizek, P.E. (Tetra Tech)		

1.0 Introduction

This technical memorandum presents Tetra Tech's infiltration, seepage, fate, and transport modeling associated with the final design of the Heap Leach Facility for the proposed Rosemont Copper Project (Project) in Pima County, Arizona. The purpose of this modeling was to:

- Develop a post-operation drain-down curve;
- Simulate the current closure plan; and
- Determine the quality of any potential seepage generated from the post-closure heap.

Additionally, several scenarios were considered for modifying the Pregnant Leach Solution (PLS) Pond and Stormwater Pond with regard to treating any on-going seepage generated from the heap following closure of the Heap Leach Facility.

Modeling was completed using the VADOSE/W and CTRAN/W programs from the GeoStudio 2007 software package (GEO-SLOPE, 2007a and b) to simulate the water flow in the system. PHREEQC (Parkhurst and Apello, 1999) was used to model the quality of the potential seepage. Modeling was performed on the final pad configuration which covers about 129 acres.

2.0 Model Construction

After leaching is complete, the heap will be allowed to drain for approximately two (2) to three (3) years before the ponds located at the base of the heap are covered with waste rock. The conceptual model provided as Illustration 1 shows the system water balance components during the initial drain-down period. These components consist of:

- Precipitation;
- Evaporation;

- Runoff;
- Infiltration; and
- Seepage.

Seepage includes drain-down of the residual leach solutions, as well as any infiltration that flows through the spent ore material.

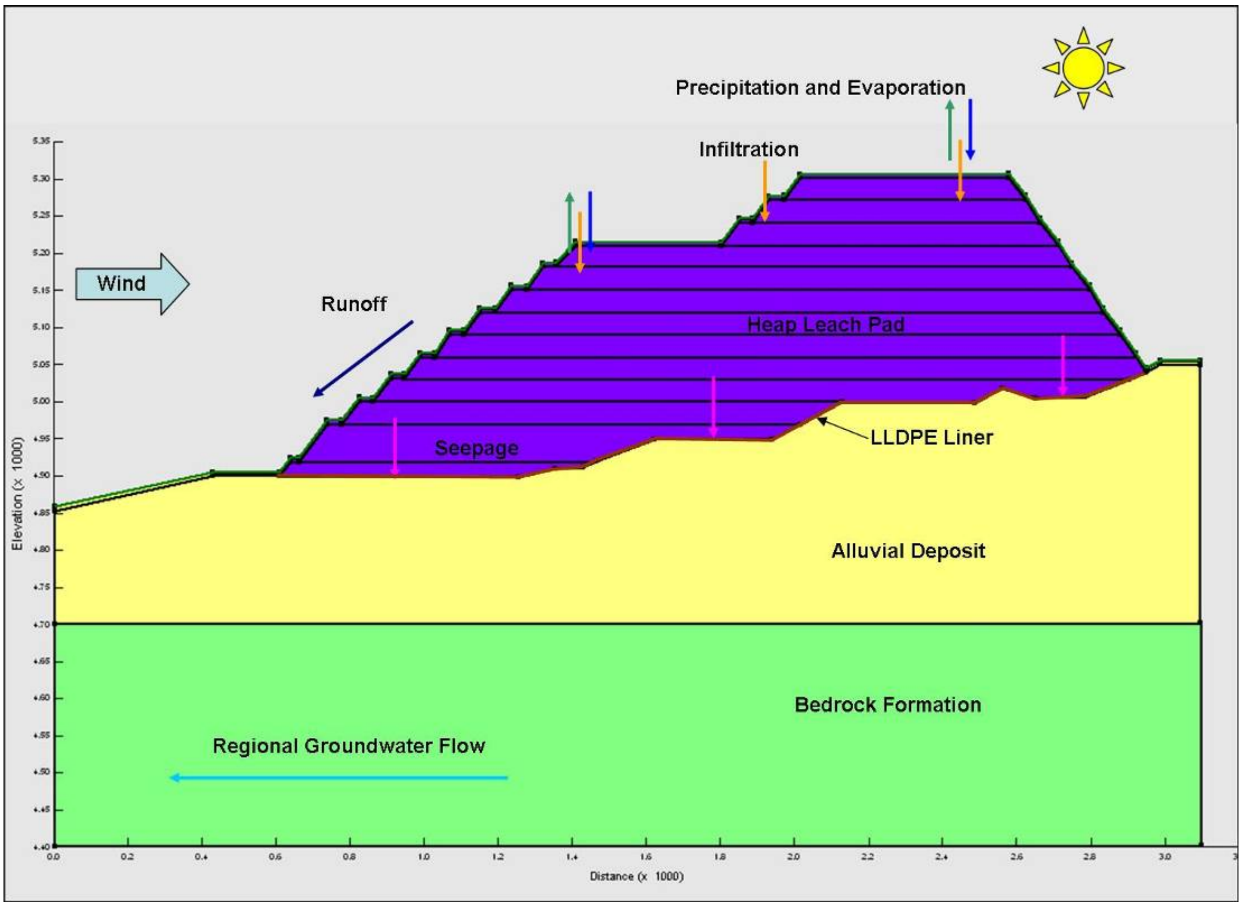

Illustration 1 Conceptual Operational Model of the Heap Leach Facility

Seepage (resulting from drain-down and infiltration) and storm runoff from the surface of heap will be collected in the PLS Pond during the initial two (2) to three (3) year drain-down period. After this period, residual drain-down seepage would continue to be collected in the former PLS/Stormwater Pond area.

By the end of the drain-down period, the PLS Pond and the Stormwater Pond will be closed per Prescriptive Best Available Demonstrated Control Technology (BADCT) guidance as established by the Arizona Department of Environmental Quality (ADEQ) (2004) as detailed in a separate technical memorandum title, “Prescriptive BADCT Closure for the Heap Leach Facility Ponds” (Tetra Tech, 2010). If drain-down from the heap is present at this time, the former PLS and Stormwater Ponds may be converted to treatment basins. These treatment basins are discussed herein.

At closure, a waste rock cover will be placed over the heap. A conceptual model of the conditions associated with the closed Heap Leach Facility is shown as Illustration 2.

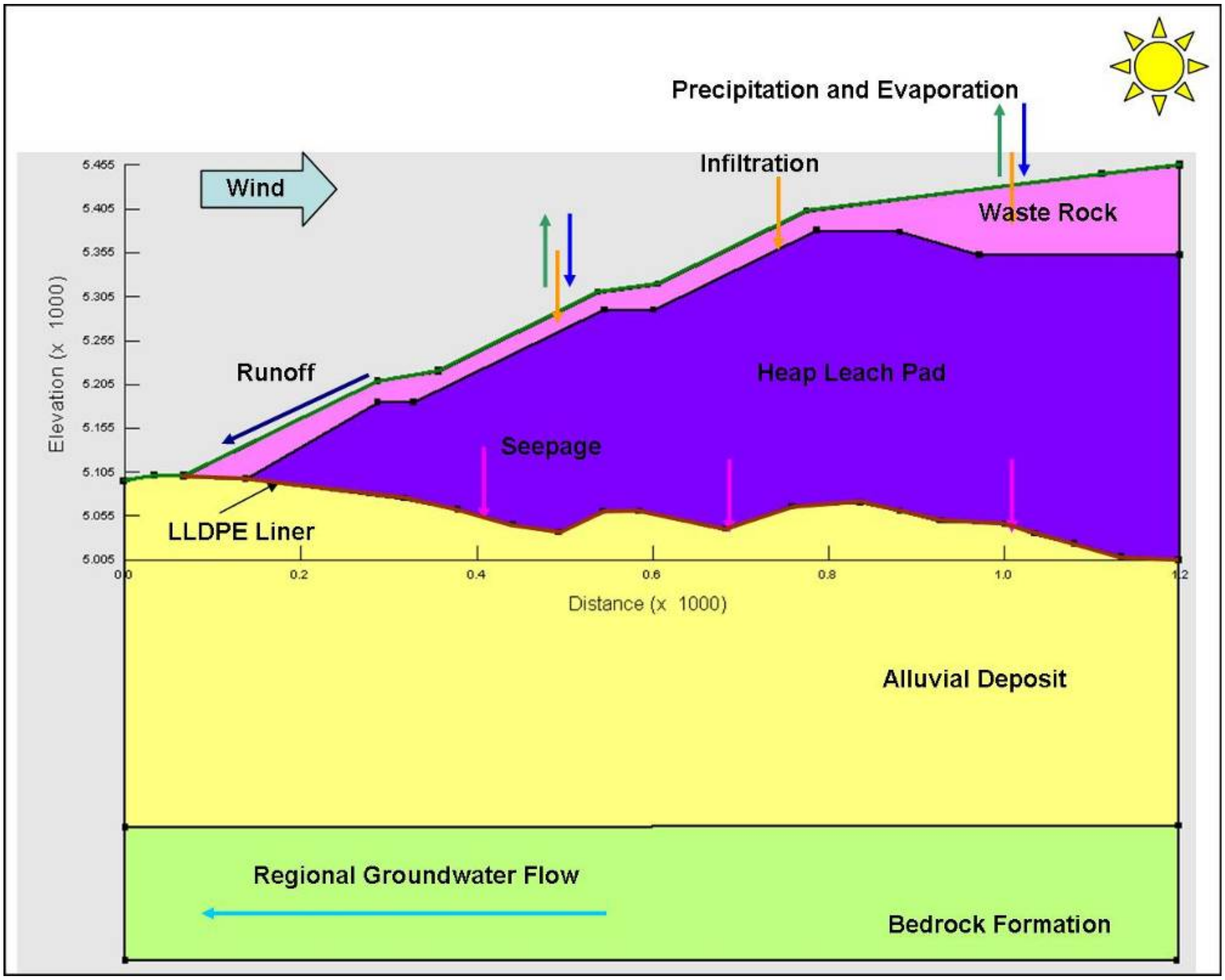

Illustration 2 Conceptual Closure Model of the Heap Leach Facility

2.1 Model Input Parameters

Modeling was performed for two (2) primary steps in the life of the Heap Leach Facility:

- Drain-down of the heap after active leaching ceases (about a two (2) to three [3] year period); and
- Facility closure.

Site specific climate data was used in the model to evaluate the potential infiltration and seepage of precipitation through the spent ore. The following parameters were included as part of the climate data file used in the modeling:

- Minimum and maximum daily temperature;
- Daily precipitation;
- Minimum and maximum daily humidity;
- Daily evaporation or net radiation; and
- Average daily wind speed.

The average climate conditions data set used for modeling the Heap Leach Facility is an average of over 50 years of daily measurements taken at the Nogales 6N Meteorological Station located approximately 30 miles from the Project site. There are several additional meteorological stations within the area, including a meteorological station installed at the Project site in April 2006. Each of these data sets was compared and considered for completeness, similarity to the site information, and period of record. Although the Nogales 6N Meteorological Station most closely matched the data collected at the Project site and was used in the modeling performed on the Heap Leach Facility, precipitation data from the Santa Rita Meteorological Station was also assessed and found to provide no substantial difference to the modeling results.

In addition to the average climate conditions, two (2) storm data sets were used for modeling of the Heap Leach Facility. The first represented a 100-year, 24-hour storm event (4.75 inches of rain over a 24-hour period) occurring during the summer. The second represented a winter event with multiple days of above average precipitation (approximately six (6) inches of rain in seven (7) days). These storm data sets allowed consideration of the worst case infiltration (winter storms) and runoff conditions (summer storms).

Unsaturated flow parameters of the materials used in the model where taken from laboratory and library data sets. Both the ore placed on the Heap Leach Facility and the waste rock placed on the spent ore will be run-of-mine (ROM) sized material. The ROM material was modeled with a permeability of 170 feet per hour (ft/hr) (10^0 cm/sec). This is equivalent to a coarse material with a broad distribution of sizes (poorly sorted) from gravel (0.1 inches) to large boulders (greater than 12 inches).

The primary difference between the spent ore and the waste rock is the moisture content of the materials. The waste rock is expected to have a moisture content of less than ten (10) percent by volume when it is placed on the surface of the heap. The moisture content of the spent ore is expected to be higher due to leaching. A moisture content of about 15% by volume is anticipated for the spent ore after the material has been leached and drained.

2.2 Modeling Technique

The analysis of the Heap Leach Facility drain-down and closure was completed in three (3) separate steps. The first step involved seepage and infiltration modeling using VADOSE/W (GEO-SLOPE, 2007a) to determine the flux into the spent ore and throughout the facility. The next step was particle tracking using CTRAN/W (GEO-SLOPE, 2007b) to determine the path of the water flow, including the direction of flow (into the facility [infiltration] or out of the facility [evaporation]). The final modeling step utilized PHREEQC (Parkhurst and Apello, 1999) to determine the anticipated water quality of the seepage and to evaluate potential treatment options. The following sections provide more detail on the steps taken to complete the modeling.

2.2.1 Flow Model Construction

In VADOSE/W (GEO-SLOPE, 2007a), a finite-element model grid was built representing the final Heap Leach Facility configuration. Each zone of the model was assigned a material property that represents the expected behavior of the material once placed in the facility. Because this modeling focused on the facility post stacking, the only grid considered was the completely stacked heap leach pad shown in Illustration 1. The ore material stacked within the Heap Leach Facility was modeled with side slopes of 2H:1V and a flat top surface.

The closure scenarios were constructed using the same grid layout as the end of leaching scenario with the addition of a waste rock layer to the outer surface of the facility (Illustration 2). These scenarios included:

- The average climate conditions;
- The 100-year, 24-hour storm event scenario; and
- The multi-day storm event scenario.

The waste rock material stacked on top of the heap was modeled with the final reclamation contouring and grading applied of the outer surface. In this final reclamation scenario, there is no surface water ponding directly above the closed heap and ponds.

Particle tracking modeling was performed using the program CTRAN/W (GEO-SLOPE, 2007b), another component of the GeoStudio software suite. The particle-tracking portion of the modeling was only considered for the closed (capped) facility since any prior seepage would have been collected in the PLS Pond and re-circulated back to the heap, evaporated, or treated and/or used in the process circuit.

The particles were initially placed in the upper portion of the facility model. The particle tracking model estimated the flow paths of the water entering, traveling through, and exiting the spent ore material and determined how long the water was in contact with the spent ore.

2.2.2 Geochemical Model Construction

Geochemical modeling was conducted using the computer code PHREEQC Version 2.15.06 (Parkhurst and Appelo, 1999), a reaction path chemical equilibrium model supplied by the United States Geological Survey (USGS). PHREEQC is able to process multiple equilibria and mixing reactions to produce the final chemical speciation of a system.

In addition to a computer code, geochemical modeling requires a database of thermodynamic and kinetic parameters associated with the chemical reactions. The database is a separate file from the PHREEQC model to allow for additions, deletions, and updates to the information without impacting the model code. No database is fully comprehensive, so it is often necessary to make these changes and additions manually (Zhu and Anderson, 2002).

For this project, the WATEQ4F database (Ball and Nordstrom, 1991) was chosen. However, this database did not include all of the metals of concern. Therefore, additional metals were added to the file. The information added was obtained from the PHREEQ database published with the computer code (Parkhurst and Appelo, 1999). The combination of the two (2) databases provided the broad range of metals needed to predict the quality of the seepage.

The information obtained from the particle tracking and the infiltration and seepage modeling was used to construct the geochemical model for the Heap Leach Facility. The geochemical model was constructed using simple mixing of the starting solutions representing water contacting the spent ore. The starting solutions were mixed with a dilute (0.5%) sulfuric acid solution to represent the residual chemical remaining in the pore spaces of the spent ore material after the cessation of leaching.

The data used to generate the starting solution was taken from the geochemical testing program of leached column material. Table 1 presents the starting solution used to represent each rock type that will be present within the spent ore. For those metals that were detected in some samples but not in all samples of each material type, one-half the value of the method detection limit was used as the input value for calculating the average material values. For those metals that were not detected in any sample for a particular material type, NA is shown in Table 1 and the metal was not included in the starting solution.

Table 1 Geochemical Starting Solutions

		Arkose	Andesite	Qmp
pH		7.8	3.34	3.65
Sulfate	mg/L	27.7	2500	772
Silver	mg/L	NA	0.017	0.007
Aluminum	mg/L	0.039	71.4	14
Arsenic	mg/L	0.0135	0.0039	NA
Barium	mg/L	0.0064	0.0271	0.0422
Beryllium	mg/L	NA	0.0291	0.0075
Cadmium	mg/L	NA	0.377	0.0849
Calcium	mg/L	14.5	526	172
Chlorine	mg/L	3.46	6.97	2.8
Chromium	mg/L	NA	0.04	0.014
Copper	mg/L	0.012	53.1	90.1
Fluorine	mg/L	0.834	6.38	1.57
Iron	mg/L	NA	1.09	0.46
Mercury	mg/L	NA	NA	0.00038
Potassium	mg/L	6.41	9.81	3.07
Magnesium	mg/L	2.86	187	32
Manganese	mg/L	0.0037	31.1	6.78
Molybdenum	mg/L	NA	0.009	NA
Sodium	mg/L	NA	10.3	6.21
Nickel	mg/L	NA	0.734	0.141
Nitrite + Nitrate as Nitrogen	mg/L	14.1	0.122	0.058
Lead	mg/L	NA	0.0342	0.0445
Selenium	mg/L	0.06	0.13	NA
Zinc	mg/L	0.06	21.5	4.95

mg/L = milligrams per liter

The solutions listed in Table 1 were mixed using the relative proportions of each material that will likely be placed on the Heap Leach Pad. Table 2 presents the mixing ratios used to construct the model.

Table 2 Model Mixing Portions

Rock Type	Tons of Heap Material	Percent of Heap Material
Arkose	33,922,000	57%
Quartz Monzonite Porphyry	14,406,000	24%
Andesite	11,095,000	19%
Totals	59,423,000	100%

Each of the starting solutions was equilibriated with atmospheric concentrations of oxygen and carbon dioxide. This was also used to determine the relative pe values (oxidation reduction potential) associated with each solution. Once the solution was mixed, it was equilibriated with common minerals to allow supersaturated minerals to precipitate out of solution.

3.0 Model Results

The following sections describe the results of the flow and the geochemical modeling associated with the Heap Leach Facility.

3.1 Flow Model Results

After leaching is complete, the spent ore will be allowed to drain for approximately two (2) to three (3) years. Based on modeling, the flow rate from the heap will be less than ten (10) gallons per minute (gpm) at the end of this period. This represents a near steady-state condition for the heap prior to the addition of the waste rock. The drain-down curve is presented in Illustration 3. This drain-down rate was developed using average climate conditions. The heap may continue to drain at a decreasing rate for several years after the spent ore is covered with waste rock.

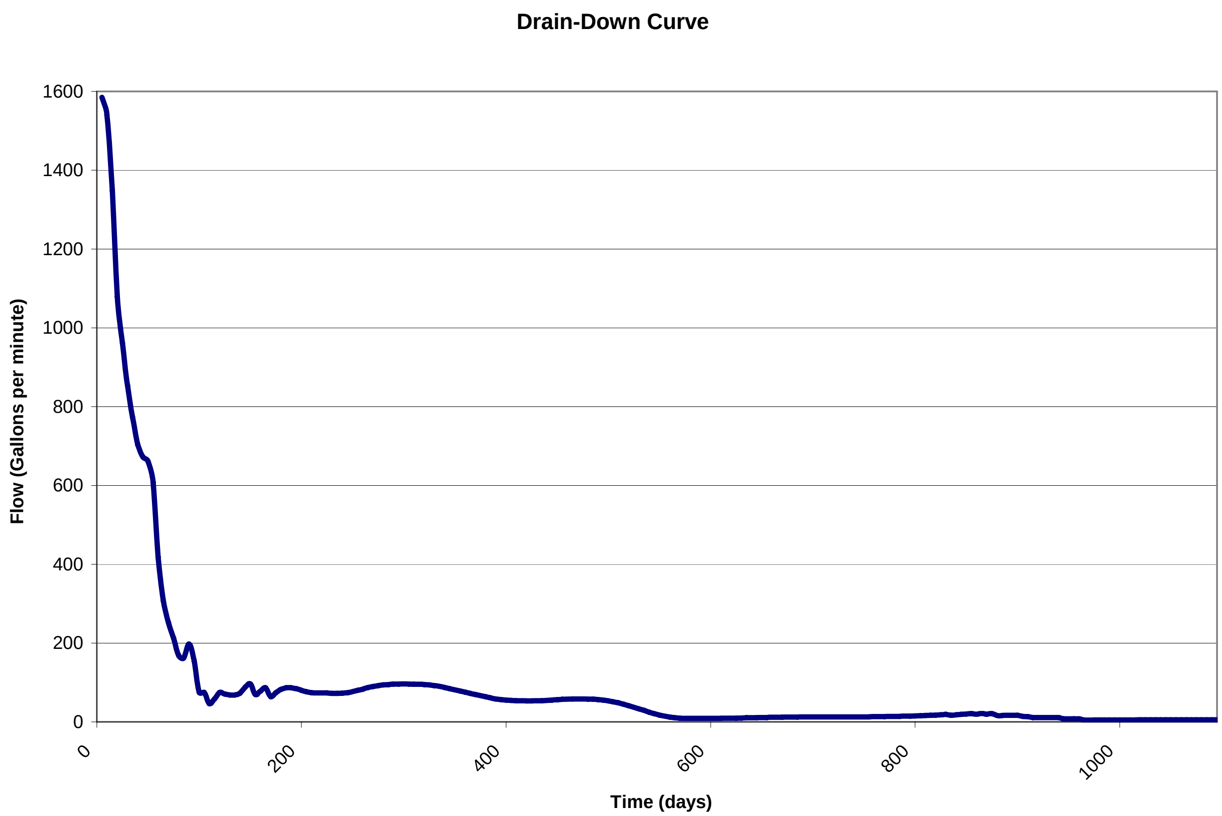

Illustration 3 Spent Ore Material Drain-Down Curve

The closed heap and the ponds located at the base of the heap will be covered with waste rock. The outer surface will be contoured and graded to prevent stormwater from ponding above the closed heap facilities. Following placement of the waste rock, seepage will be limited to the residual drain-down solution as evaporation will prevent meteoric precipitation from infiltrating through the waste rock and into the spent ore. Illustration 4 presents the volumetric moisture content of the closed heap.

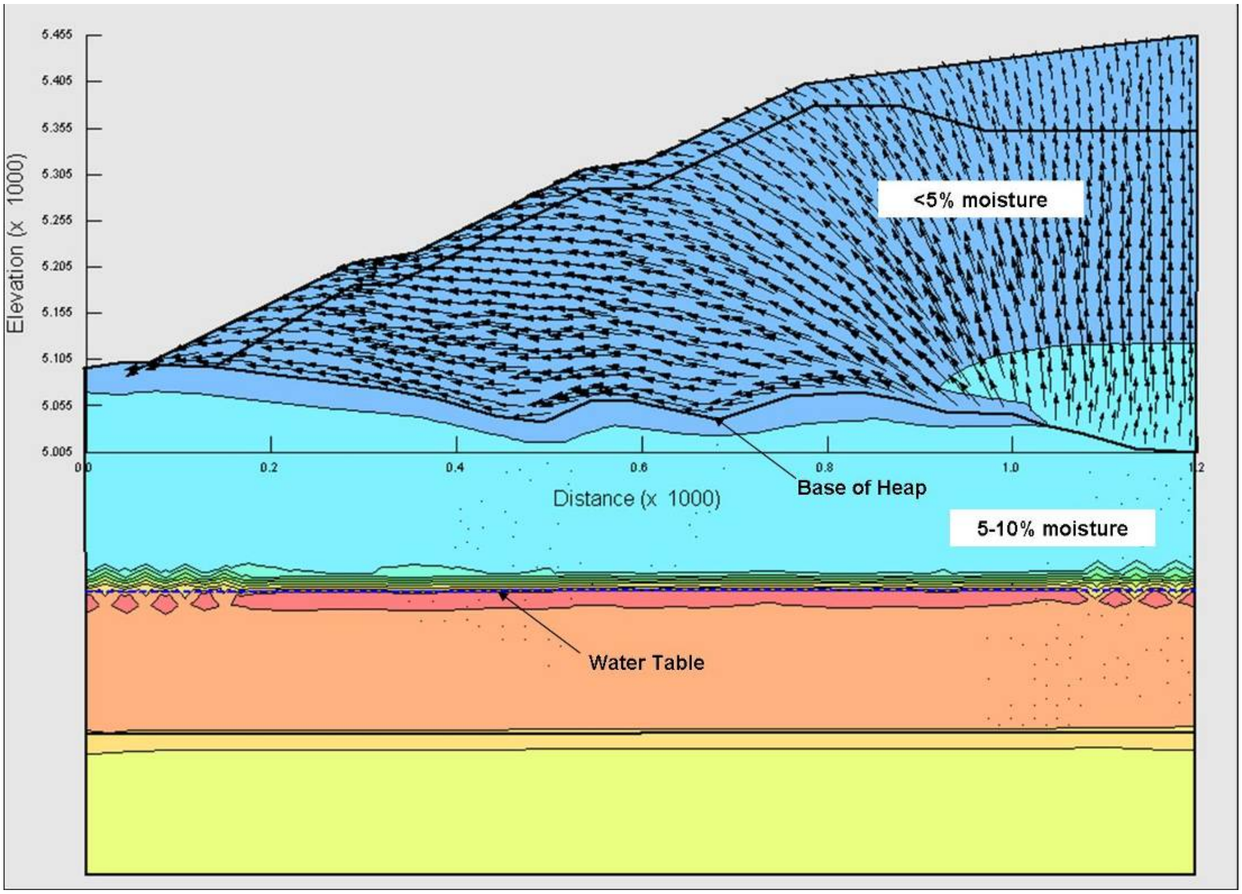

Illustration 4 Volumetric Moisture Content Distribution within the Closed Heap

The volumetric moisture content in the spent ore material is shown to be less than five (5) percent at one (1) year after waste rock is placed over the heap. This represents a saturation level of about 20%. The arrows shown in Illustration 4 represent flow vectors (magnitude and direction) of water in the system. Once the waste rock is placed over the spent ore, the dominant component of the system becomes evaporation and water is drawn up and out of the facility.

This is also supported by the graph in Illustration 5 which presents the water balance of the closed heap for a one (1) year model period having average climate conditions.

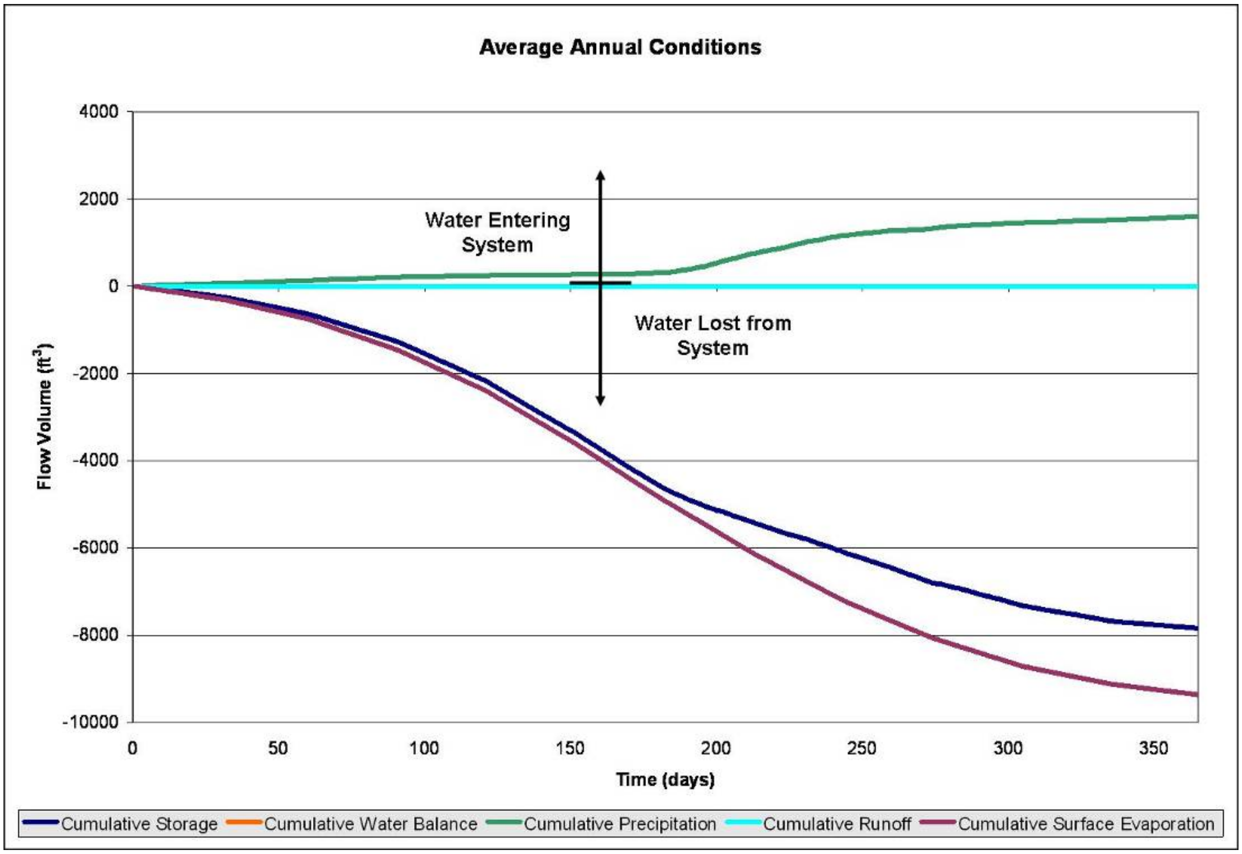

Illustration 5 Closed Heap Water Balance

The lines shown above zero (0) cubic feet (ft^3) represent inflows to the system, while the lines below zero (0) ft^3 represent outflows or loses from the system. The outflows (evaporation and storage) are significantly greater than the inflows, i.e., a negative water balance is observed. Based on these results, water is being removed from storage, thus helping to prevent the future movement of water downward through the spent ore.

The final step of the flow modeling was to confirm the observations of the flow vectors and moisture contents generated by the VADOSE/W model (GEO-SLOPE, 2007a). This was accomplished through particle tracking using CTRAN/W (GEO-SLOPE, 2007b).

A series of particles were placed in the upper portion of the model to determine the inflows/outflows anticipated once the spent ore was covered by waste rock. Additionally, particles were placed in the model regions representing both the waste rock and the spent ore material to determine the depth of influence from evaporation. Illustration 6 presents the configuration of the particle tracking model.

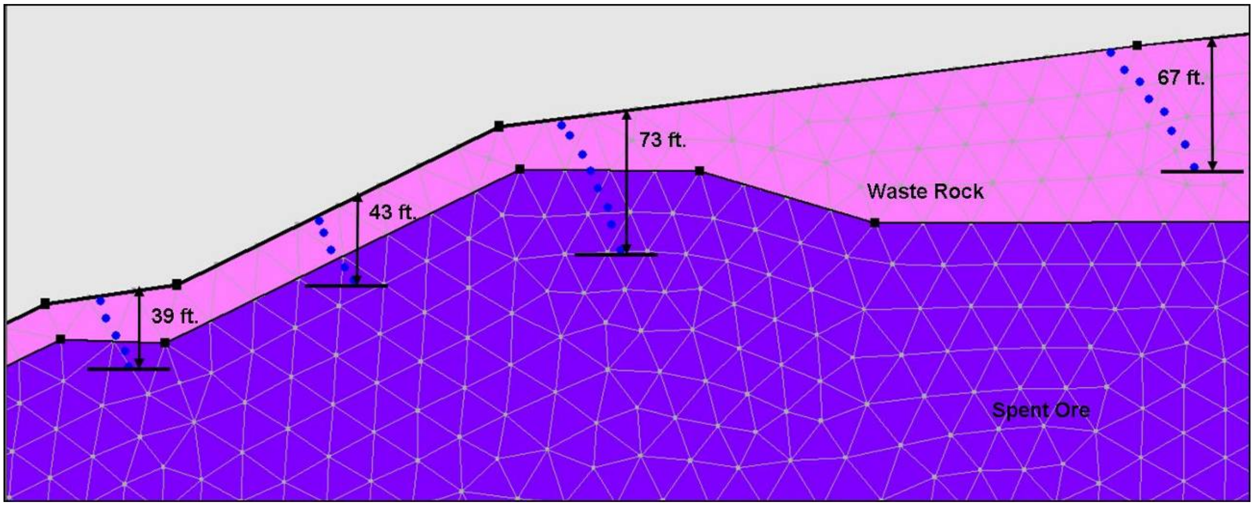

Illustration 6 Closed Heap Particle Tracking Model Setup

The particle tracking model was also run for a one (1) year period based on average annual climactic conditions and flow results from the VADOSE/W (GEO-SLOPE, 2007a) modeling. Illustration 7 presents the results of the particle tracking model.

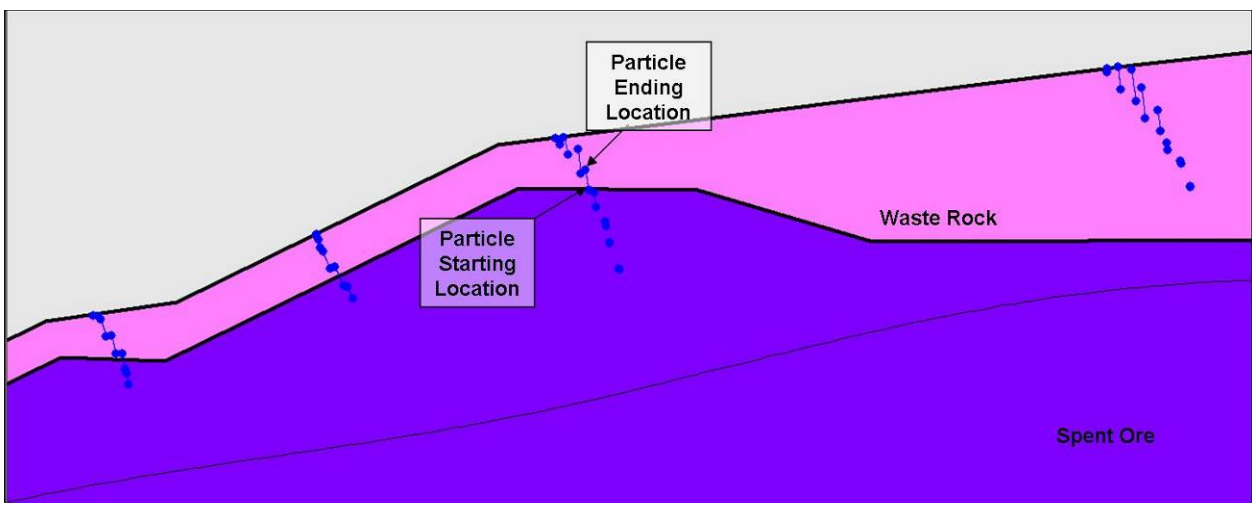

Illustration 7 Closed Heap Particle Tracking Results

The particles either moved toward the surface of the closed facility or did not move over the one (1) year period. On average, particles within 40 feet of the surface moved upward. Below this point, the particles did not move.

In addition to average annual climate conditions, the closure scenario was also modeled using two (2) storm events (100-year, 24-hour and multi-day precipitation). The 100-year, 24-hour storm represents a short, but intense storm event that has a high potential for above average runoff. The multi-day storm represents a potentially higher than average infiltration condition. Table 3 presents a comparison of changes in storage, runoff, and evaporation due to the storm events as a percentage of the total precipitation.

Table 3 Comparison of Modeled Storms to Average Conditions

Scenario	Storage	Runoff	Evaporation
	as a percent of precipitation		
Average Annual Conditions	> -100%	0.00%	> -100%
100-year, 24-hour Storm Event	90.9%	6.16%	-4.96%
Multi-day Storm Event	86.7%	3.65%	-10.0%

Note: Negative values represent water lost from the system.

When these storms are compared to the model results associated with the average conditions, both storms resulted in increased runoff and storage. The increased storage relates directly to increased infiltration. However, it is anticipated that any precipitation that does infiltrate into the waste rock cover will be removed from the facility through evaporation following the storm event.

3.2 Seepage and Geochemical Modeling Results

Based on the flow modeling results, the generation of additional seepage from meteoric precipitation is not anticipated once the waste rock cover is placed. The modeling assumes a minimum waste rock thickness of 20 feet is placed over the spent ore as determined from a separate analysis. However, a waste rock thickness of five (5) feet with a one (1) foot thick soil layer was also determined to provide equal protection as 20 feet of waste rock.

Chemical modeling indicates that drain-down from the spent ore pile will have a low pH and a few constituents slightly above the AWQS. Following completion of the drain-down management, these seepage amounts are expected to be minimal.

4.0 Residual Drain-Down Treatment Options

Seepage (drain-down and infiltration) and storm runoff from the surface of heap will be collected in the PLS Pond during the initial two (2) to three (3) year drain-down period. If after this period (approximate operation Year 10) residual seepage (drain-down) continues, the former PLS and Stormwater Ponds would be converted to a passive treatment system, as needed. Should drain-down have ceased by this time, the closed ponds would only be filled with waste rock without construction of the treatment system.

Two (2) different passive treatment systems were considered. The first was an engineered biological type system. This type of a system would be constructed using a variety of carbon sources (manure, straw, wood chips, etc.) to feed the biological system and limestone to maintain proper alkalinity. Seepage would be routed to the former PLS Pond (Treatment Basin 1) and allowed to attenuate through the treatment materials (crushed limestone, manure, straw, wood chips, etc.). Attenuated solutions would flow into the former Stormwater Pond (Treatment Basin 2) and be further treated. The former Stormwater Pond would be filled with crushed limestone. The second system would only use crushed limestone in both basins. Figure 1 provides a concept of the treatment basins.

In both cases, the concept calls for Treatment Basin 1 to be lined and Treatment Basin 2 to be unlined. Both ponds would first be closed per BADCT guidance prior to construction of the treatment basins.

Seepage from the closed heap would be routed to Treatment Basin 1 using the existing header pipe system associated with the operational phase of the heap. Header pipes would be connected to perforated piping placed above the carbon material, or above crushed limestone, allowing the seepage water to flow down through the material. Attenuated solutions would flow along the bottom of the lined basin, through pipes, and into Treatment Basin 2. The primary treated solutions would then flow down through more crushed limestone and be allowed to infiltrate into the ground.

For both systems, both basins would be mounded with crushed limestone and then covered with geotextile prior to placing waste rock in the area (see Figure 1).

For the first treatment option, the following materials are anticipated:

Treatment Basin 1 (former PLS Pond)

30% crushed limestone (2-inch minus material)

10% manure

10% straw

40% wood chips

10% sawdust

Treatment Basin 2 (former Stormwater Pond)

Crushed limestone (2-inch minus material)

For the second treatment option, crushed limestone would be placed in both basins.

The resulting water quality from these two (2) treatment scenarios are presented in Table 4 and are compared to the Arizona Water Quality Standards (AWQS) and also to non-treated residual seepage.

Table 4 Passive Treatment Geochemical Model Results

	AWQS	Seepage Without Treatment	Seepage Through Engineered Biological System	Seepage Through Crushed Limestone
	milligrams per liter (mg/L)			
pH	NE	3.23	6.24	6.84
Pe	NE	17.4	-3.2	13.8
Total Alkalinity (as $CaCO_3$)	NE	-86.9	1215	241
Total Dissolved Solids	NE	970	2185	1207
Percent error	NE	2.00	1.96	1.71
Silver	NE	0.005	0.005	0.005
Aluminum	NE	16.0	1.2	0.6
Arsenic	0.01*	0.008	0.008	0.008
Barium	2	0.015	0.015	0.015
Carbon	NE	0.65	1217	153
Calcium	NE	149	149	249
Cadmium	0.005	**0.087**	**0.087**	**0.087**
Chlorine	NE	3.77	3.76	3.77
Chromium	0.1	0.010	0.010	0.010
Copper	NE	30.2	30.2	30.2
Fluorine	NE	1.95	1.95	1.95
Iron	NE	0.300	0.300	0.003
Potassium	NE	5.93	5.93	5.93
Magnesium	NE	42.3	42.2	42.3
Manganese	NE	0.008	0.008	0.000
Molybdenum	NE	0.002	0.002	0.002
Sodium	NE	10.9	10.9	10.9
Nickel	0.1	**0.163**	**0.163**	**0.163**
Nitrite + Nitrate as N	10	0.035	0.035	0.035
Oxygen	NE	7.47	0.00	7.47
Lead	0.05	0.016	0.016	0.016
Sulfur (Sulfate + Sulfide)	NE	704	235	704
Selenium	0.05	**0.056**	**0.056**	**0.056**
Zinc	NE	4.97	4.97	4.97

NE = A numeric AWQS has not been established for the constituent.
* The proposed AWQS for arsenic is 0.01 mg/L. The current AWQS for arsenic is 0.05 mg/L.
Bold values are those that exceed the AWQS

The results of the geochemical models for the two (2) treatment options improved the water quality of the seepage. Both options increased the pH of the seepage water due to the alkalinity sources of the treatment systems. In addition to an increase in pH, the engineered biological system also significantly reduced the quantity of sulfate in the seepage water. Although not shown in the model results, this type of treatment will also tend to enhance the removal of metals from the system through precipitation and are more effective under anoxic (oxygen deficient) conditions. Additionally, the materials required to construct this type of system are often readily available at a relatively low cost.

Although the crushed limestone does not have an impact on the sulfate concentration, these types of systems also effectively remove other metals through combined pH adjustment and precipitation of metal oxy/hydroxides onto the limestone surface. The precipitation of metals can cause a crushed limestone system to lose its effectiveness over time by blocking access to the alkalinity.

5.0 Conclusions

Drain-down from the heap is expected to reach a near steady-state flow rate of less than ten (10) gpm two (2) to three (3) years after the cessation of leaching. Waste rock is anticipated to be placed over the heap and the ponds located at the toe of the heap in approximate operational Year 10, after the initial drain-down period.

After the placement of waste rock on the heap, the drain-down rate, if still continuing at this time, will decrease and will not be subject to additional seepage from meteoric precipitation. The closed heap facility will experience a negative water balance since evaporation is expected to draw water out of the system in the upper 40 feet of the facility.

For the Heap Leach Facility, drain-down seepage from the heap is expected to be of low pH and have a few constituents (cadmium, nickel, and selenium) that are at or slightly above the AWQS. Residual low pH leach solution is expected to remain in the pore spaces of the spent ore, thus resulting in low pH drain-down seepage. Treatment, however, is expected to raise the pH of the seepage and possibly attenuate some of the metals.

6.0 References

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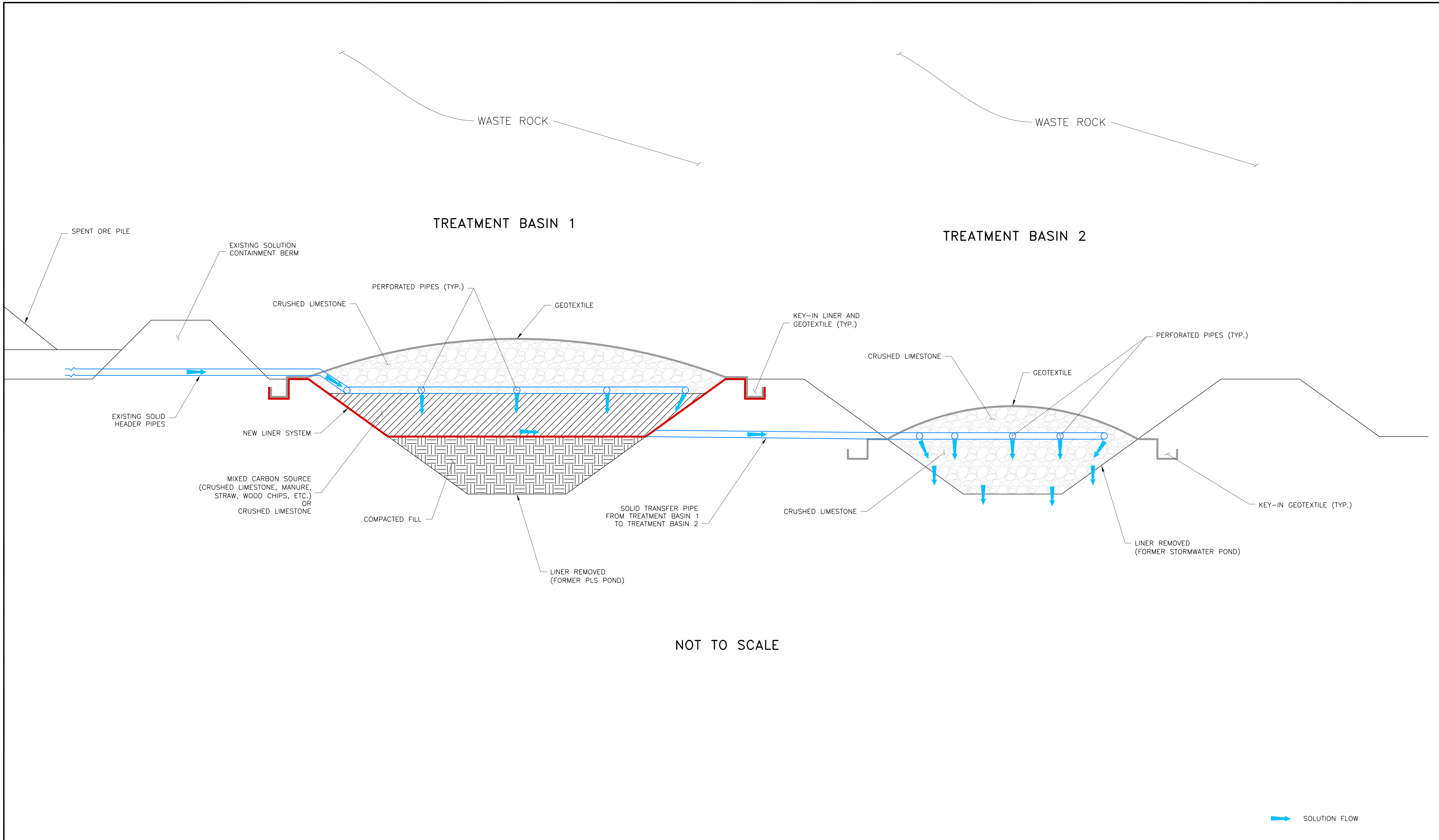
FIGURE



JANUARY 2010

FIGURE 1
DRAIN-DOWN TREATMENT CONCEPT
ROSEMONT COPPER PROJECT