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Memo

To:	Chris Garrett, P.HGW.	**Date:**	July 18, 2012
Company:	SWCA	**From:**	Corolla Hoag, P.G. Mike Sieber, P.E. Jan Rasmussen, Ph.D., P.G
Copy to:	Dale Ortman, P.E. Stephen Day, SRK Principal Consultant (Geochemistry)	**Project #:**	183100.02
Subject:	Rosemont Copper DEIS – Response to EPA Geochemistry Comments - Final		

This memorandum provides a technical response to concerns and questions by the U.S. Environmental Protection Agency (EPA) in their detailed agency review of the *Draft Environmental Impact Statement for the Rosemont Copper Project* (EPA, 2012). The comments were compiled and summarized for Coronado Forest Service (CNF) in SWCA's memorandum *Request for Professional Opinion on USEPA Comments on Geochemistry, Memorandum*, March 2, 2012 (SWCA, 2012).

This review was undertaken, and the Technical Memorandum prepared, at the request of SWCA and the EPA, in accordance with a *Statement of Work and Request for Cost Estimate* from Mr. Dale Ortman dated March 4, 2012. This memorandum was prepared by the following SRK personnel:

- Mike Sieber, P.E. Consultant (Hydrology) – Sections 1 and 6;
- Corolla Hoag , P.G., Principal Consultant (Geology) – Sections 2, 3, 4;
- Jan Rasmussen, Ph.D., P.G., Associate Senior Consultant (Geology) – Section 5;
- Staff under the supervision of David Bentel, Principal Consultant (Civil Engineering) – Section 7.

Internal review was performed by S. Day, C. Hoag, C. Stone, and D. Bentel.

Complete references for the cited documents are provided in Section 8. In the interest of clarity, the complete text of the USEPA questions are presented in blue italicized text and the original numbering scheme is retained.

1 Infiltration and Seepage Estimates

- *Whether or not estimates of infiltration and associated seepage are under-reported using the current modeling techniques.*

<u>Executive Summary</u>

Infiltration and seepage models for the proposed Rosemont mine facilities were prepared by AMEC (2009) for the Dry Stack Tailings and by Tetra Tech (2010e) for the Waste Rock Storage Area and Heap Leach Facility. Assumptions were provided in the reports regarding climate (rainfall, evaporation) and saturated and unsaturated material properties for the tailings, waste rock, and heap leach. SRK reviewed the reports and responded with numerous comments on both models as documented in Section 1.1 of this report and as listed in reference citations in Section 8 of this report. Additional information was provided by AMEC and Tetra Tech in response to questions by the Arizona Department of Environmental Quality (ADEQ) as part of the Aquifer Protection Permit application process (see Tetra Tech, 2010l) and technical review by SRK, and others. Tetra Tech made adjustments to the model parameters based on technical reviews, and as a result issued

Infiltration, Seepage, Fate and Transport Modeling Report – Revision 1 in November 2010 (Tetra Tech, 2010k).

Infiltration seepage model results indicate that draindown seepage for the Dry Stack Tailings is predicted to be approximately 8.4 gpm (or 0.0074 gpm tailings per acre). Seepage through the Waste Rock Storage Area is controlled by evaporation and runoff and is predicted to be *de minimus*. After the initial draindown from the spent Heap Leach Facility Approximately 10 gpm of draindown is expected through a 3-year period after the leaching ceases (Mine Operation Year 9). Tetra Tech modeled the infiltration and seepage for placement of 5 to 25 ft of waste rock over the Heap in Year 10; placement of a waste rock cover is intended to reduce the rate of continued infiltration into and seepage from the spent Heap Leach Facility. Post-cover draindown is predicted to continue at approximately 5 gpm within 5 years, 2.5 gpm within 15 years, and approximately 1 gpm within 45 years of placement of the waste rock cover.

Tetra Tech (2010e; 2010k) used a climate dataset with a 1-year average precipitation amount, applied a small amount of the precipitation on a daily basis, and then removed it by evaporation. This is not how precipitation typically occurs in southern Arizona. Rain occurs year round with greater daily amounts during the winter months and late summer “monsoon” season. Model estimates could be refined to provide a more defensible pre-mining estimate and/or evaluated through sensitivity analyses to assess the maximum seepage estimates. The model estimates will be most reliable, however, when actual rock material is available for observation and actual measurement under a variety of climate conditions. SRK’s experience shows that field construction errors are another source of seepage that is greater than expected or modeled. For the various facilities, it is therefore prudent to assume that seepage will occur in potentially greater amounts than was modeled and to put into place (1) a facility inspection plan to monitor seepage rates and volumes and (2) a contingency plan if seepage exceeds modeled estimates. A refined model using longer term data with realistic application of seasonal precipitation and evaporation rates is recommended for closure planning.

<u>Dry Stack Tailings Facility</u> – Estimates of infiltration and seepage have the potential to be underestimated annually or seasonally owing to the use of an average daily precipitation in the model as described above. The current model assumes that a small amount of precipitation occurs on a nearly daily basis and that evaporation occurs to remove the small daily quantity. Long-term transient simulations with actual daily climate data would provide a more defensible estimated seepage rate.

<u>Waste Rock Storage Area</u> – Estimates of infiltration and seepage through the Waste Rock Storage Facility were modeled with various climate scenarios. The infiltration seepage model may have the potential to underestimate seepage with a model developed with average daily precipitation. Tetra Tech revised the model, using University of Arizona Tucson Meteorological Station daily precipitation data for a 10-year simulation. Tetra Tech did not compare this precipitation to the precipitation data from the Nogales or Santa Rita Meteorological stations; therefore, the Tucson precipitation dataset was not established to be valid for the Rosemont project area. The revised Tetra Tech model seepage was controlled by evaporation. A transient infiltration seepage model, with long-term actual daily climate data valid for the Rosemont project area, would provide a more defensible estimated seepage rate.

<u>Heap Leach Facility</u> – Estimates of the Heap draindown rate may underestimate the time to achieve draindown of 10 gpm. If Heap run-of-mine material is finer than currently estimated, based on known material properties, or if the blocky run-of-mine material breaks down more than anticipated during placement and leaching the estimate would be underestimated. The 20-ft waste rock cover will reduce, but not completely prevent infiltration and seepage, so long-term, low-flow drainage was predicted (Tetra Tech, 2010d). Plans were developed to manage the draindown solution throughout the residual draindown period because the quality of Heap draindown is predicted to exceed groundwater or surface water quality standards, even using the proposed one- or two-stage treatment plan (Tetra Tech, 2010k; 2011a). Further refinement of the Heap infiltration and seepage model is not recommended at this time. Re-calibration of the model can be refined most effectively and more accurately when actual materials have been placed and daily and seasonal infiltration and drainage rates have been tracked for a sufficient period by site operators.

1.1 Summary of Work Completed by Rosemont

Infiltration seepage modeling analyses were performed for the Rosemont Project Heap Leach Facility, Waste Rock Storage Area, and the Dry Stack Tailings. Tetra Tech (2010e) performed the infiltration and seepage modeling for the Heap Leach Facility and the Waste Rock Storage Area. AMEC (2009) performed the infiltration seepage modeling for the Dry Stack Tailings. The models were based on regional climate data (daily average precipitation data for 1-year) and the sites-specific geotechnical properties generated through physical test work.

SRK reviewed and responded to the AMEC (2009) document (SRK, 2009b). SRK prepared two additional memos responding to AMEC's comments (SRK, 2009c; 2010b). SRK reviewed the Tetra Tech *Infiltration, Seepage and, Fate and Transport Modeling Report* (Tetra Tech, 2010e) and prepared a review memo (SRK, 2010d). SRK also reviewed Tetra Tech's *Infiltration, Seepage, and Fate and Transport Modeling Report Model Report–Revision 1* (Tetra Tech, 2010k) and prepared review comments (SRK, 2011a). Tetra Tech prepared a memo responding to the SRK memo, February 14, 2010 (Tetra Tech, 2011b). SRK prepared a follow-up response memo (SRK, 2011b).

1.2 Dry Stack Tailing Storage Facility (AMEC, 2009)

The AMEC infiltration and seepage analysis was a draindown model of the tailings using an as-placed moisture content of 18 percent that is expected to drain to a field capacity of 11 percent. They reported a peak draindown rate of 8.4 gpm. Their report was reviewed by SRK (SRK, 2009). AMEC responded to SRK comments (AMEC, 2010a) and conducted additional infiltration seepage analysis. AMEC modeled a 100-year 24-hour storm event followed by average yearly values of evaporation. Most of the precipitation was reported as runoff owing to the short-duration, high intensity events that were assumed would not infiltrate into the tailings. The precipitation was reported as evaporation and as storage in the rock buttress; 1 percent of the precipitation was reported as seepage to groundwater.

AMEC did not complete a long-term transient simulation with historical daily climate data applicable to the Rosemont project; therefore, the infiltration and seepage may have the potential to be underestimated on an annual or seasonal basis.

1.3 Heap Leach Facility (Tetra Tech, 2010e and 2010k)

SRK reviewed the initial Tetra Tech's 2010 *Infiltration, Seepage, Fate and Transport Modeling Report*, which included the infiltration seepage model for the Heap Leach Facility (Heap), and prepared review comments (SRK, 2010c). Tetra Tech reported the Heap design used for the Heap infiltration seepage model was run-of-mine with three layers. The top portion (Layer 1) was described as gravel to boulders greater than 12-inches. Layer two was described as poorly sorted sand to boulders. Layer three was described as poorly sorted fine sand to boulders. The Heap infiltration and seepage simulation used 1-year of average climate data. Based on model results, Tetra Tech reported that approximately three years following cessation of leaching the draindown rate would be less than 10 gpm, 5 gpm within 5 years, and 2.5 gpm within 15 years, and continue draining at approximately 1 gpm for 45 years. The use of 1-year of average climate data will artificially eliminate the effects of infiltration related to longer-term precipitation, evaporation, temperature, and humidity data. SRK previously addressed this shortcoming with the Tetra Tech Heap conceptual model (SRK, 2010c, 2011a, and 2011e).

Tetra Tech elected not to change the conceptual model of the Heap as recommended (SRK, 2010c, and 2011e). Although Tetra Tech did not revise the Heap conceptual model (Tetra Tech, 2011b, and 2011d), they did prepare *Infiltration, Seepage, Fate and Transport Modeling Report - Revision* 1 (TT, 2012b). In the revised report Tetra Tech described a 10-year infiltration seepage simulation for which they used 10 years of precipitation data from the University of Arizona meteorological station in Tucson. The evaporation data used were from the Rosemont weather station. Tetra Tech did not compare the U of A precipitation data to the data from the Nogales or the Santa Rita meteorological stations. The infiltration and seepage from the Heap may be underestimated because of the relatively short model period (10 years) and the use of precipitation data from Tucson.

1.4 Waste Rock Storage Area (Tetra Tech, 2010e and 2010k)

The Tetra Tech conceptual model of the Waste Rock Storage Area (WRSA) was the same as described above for the Heap. The coarse rock size fractions assumed in the model are appropriate for the WRSA. As previously mentioned, it is SRK's opinion that the Tetra Tech method of applying precipitation in small daily quantities spread over the year has the potential to underestimate seepage annually or seasonally that could occur from the WRSAs. In *Infiltration, Seepage Fate and Transport – Revision*, Tetra Tech reported on a 10-

year infiltration seepage simulation for which they used 10 years of historical precipitation data from the University of Arizona Meteorological station in Tucson (Tetra Tech, 2010k). The evaporation data used was from the Rosemont weather station. Tetra Tech did not compare the U of A precipitation data to the data from the Nogales or the Santa Rita meteorological stations to see how they correlated seasonally or by month. SRK concludes that infiltration and seepage from the WRSA has the potential to be underestimated owing to the assumption of small daily precipitation quantities, the relatively short model period, and use of precipitation data from Tucson, which may not correlate with conditions at Rosemont.

2 SPLP Data

- *Whether the use of SPLP data as the basis for geochemical modeling potentially underestimates concentrations of contaminants in seepage.*

Executive Summary

Synthetic Precipitation Leaching Procedure (SPLP) and Meteoric Water Mobility Procedure (MWMP) data, in conjunction with humidity cell test (HCT) data, were used to generate solution source terms for the geochemical fate and transport models prepared for mine facilities at Rosemont. The facilities include the Waste Rock Storage Area, Heap Leach Facility, Dry Stack Tailings, and a Pit Lake. The models predict the water quality that would result when precipitation: (1) infiltrates into the rock materials stored in the mine facilities, (2) interacts with oxidizing rock materials, secondary mineral salts, and mineral precipitates, and (3) seeps from the facilities. The Pit Lake model predicts the water quality of a post-closure recovering lake composed of inflowing groundwater, direct precipitation, and runoff of precipitation from the pit benches, including the intensely fractured blast zone.

Concern was expressed by SRK during previous reviews about the use of SPLP data in the geochemical models because of the potential to underestimate concentrations in the starting solutions and in the resulting modeled seepage. The concern arose from the high water-to-solid ratio used in the SPLP and questions about the implications for understanding trace element solubility.

For this deposit and the models constructed, however, Tetra Tech has provided sufficient statistical and written documentation to show that the SPLP data, where used, provide appropriate starting solutions for their geochemical models. They have also documented that scaling the SPLP results for Rosemont rock materials is not necessary to match the results expected in HCTs because SPLP results for many constituents are higher than those found in the HCT results (Tetra Tech, 2010o). Factoring SPLP results, however, was performed in the source term for the blast zone. SRK will not repeat all previous comments provided to CNF, but brief supporting comments are provided below.

2.1 Summary of Work Completed by Rosemont

Geochemical test work was performed by Rosemont's consultant Tetra Tech in a staged process that acquired and analyzed oxide and sulfide ore, tailings, waste rock, and pit wall materials according to the proportions of materials to be mined and/or exposed in the ultimate pit wall. The test work followed guidance recommended by Arizona Department of Environmental Quality (ADEQ) for Tier #1 and Tier #2 geochemical characterization of waste rock, heap leach, tailings, and open pit rock materials (ADEQ, 2004).

The sample descriptions, sample selection methods, and updates on test results are described in a number of Tetra Tech's reports and technical memoranda (2007; 2008a; 2008b; 2009c; 2010a; 2010j; 2010n; 2010p). Preliminary screening results were reviewed and a work plan developed to address sampling gaps and to identify which materials required additional testing including those materials with the potential to generate problematic water quality. After the characterization work was completed in 2006-2007 on waste rock materials, additional similar core materials were selected to characterize pit wall run off.

Sample materials included historic and recent diamond drill core, crushed core coarse rejects, simulated tailings materials, grab samples from historic waste rock dumps, soils, and column test residues. Tetra Tech has documented that the materials tested were representative of the spatial and lateral geological variability expected to be seen in the steeply dipping mineralized and unmineralized Paleozoic sedimentary formations, Precambrian and Tertiary intrusive rocks, and younger sedimentary overburden formations (i.e. Willow

Canyon arkose, Gila Conglomerate). The heap leach and simulated tailings materials tested appear to be representative of the dominant materials to be mined during the life of mine for the Heap Leach and Dry Stack Tailings facilities.

Analyses were performed by laboratories certified to perform environmental analyses by industry standard methods. The SPLP leachates for the Rosemont samples were analyzed for major cation/anions, common ions, trace metals, and radiochemicals. MWMP leachates were analyzed for major cation/anions, common ions, and trace metals. HCT leachates were analyzed weekly for field parameters and common ions for 35 weeks and major cations/anions and trace metals every five weeks for 20-25 weeks. Field column test leachates were measured every five weeks for 22 weeks for field parameters, common ions, major cations/anions, and trace metals.

The SPLP analyses using an EPA-approved method (EPA, 1994) was one of several geochemical tests performed during Rosemont's site characterization efforts as listed in Table 1. Static laboratory tests performed for the Rosemont studies include acid base accounting (ABA) with LECO sulfur speciation analyses (Sobek and others, 1978), acid generation potential, acid neutralization potential, net acid generation pH (NAG pH) (Stuart, 2005), whole rock analysis, SPLP, and MWMP (ASTM, 2002). Short-term leach tests performed include tests SPLP and MWMP. ADEQ approved and designated preliminary analytical procedures (i.e. mineralogical characterization, bottle roll tests, ABA analysis, acid generation potential, acid neutralization potential, NAG pH, physical properties tests, and whole rock analysis) and short-duration leach tests (SPLP, MWMP, Leachable sulfate/soluble solids) as Tier #1 geochemical characterization methods for characterization of mine waste materials.

Kinetic test work was performed using humidity cell tests (ASTM method D5744-96) on rock types that required additional test work according to the sampling results, and interpretation of the earlier tests as described in Tetra Tech's geochemistry report (2007) and technical memoranda (2009c; 2010a; 2010n; 2010s). On-site column tests were also initiated but were terminated after 22 weeks owing to cementing of the materials within the column. ADEQ has approved and designated long-term predictive tests such as HCTs, column/lysimeter tests, and test plots/piles as Tier #2 geochemical characterization methods for mine wastes. Also approved is analysis of radiochemical constituents. A more detailed summary is provided in Section 2.2 of the test methods used to characterize mine wastes for the geochemical modeling efforts.

2.2 Summary of Test Methods Used in Geochemical Evaluation

SPLP tests are used to assess which elements have the potential to leach when meteoric water comes in contact with the rock. They are relatively inexpensive tests requiring small test volumes relative to other procedures, so a large number of Tier #1 characterization screening tests can be performed in an effective manner. EPA Method 1312 method calls for analysis of the solids for total metals and treatment of the solids with a weak sulfuric and nitric acid rinse. The rinse has a pH of 5.0 to simulate natural precipitation and a water-to-rock ratio of 20:1. This method provides an indication of short-term leaching (18±2 hours) of soluble constituents and readily dissolvable constituents from dried mined materials. The solids are screened to be less than 9.5 mm (0.4 in); reducing the grain size may increase the reactivity. Short-term leach tests such as SPLP provide no information on long-term conditions (such as depletion of carbonate minerals and resulting acidification) and may underestimate leachability and resulting concentrations owing to high solution to solid ratio.

The MWMP test procedure is similar to that of SPLP except that the rinse solution has a pH of 5.5 (matching the less acidified precipitation and meteoric water in the western U.S. relative to the eastern U.S.) and a water-to-rock ratio of 1:1. The procedure requires screening the test materials to be less than 50 mm (<2 in) and a larger test volume is needed than for SPLP. MWMP has primarily been used in Nevada but is increasingly favored elsewhere, including Arizona, because it has a lower solution to solid ratio and has a longer test duration compared to SPLP (typically 24 hrs but <48 hrs). It has the same disadvantages as SPLP in that it cannot provide information on leaching related to long-term processes.

Humidity cell tests (HCT) are longer-duration kinetic tests that provide information on which to base long-term water quality but are expensive to run and manage relative to Tier #1 test work. They are commonly performed on the materials demonstrated in short-duration characterization test work (e.g. ABA, sulfur analyses, and NAG pH) to be potentially ARD generating or to be of uncertain potential to generate acid or to have the potential to generate problematic water quality under long-term natural weathering processes. The

HCT method incorporates weathering reactions of primary minerals and the resultant leachate interactions. Deionized water is used in a 0.5:1 to 1:1 (depending on the preference of the geochemist) water-to-rock ratio. Weekly cycles of 3-days of alternating dry and wet air are followed by leaching. The test period is a minimum of 20 weeks, but can run longer depending on the results of test results. Weekly testing is done for acid rock drainage indicator parameters with less frequent analysis of major cations/anions and trace metals (typically every week to start and every 4-5 weeks later in the test period). The granular material used is less than 6.3 mm (<0.25 in); grain size reduction may increase reactivity. This test is not suitable for saturated materials.

Field column tests are designed to provide long-duration leaching information including mineral reactions, precipitation/mobilization of secondary salts under the site climate conditions. Weekly testing is done for indicator parameters with less frequent analysis of major cations/anions and trace metals. There is a potential for channel flow or blinding to occur in the columns.

Table 1 Geochemical test methods completed by Rosemont

Test Type	ADEQ Test Level	Test Method and Description	Materials Tested	Analysis Completed
Chemical Composition	Tier #1	Total Metals EPA 6010B, EPA 200.7	Historic/Recent Drill Core, Recent Coarse Rejects, Soils, Historic Waste Rock Dumps, Simulated Tailings	Total Metals
	GW characterization	Dissolved & Total Metals	Groundwater	Indicator parameters, major cations/anions, trace metals
Acid Base Accounting (ABA)	Tier #1	Modified Sobek Method w. LECO sulfur analysis	Historic/Recent Drill Core, Recent Coarse Rejects, Soils, Historic Waste Rock Dumps, Simulated Tailings	AP, NP, NPR, NNP total-S, pyritic-S, sulfide S, organic-S, residual-S
Net Acid Generating (NAG	Tier #1	Single addition NAG (Stuart, 2005)	Historic/Recent Drill Core, Recent Coarse Rejects, Soils, Historic Waste Rock Dumps, Simulated Tailings	NAG pH
Mineralogical Composition	Tier #1	Visual	Historic/Recent Drill Core, Recent Coarse Rejects, Waste Rock Dumps, Outcrops	Visual, qualitative description of minerals present
Short-term Leach Tests (Static)	Tier #1	Synthetic Precipitation Leaching Procedure (SPLP) EPA Method 1312	Historic/Recent Drill Core, Recent Coarse Rejects, Soils, Historic Waste Rock Dumps, Simulated Tailings	Indicator parameters, major cations/anions, trace metals
	Tier #1	Meteoric Water Mobility Procedure (MWMP) ASTM E2242-02	Historic/Recent Drill Core, Recent Coarse Rejects, Soils, Simulated Tailings	Indicator parameters, major cations/anions, trace metals
Radiochemical Analysis	Tier #2	SPLP EPA Method 1312	Selected Historic/Recent Drill Core, Coarse Rejects, Simulated Tailings	U, gross/adjusted alpha, gross beta, radium226+228,
Long-term Leach Tests (Kinetic)	Tier #2	Humidity Cell Test (HCT) ASTM D5744-96	Coarse rejects selected from rock types with potential to generate acid (andesite, arkose, Bolsa, Epitaph, Earp); Simulated Tailings for dominant rock types	Indicator parameters, major cations/anions, trace metals, alkalinity, acidity
	Tier #2	Field Column Tests	Recent Coarse Rejects for arkose and andesite	Indicator parameters, major cations/anions, trace metals, alkalinity, acidity

Source: Compiled by SRK from several Tetra Tech reports – primarily Tetra Tech (2007, 2008a; 2008b; and Attachment 3 of 2010s).

2.3 How SPLP Data Was Used in Geochemical Models

For the three mine facilities, both SPLP and MWMP data were used in the starting solutions in simple mixing models. SPLP results were not scaled or factored in any way. MWMP analyses were preferentially used in the source terms if available (Tetra Tech, 2010k; 2011c). These MWMP results for waste rock primarily included andesite and Willow Canyon arkose.

For the Pit Lake model, the starting solutions were derived from mixing proportional volumes of groundwater and precipitation chemistry with the runoff chemistry expected from precipitation contacting and reacting with the pit walls and blast zone (Tetra Tech, 2010o; 2010p; 2010r). The most significant input volume in the Pit Lake model is the inflowing groundwater component, which uses chemical loads established from average water quality sampling data collected from the pit monitor wells (Montgomery and Associates, 2007; 2009a). SRK reviewed the use of average groundwater quality for the Pit Lake source term in another memorandum (SRK, 2011f). SPLP data were used to simulate the chemical load for pit wall runoff, which is a much smaller water volume than the groundwater inflow but can be more concentrated in cations/anions and trace metals. For the blast zone, HCT initial flush chemistry was used to address the chemistry associated with the dominant pit wall rocks such as arkose. Where HCT data were unavailable, SPLP data were used instead. As a conservative measure, however, the major cations/anions were multiplied by a factor of three and the trace metals by a factor of two.

2.4 Appropriateness of SPLP Data

SRK previously questioned the use of SPLP results as inputs to the geochemical models (SRK, 2010c; 2010d; 2011b; 2011c; 2011f). SPLP results have been documented in many case studies to be less concentrated than those seen in MWMP results owing to the more dilute solution to rock ratio. SPLP results are also typically less concentrated than results measured in the first flush rinse from a HCT but can be consistent with concentrations found in HCTs in later rinses. These differences can be explained by differences in the liquid to solid ratios used in the test. In tests such as SPLP (20:1 solution-rock ratio), soluble minerals are dissolved but diluted to low concentrations. As the contact ratio decreases, the soluble products are diluted less and concentrations increase.

Tetra Tech explained the use of SPLP analyses in their models and responded to SRK's comments in a number of reports and technical memoranda (2010k; 2010o; 2010p; 2010r). The differences in concentrations expected in different tests were generally not apparent. This surprising finding appeared to indicate that solubility of trace elements is low in this geological setting. After reviewing the responses and discussing this with key Tetra Tech personnel in a conference call, SRK concluded SPLP data could be used in the geochemical model source terms (SRK, 2011f). SRK acknowledges that while the data are the best available to develop contact water chemistry for the mine wastes, uncertainty remains in the interpretation of differences between the various leaching tests because the procedures are variable in other ways (for example, differences in particle size). This uncertainty needs to be considered in the design of water management and monitoring programs.

A brief review with respect to the Pit Lake geochemical model is provided below.

Tetra Tech (2010o) compared the results of SPLP, MWMP, and HCT results as related to characterizing the pit wall run-off and providing source terms for the Pit Lake geochemical model. Plots showing a range of SPLP and MWMP results (and average values) for sulfate (SO_4), calcium (Ca), magnesium (Mg), selenium (Se), arsenic (As), and copper (Cu) were graphically plotted in comparison to the HCT results for the same formations. The HCT program focused on rocks demonstrated during Tier#1 testing to be acid generating or that have unknown potential to generate acid (i.e. andesite, Willow Canyon arkose, Bolsa Quartzite, Epitaph, and the Earp Formation). A comparison of leachate results can be made for these five formations.

A completely qualitative comparison is presented in Table 2 using Tetra Tech's graphical plots for seven constituents in the five potentially problematic formations. For silica-rich Bolsa, for example, SPLP results for SO_4, Ca, Mg, Se, and Cu are very similar if not slightly higher in concentration than seen in long-term HCT results over 35 weeks of analysis. The average SPLP arsenic result for the Bolsa is significantly higher than seen in the HCT results indicating higher and more variable concentrations were tested in the numerous SPLP samples versus the material used for the HCT. Use of SPLP values in the Pit Lake Model source term for arsenic would be a conservative approach relative to using the HCT results. There would be no difference in using SPLP concentrations relative to HCT in the source terms for the other parameters as the results are near-identical. MWMP results are slightly higher than SPLP results for arkose and andesite (shown in brown shading in Table 2); the SPLP results for these two rock types, however, look nearly identical to what was measured in the HCTs after the first week of leachate analysis.

Table 2 Qualitative visual comparison of plotted SPLP/MWMP results with HCT for selected formations (Tetra Tech 2010o)

Parameter	Andesite	Arkose	Bolsa Quartzite	Epitaph	Earp Formation
Calcium	SPLP equal to HCT. MWMP slightly higher than HCT.	SPLP slightly lower than long-term HCT; MWMP slightly higher than long-term HCT.	SPLP equal to long-term HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT. High variability owing to evaporate interbeds and skarn.	SPLP equal to long-term HCT
Magnesium	SPLP & MWMP equal to long-term HCT	SPLP slightly lower than long-term HCT; MWMP slightly higher than long-term HCT.	SPLP equal to long-term HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT. High variability owing to evaporate interbeds and skarn.	SPLP less than HCT
Manganese	SPLP & MWMP equal to long-term HCT	SPLP & MWMP equal to long-term HCT	Not plotted.	SPLP slightly higher than HCT	SPLP equal to long-term HCT
Sulfate	SPLP equal to HCT. MWMP slightly higher than HCT.	SPLP slightly lower than long-term HCT; MWMP slightly higher than long-term HCT.	SPLP equal to long-term HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT. High variability owing to evaporate interbeds and skarn.	SPLP equal to long-term HCT
Arsenic	SPLP & MWMP results are significantly higher than HCT.	SPLP & MWMP low range equal to HCT results; average SPLP & MWMP is significantly higher than HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT	SPLP low range equal to HCT results; average SPLP is significantly higher than HCT.
Copper	SPLP & MWMP equal to long-term HCT	SPLP & MWMP low range equal to HCT results; average SPLP & MWMP is slightly higher than HCT	SPLP slightly less than HCT	SPLP equal to long-term HCT	SPLP equal to long-term HCT
Selenium	SPLP equal to long-term HCT. MWMP is higher than HCT.	SPLP & MWMP equal to long-term HCT	SPLP equal to long-term HCT	SPLP equal to long-term HCT	SPLP equal to long-term HCT

Source: Qualitative comparison compiled by SRK, 2012
Notes:
Blue boxes = formations/ constituents with no appreciable difference between SPLP, MWMP, and HCT results.
Red boxes = formations/parameters with higher SPLP or MWMP results than seen in HCT.
Brown boxes = formations/ parameters with SPLP results equal to HCT but MWMP results are higher than HCT.
Green boxes = formations/ parameters where SPLP results are less than HCT.

Tetra Tech also addressed SRK's questions about scaling SPLP analyses with respect to HCT results and using scaled SPLP source terms used in Pit Lake predictive model (Tetra Tech, 2011b). Scaling laboratory SPLP and MWMP results is often necessary to match acid drainage conditions seen in the field. As the water to rock ratio for SPLP and HCT is 20:1 and 1.5:1, respectively, one can scale SPLP result to match HCT results by dividing SPLP by 13.3. Tetra Tech found good agreement in scaled SPLP results for major chemical constituents (Illustration 1, Tetra Tech, 2011c) in comparison to those from the HCT first flush results. The scaling correction performed poorly for the concentration of trace metals, which were significantly over estimated. For long-term HCT results, scaling was not successful for either major or trace constituents as SPLP results were commonly higher in concentration than were HCT (see Illustration 2, Tetra Tech, 2011b).

As mentioned in Section 2.3, HCT data and factored SPLP data (2 to 3 times laboratory concentrations) were used for source terms for the highly fractured blast zone and pit wall run-off. Ultimately, the net effect of using SPLP results versus only HCT first-flush and long-term data is relatively small and would not result in a change to the final Environmental Impact Statement preferred alternative or mitigation alternatives. This is because rainfall run-off down the pit walls and through the blasted rock is relatively infrequent (with high evaporation rates) and the majority of the chemical loading to the recovering alkaline Pit Lake is from groundwater inflow.

3 Additional Kinetic Testing

- *Whether kinetic testing would have been more appropriate or made a difference to the modeling and the applicability of the additional tests (bottle roll) suggested by the USEPA.*

Executive Summary

Kinetic test work was performed by Rosemont on the five rock formation materials demonstrated to be acid generating or to have uncertain potential to generate acid based on Tier #1 geochemical test work. Question 2 above addressed the applicability of using SPLP or MWMP results for source terms for rock types lacking HCT results.

Adequate static and kinetic leaching test work and modeling has been performed during the pre-mine characterization, modeling, and permitting activities to assess the expected water quality related to the proposed mine facilities. Additional kinetic test work is not warranted during the current permitting phase. Additional update tests, performed during the mine life with actual waste rock, tailings, pit wall bench faces, and spent leach materials, will be needed to support detailed closure studies and the final closure designs.

Bottle roll tests are another short-duration leach test similar to the SPLP and MWMP that can be used for environmental characterization of mine-related leachates. The overall model results would not be expected to change if the Tier #1 test work were redone using this method or if additional kinetic testing was performed.

3.1 Is Additional Kinetic Testing Needed?

As recommended in ADEQ guidance, Rosemont performed long-duration kinetic testing to evaluate the results seen during static tests and to estimate the rates of acid generation, acid neutralization, and sulfide oxidation (ADEQ, 2004) from mine waste materials. HCTs were performed on rock materials that were demonstrated to be acid generating or which have uncertain potential to generate acid based on the results of the Tier #1 phase of geochemical characterization per ADEQ and other industry standard guidance (ADEQ, 2004).

Acid-generating rock types (Cambrian Bolsa Quartzite and Tertiary andesite) and rocks with uncertain acid-generating characteristics (Pennsylvanian-Permian Earp Formation, Permian Epitaph Formation, and the Cretaceous Willow Canyon Formation) were evaluated by HCTs. The andesite and arkose represent approximately 79% of the materials to be placed on the Heap Leach Facility, 48% of the materials to be placed on the Waste Storage Area, and 30% exposed in the ultimate pit wall. The Bolsa, Earp, and Epitaph comprise minor components of the Waste Rock Storage Area, Dry Stack Tailings, and ultimate pit wall.

Additionally, two HCTs were performed on simulated tailings samples representing the dominant sulfide formation (Horquilla Limestone) and a mix of five sedimentary formations (in proportional amounts) to be mined in Year 0 to Year 3. During the 35 weeks of HCT analyses, the effluent from the two tailings samples maintained neutral pH and constant, elevated alkalinity (Tetra Tech, 2008a). A decrease in alkalinity (with or without decrease in pH) is an indicator that pH values may be about to decrease and generate more acidic effluent. Many of the trace metal constituents were not detected above detection in the alkaline effluent, and none of the constituents exceeded the reference Arizona Aquifer Water Standards (AWQS). Arsenic was detected at low levels above detection in the Tailings-022807 and was detected in concentrations that exceed the reference national drinking water Maximum Contaminant Level for arsenic (0.01 mg/L) in Week 20. Elevated arsenic concentrations were measured in the initial flush in Week 0 for Year 0-3 Tailing. Elevated arsenic and selenium (above MCL), and elevated total dissolved solids and sulfate (above the reference secondary drinking water standard of 250 mg/L) were noted in a number of first flush analyses in the tests for arkose and andesite. Elevated arsenic and selenium were noted previously in SPLP and MWMP analyses for several of the rock samples tested.

SRK has reviewed Tetra Tech's reports and memoranda explaining the geochemical test program including HCT test setup, sample selection and compositing, justification for test duration, results and treatment of results in setting up source terms for the geochemical models (SRK, 2010a; 2010c; 2010d; 2011b; 2011c; 2011d; 2011f). Questions posed to Tetra Tech were answered satisfactorily. Question 2 above in this memorandum addresses the appropriateness of using SPLP or MWMP data to represent source terms for those rock types without HCT analyses. HCT analyses were used in the Pit Lake Model but not in the models for mine facilities (Waste Rock Storage Area, Dry Stack Tailings, and Heap Leach). There were no exceedances of reference AWQS modeled for the Dry Stack Tailings and very low seepage levels are expected (0.0074 gpm per acre). Elevated concentrations of arsenic are expected in seepage from the Waste Rock Storage Area if it occurs, but seepage is not expected or is expected to be *de minimus*. Heap draindown is predicted to have exceedances of AWQS post water treatment, so will not be discharged.

Adequate static and kinetic leaching test work and modeling has been performed to assess the expected water quality related to the alternatives for the mine facilities and mitigation alternatives. Updated kinetic tests, performed during the mine life with actual waste rock, tailings, pit wall bench material, and spent leach materials, will be needed to support detailed closure studies and the final closure designs. Additional kinetic test work is not warranted during the current permitting phase because it will likely not change the outcome of the four geochemical models.

3.2 Bottle Roll Tests and Applicability to Geochemical Modeling

Bottle roll tests are another ADEQ-approved Tier #1 preliminary test for characterization of mine waste materials. This test is a method in which a ground sample (<2 mm or <0.787 in) is agitated in an extractant solution for 48 or 72 hours and then analyzed for indicator parameters, major cations/anions, trace metals, radiochemicals, or organic compounds. This test procedure calls for finer particle size than SPLP (<9.5 mm) or MWMP (<50 mm) and a longer leach time than SPLP (18-20 hrs) or MWMP (24-48 hrs). Higher concentration results may occur given the finer surface area and longer leaching time. SRK is not aware of a case study that presents bottle roll, SPLP, and MWMP analyses on comparable samples from a deposit similar to the Rosemont deposit.

SRK's experience is that bottle roll tests are typically performed during pre-feasibility or feasibility metallurgical test work (or for optimization studies after production has begun) rather than for environmental test work. The tests are used to assess solubility and extraction under various concentrations of processing reagents such as sulfuric acid raffinate for copper or sodium cyanide for gold. Using bottle roll tests in place of other Tier #1 environmental tests is not expected to generate appreciably different analyses or change model outcomes owing to their general similarity to MWMP and SPLP tests, although some specific constituents may be more concentrated in specific samples.

4 Possible Underestimation of Arsenic and Selenium

- *Whether arsenic and selenium concentrations specifically may be underestimated by the geochemical modeling.*

<u>Executive Summary</u>

Geochemical modeling for Rosemont's APP-regulated facilities (Dry Stack Tailings Facility, Heap Leach Facility, Waste Rock Storage Area, and the Pit Lake) has been completed and submitted to the regulatory agencies for review. The model simulations and sensitivity analyses predict the water chemistry from three processing related facilities and a future pit lake. Laboratory test work, primarily on recent and historic drill core, was performed on geological materials representative of these facilities. The model assumptions and source terms are based on currently known information about the site climate conditions, hydrogeology, geology, and geomorphology and incorporate the conceptual designs for the facilities. Industry standard modeling code was used to perform the simulations.

All model simulations have the potential to underestimate or overestimate specific constituents for a variety of reasons – the primary reason being if non-representative materials were used for the testwork. In comparison with various water quality standards (for reference purposes only) seepage from the Waste Rock Storage Area (if it occurs), is predicted to be elevated with respect to the National Primary Drinking Water Standard of 0.01 mg/L arsenic, but not exceed the Arizona Aquifer Water Quality Standard of 0.05 mg/L. Draindown from the spent Heap Leach Facility is predicted to exceed reference national and state numeric groundwater standards for three constituents (cadmium, nickel, and selenium) even with a proposed two-stage treatment method. It cannot be discharged to the environment regardless of concentration or draindown rate and will need to be managed throughout the draindown period. Contingency planning typically allows for mechanisms to inspect and monitor seepage that may occur from engineered facilities and to respond to unexpected excessive routine or seasonal seepage through implementation of additional engineering controls (i.e. sumps, collection basins, pumpback wells, etc.) if needed.

4.1 Comparison of Leachate Values to Reference Water Quality Standards

Although there are no mandatory compliance limits for laboratory derived leachate results, it is standard practice to compare the results to relevant reference groundwater standards as an indication of the potential for leachates to exceed local groundwater quality standards during operations or post-closure. Mines subject to environmental regulation under an Aquifer Protection Permit (APP) issued by ADEQ report their compliance monitoring results with respect to the Arizona Aquifer Water Quality Standards (AWQS). The AWQS is generally set to the same numeric standard as the National Drinking Water Maximum Contaminant Limit (MCL), with the exception of arsenic (As) (0.05 mg/L versus 0.01 mg/L for MCL) and uranium (no AWQS set for this constituent). When naturally occurring background concentrations for a constituent exceed an AWQS, a calculated site-specific Aquifer Quality Limit is set for this constituent.

4.2 Summary of Work Completed by Rosemont and Results

Assessment of the concentrations of arsenic and selenium found at the site in groundwater and rock and soils materials has been completed by Rosemont. Laboratory test work has been completed to assess concentrations of leachate derived when meteoric water or precipitation contacts rock materials over short test durations (static tests) and the concentrations measured in long-duration (kinetic) tests in which weathering and mineral reactions may contribute to water quality. The test work was completed on representative geological materials found in approximate proportions as the material to be mined. A summary of arsenic and selenium analyses performed by Tetra Tech and used in the geochemical models is presented below.

Arsenic Results: Elevated naturally occurring arsenic is documented in numerous wells in Arizona (Spencer, 2002). Site water ranges from very low arsenic concentrations to concentrations nearly three times the reference national MCL of 0.01 mg/L. The presence of arsenic-bearing minerals at site was documented in the results of the total element analyses. The geochemical model simulations indicate the water quality for seepage from the Dry Stack Tailings Facility and Heap Leach Facility is <u>not predicted</u> to exceed the Arizona Aquifer Water Quality Standards (AWQS) for arsenic of 0.05 mg/L. Arsenic is estimated to be non-detect in the Dry Stack Tailings draindown with very low concentrations (0.0052 mg/L) expected in the recharge from flow-through drains. Seepage is not expected to occur from the Waste Rock Storage Area. If seepage does occur, arsenic <u>is predicted to exceed</u> the reference national MCL of 0.01 mg/L, but will not exceed the AWQS. Elevated arsenic may occur for first-flush rinsing of arkose and andesite in the bench faces of the ultimate pit wall but the Pit Lake water quality <u>is not expected to exceed</u> reference standards owing to the dilution by inflowing groundwater. The Pit Lake is expected to be a terminal sink on a long-term basis.

Selenium Results: Elevated concentrations of naturally occurring selenium have not been measured in site groundwater wells or in nearby springs or seeps. Selenium was not measured above detection in the majority of total element analyses that were performed. It was measured above detection in one solids sample each of Martin, Epitaph, and quartz monzonite; two solids samples of andesite; and in four tailings samples (Colina, Escabrosa, Horquilla, 4-7 Year). The SPLP and MWMP analyses for selenium were generally below detection. The model simulation results indicate the leachate water quality for the Dry Stack Tailings Facility, and Waste Rock Storage Area is <u>not predicted</u> to exceed the reference AWQS and national MCL for selenium of 0.05 mg/L but will be elevated with respect to natural groundwater (Tetra Tech, 2010h; 2010m). Selenium in the draindown solution from the spent Heap Leach Facility <u>is predicted to exceed</u> the AWQS even with two-stage treatment. The draindown solutions are not planned to be discharged to the environment and will be evaporated in a double-lined process pond during the draindown, sent to the SX/EW Plant, sent to the Mill, or otherwise managed (Tetra Tech, 2010b). Selenium elevated above the reference national MCL may be expected from first-flush rinsing of broken and blasted pit walls, but the Pit Lake water quality is not expected to exceed reference standards owing to dilution by large volumes of in-flowing groundwater.

4.3 Prediction Success and Work on Area-Wide Fate and Transport Model

Case studies for new and existing mines indicate caution is always warranted with predictive geochemistry modeling work (Kuipers and others, 2006). Recalibration of models may be a recommended procedure once sufficient operations data have been acquired. Prior to mining, infiltration, seepage, and fate and transport geochemical modeling based on sound assumptions about site-specific material properties, climate data, and test results is the best estimate possible of the potential volumes and seepage water quality during the environmental permitting phase.

There is always a potential in any model to underestimate or overestimate a specific constituent. Additional refinement to the Rosemont fate and transport models at this time is not expected to change the outcome of model conclusions that currently show some constituents are expected to be elevated in concentration. With respect to Rosemont facilities, the Heap draindown will require management regardless of the draindown rate as the spent solution has been predicted to exceed one or more water quality standards including selenium. For the Dry Stack Tailings, a number of constituents such as magnesium, potassium, sulfate, fluoride, total dissolved solids, selenium, and molybdenum are predicted to be elevated above background groundwater quality conditions (Tetra Tech, 2010m) but not elevated above reference AWQS or national MCLs where applicable.

Two groundwater numerical flow models has been prepared and submitted to ADEQ (Montgomery & Associates, 2009b; Tetra Tech, 2010q). Groundwater baseline monitoring is in progress to establish background water quality in the proposed Point-of-Compliance (POC) wells. ADEQ requires a technical demonstration that water quality standards or site Aquifer Quality Limits will be met at the applicable POCs. The demonstration of compliance with groundwater quality standards incorporates the facility's expected leachate volume and leachate water quality (derived from laboratory test work), the background water quality and aquifer properties, and results of a numerical flow model to predict the downgradient water quality at the POC. Arizona Revised Statutes 49-244(2)(b)(iii) specifies the maximum distance an POC monitoring point can be located from the toe of a pollutant management facility such as a heap or tailings facility. Mitigation measures are required if water quality standards will be exceeded based on an area-wide fate transport model or other numeric calculation that incorporates site groundwater quality, site aquifer properties, and the aquifer loading calculations from seepage volumes/quality derived from geochemical modeling.

Tetra Tech has provided evidence that the mine facilities are located within the open pit water shed and the Pit Lake is predicted to be a terminal sink with long-term inward hydraulic gradient. Regardless of model predictions (calculated versus actual concentrations) or the facility location, BADCT engineering controls and best management practices are required by ADEQ to minimize and mitigate degradation to the aquifer caused by any potential discharges during construction, operation, closure, and post-closure activities. Regardless of concentrations found in actual leachate versus test work or modeled in facility fate and transport models, the ultimate test is meeting groundwater standards at the POC. If the numeric standards are not met, mitigation measures must be implemented.

5 Porphyry Copper Site Analogs

- *Whether there are appropriate site analogs among other Arizona mines or other mines in similar climates, considering the geology and nature of the Rosemont copper deposit; model.*

Executive Summary

EPA has asked if there is site analogue for the Rosemont deposit and proposed operation – presumably to assess whether environmental issues occurring at an analog site might also have the potential to occur at the Rosemont operation. There are no identical analogs to the geologic setting at Rosemont among other porphyry copper deposits in Arizona or nearby areas considering the deposit geology (proportions of similar rock types), mineralization, and alteration. The deposit geologically that is most similar to Rosemont is the Mission mine located west of Rosemont within Pima County near Sahuarita, Arizona. Mission has similar Paleozoic carbonate host rocks, a quartz monzonite porphyry intrusion, copper + molybdenum + silver mineralization, and a thick cover of arkose overlying the mineralized rock, all of which are similar to Rosemont but in different proportions.

There are no identical analogs to Rosemont's Dry Stack Tailings facility among other porphyry copper mines in Arizona or nearby areas. Copper tailings facilities for active and inactive open pit operations in Arizona, New Mexico, Nevada, and Utah are conventional tailings facilities built between 15 to 100+ years ago by upstream or downstream construction methods with slurried tailings materials. These tailings facilities (if active and not drained) have high water content relative to the water content in a dry stack tailings facility such as is proposed for Rosemont. Rosemont's Dry Stack Tailings is expected to have 15-18% moisture and will be built on Cretaceous Willow Canyon Formation – an indurated sedimentary formation consisting of sandstone, siltstone, and conglomerate. Many of the tailings facilities in Arizona were sited on Holocene alluvium (i.e. Mission), Tertiary unconsolidated or semi-consolidated basin fill, sedimentary formations, or dacite tuff (i.e. Hayden, Pinto Valley, Sacaton, Sierrita, San Manuel, Twin Buttes). Others were sited on a mix of young basin-fill formations and older less permeable sedimentary, crystalline igneous or metamorphic rocks (i.e. Bagdad, Christmas, Ray).

The most recently built analogs to Rosemont's proposed Heap Leach Facility Heap are the heap leach pads at the Safford operation (ADEQ, 2012) and at the Carlota operation (ADEQ, 2008). Both facilities use geosynthetic clay liners, overliner cushion material, and low linear density polyethylene 60-mil liner with leak detection and recovery system similar to what is being proposed. Both operations have double-lined process ponds with leak detection and recovery systems, but these types of process ponds are found at several operations. Rock leach dumps without liners are in use at Bagdad, Mineral Park, Ray, and Silver Bell but are not analogous to Rosemont's Heap Leach Facility. These unlined rock leach dump facilities are typically placed in an open pit watershed and incorporate engineering controls and geological properties to ensure best available demonstrated control technology (BADCT) measures are in place.

There are waste rock storage analogs to Rosemont among other porphyry copper mines. Waste rock at nearby mines is typically placed in stand-alone storage facilities close to the pit rim or in an in-pit dump (i.e. Copperstone, San Manuel, and Mission). The Waste Rock Storage Area at Rosemont will be placed within the Open Pit watershed. Any seepage that penetrates deeper than the vadose zone and reaches the water table will co-mingle with groundwater and ultimately report to the Open Pit and future Pit Lake. Waste rock has been over dumped on closed gold heap facilities in Nevada.

5.1 Introduction

Exact geological site analogs to the geology of the Rosemont deposit are those porphyry copper deposits that contain sulfide mineralization in skarn[1] from Paleozoic carbonate formations and a thin overlying layer of oxide mineralization in skarn, but that do not include significant quantities of mineralized calc-alkaline intrusive igneous rock within the mine.

The Rosemont deposit is classified as U.S. Geological Survey Model 18a Porphyry copper, skarn-related deposits (Cox, 1986, p. 82), although the intrusive rocks at Rosemont are scarcer than those at the other deposits listed for the model type. These types of deposits contain chalcopyrite in stockwork veinlets in hydrothermally altered intrusive rocks and in skarn. Examples given in the model description include Ruth (Ely), Nevada, Christmas and Silver Bell, Arizona. Additional deposits used for the grade-tonnage graphs include Lakeshore (Tohono), Mission, Silver Bell, and Twin Buttes, Arizona.

Nearly all porphyry copper deposits in Arizona and nearby areas (Figure 1) contain considerable amounts of the mineralized intrusive igneous rocks (30 to 100% of volume mined). The ore-bringing intrusive in Arizona porphyry copper deposits is most commonly mapped as Tertiary quartz monzonite porphyry (Tqmp) or Tertiary-Cretaceous granodiorite or porphyry (TKp or Tgdp). There are several lithologic variants of these dominant mineralizing intrusive units based on slight differences in chemistry and texture. There are also numerous map abbreviations for both quartz monzonite porphyry and granodiorite porphyry. For simplicity,

[1] Skarn is defined as coarse-grained calc-silicate minerals that replace carbonate-rich rocks during contact metamorphism (Einaudi, 1982).

the following comments will use term quartz monzonite porphyry (Tqmp) to refer to a family of related Early Tertiary/Late Cretaceous-age calc-alkaline porphyry intrusions found in Arizona and adjacent areas.

5.2 Rosemont Deposit

Rosemont is dominantly a copper sulfide deposit but it also contains recoverable copper oxide, molybdenum sulfide, and silver mineralization (Anzalone, 1995). Mineralization is hosted by steeply dipping Paleozoic carbonate rocks. The rocks are overlain by Lower Cretaceous Willow Canyon Formation (indurated Bisbee Group sedimentary rocks), Tertiary Gila Conglomerate (semi-consolidated sedimentary rocks), and unconsolidated Quaternary alluvium. Tertiary-Cretaceous-aged, quartz monzonite porphyry and/or feldspar porphyry is a minor component of the rocks found at surface based on geologic mapping (Bradford and Ferguson, 2007; Figure 20 of Draft EIS). It is a minor component of the rock in the proposed open pit based on exploration drilling and 3-dimensional (3D) geologic modeling. As shown in Table 3, Tqmp comprises approximately 6% of the total materials to be mined during the life of mine including waste rock, oxide ore, mixed oxide/sulfide ore, and sulfide ore.

Relative to other rock types, Tqmp comprises approximately 2% of the sulfide ore to be mined. The Tqmp remaining after the chalcopyrite (copper iron sulfide) is removed will be mixed with other ground rock and deposited in the Dry Stack Tailings. At Rosemont, the oxide copper ore is 11% of the total ore materials to be mined; these materials will be placed on a lined Heap Leach Facility (Heap). Although Tqmp is 21% of the oxide ore placed on the Heap, this material is only 2% of the total ore at Rosemont and 0.77% of the total materials (ore plus waste) to be mined.

The rocks exposed in the ultimate pit wall consist dominantly of Paleozoic carbonate units, Willow Canyon Formation, and Gila Conglomerate. Minor amounts of Precambrian granite and Willow Canyon andesite are found in the upper benches. The ultimate pit wall contains only minor exposures of Tqmp intrusive on the upper benches of the northwest part of the open Pit. It is called Cretaceous-Tertiary intrusive [KTi]) on the cross section shown on Figure 2 (and Figure 5 of Montgomery & Associates, 2010).

The general climate assumptions for Rosemont are summarized in Table 4 with similar data for comparable mine sites. For the examples provided, Rosemont has higher annual precipitation, higher annual maximum temperatures, and higher annual evaporation rate than the other two sites. A greater percentage of annual precipitation is in the form of snow at two of the examples (Robinson and Santa Rita/Chino. A list of geologic abbreviations is presented in Table 5.

5.3 Porphyry Copper Deposits with Skarn

Porphyry copper deposits or copper mines that contain skarn in carbonate rocks in Arizona and surrounding areas are presented in Table 6. These include the Rosemont, Christmas, Johnson Camp, Mission, Silver Bell, and Twin Buttes deposits in Arizona, Pinos Altos and Chino deposits in New Mexico, and the Robinson deposit in Nevada,

Mission (including Pima and San Xavier), Silver Bell, Chino, and Robinson mines are the only active porphyry copper deposits that mine skarn that contains sulfide mineralization. In addition, these Chino and Robinson contain an estimated 35% or more of mineralized quartz monzonite, which differs from Rosemont.

Twin Buttes, Christmas, and the underground Pinos Altos (NM) mines are either inactive or were closed before current regulations were in effect. These mines did contain mineralized carbonate host rocks (skarn), but they also had 30% to 50% quartz monzonite porphyry, which differs from Rosemont.

Johnson Camp does not mine sulfide ore and does not contain quartz monzonite porphyry intrusions; it is classed as a carbonate replacement or disseminated bulk-mineable copper deposit, rather than a porphyry copper deposit.

5.4 Nearest Porphyry Copper Mines

The nearest Cu-Mo sulfide-bearing skarn deposits with similar geology to Rosemont are Mission (active) and Twin Buttes (inactive) in the Pima mining district on the west side of the Santa Cruz valley. The Twin Buttes and Mission-Pima-San Xavier deposits are porphyry copper deposits that were formed at similar structural depths on opposites sides of a large pluton (the northern equigranular phase of the Ruby Star granodiorite dated at 58.9 Ma). The deposits in the Pima district were later sliced into separate blocks by numerous episodes of normal faulting (Stavast and others, 2007).

The Mission mine differs from Rosemont because a significant mass of Tertiary quartz monzonite porphyry occurs in the consolidated Mission and Pima open pits (Jansen, 1982), but Tqmp is less than 6% of the planned Rosemont open pit. The Mission mine also differs from Rosemont in that there has been no heap leach production of oxide ores. There is only a minor amount of oxide and secondary copper enrichment in the Mission deposit, due to Cenozoic erosion or faulting. More than half of the mineralization in the Mission-Pima deposit is in Triassic-Jurassic volcaniclastic rocks, with the remainder split between Paleozoic contact metamorphosed carbonate rocks and Tertiary quartz monzonite porphyry (Einaudi, 1982). The Mission mine has been in continuous open pit operation since 1961, with earlier underground mining in the 1940s. The Mission waste rock and tailings facilities are located east of the open pit on permeable, unconsolidated Holocene alluvium and Holocene pediment alluvium (<10,000 years).

The Twin Buttes mine is similar to Rosemont in that it contains diopside hornfels and both calcic (andradite +wollastonite) and magnesian (forsterite-tremolite-serpentine) skarn (Stavast, 2007). It differs from Rosemont in that more than half of the open pit is in Tertiary quartz monzonite porphyry, with the remainder in Paleozoic sedimentary rocks and Mesozoic volcanic rocks (Einaudi, 1982). The Twin Buttes mine also differs from Rosemont in that the pre-ore, upper Paleozoic formations, particularly the Epitaph Dolomite, contain thick layers of anhydrite (Barter and Kelly, 1982). The Sierrita Mountains area was located at the northwestern end of the Permian Pedregosa Basin, which would have contained more brackish water and evaporite facies than occurs in the type formations at Rosemont or further south in Cochise County. The Twin Buttes mine began mill/concentrator and tailings operations in 1969, but ceased operations in 1994.

Another geological difference between Rosemont and the Twin Buttes and Mission mines is that the tailings and waste dumps for the mines in the Pima mining district are placed on permeable, unconsolidated Holocene-age sand and gravel. In contrast, Rosemont's waste rock dump and tailings are placed on less permeable Lower Cretaceous Willow Canyon Formation, which consists of indurated, less permeable sandstone and conglomerate.

The Sierrita mine consists of the consolidated former Sierrita and Esperanza open pit mines in the Pima mining district. It is located near Rosemont just south of the Twin Buttes and Mission mines near Sahuarita. It is not geologically similar to Rosemont because the host rocks are early Mesozoic volcanic and Tertiary intrusive rocks, rather than Paleozoic or Cretaceous carbonate rocks. The majority of the Sierrita mine is in the Ruby Star granodiorite and related porphyry intrusive phases. These rock types have much lower capacity to neutralize acid generated by oxidation of contained sulfides. The tailings and waste rock are situated on permeable Holocene sand and gravel in pediment gravel formations and alluvium in shallow arroyos.

5.5 Other Arizona Porphyry Deposits Containing Skarn

Silver Bell does have Paleozoic formations that have been mineralized to form sulfide-bearing skarns. It is not a site analog to Rosemont because of the extensive exposures of dacite and quartz monzonite porphyry in the El Tiro pit (Graybeal, 1982) and Oxide pit (Richards and Courtright, 1966). The minor sulfide-bearing Paleozoic limestone is not processed because Silver Bell only produces copper only from oxide ores. The oxide ore at Silver Bell is rubbleized in place within the open pit or placed on a leach pad.

The Christmas mine is not a site analog to Rosemont because large amounts of the intrusive (estimated 40%) are exposed in the pit walls, whereas Rosemont has only minor outcrops of the intrusive (less than 5%) in the proposed mine area. The open pit at Christmas exposes one third Cretaceous Williamson Canyon Volcanics (basalt and clastic sedimentary rocks), one third Middle Paleozoic carbonates and upper Paleozoic Naco Limestone, and one third Tertiary biotite granodiorite porphyry (Koski and Cook, 1982). Oxide ore was not mined at Christmas and the mine ceased operations in 1982, with recent reclamation work by Freeport-McMoRan Copper & Gold.

The Johnson Camp mine is similar to Rosemont in containing exposures of skarn from Paleozoic carbonates. However, Johnson Camp extracts oxide copper such as chrysocolla, azurite, tenorite, etc. exclusively from the Paleozoic carbonates via heap leach and SX-EW processing. Oxide copper at Rosemont is contained primarily in the Cretaceous arkose, with 16% in andesite and 21% in Tqmp. The Paleozoic carbonates and skarns at Rosemont are dominantly sulfide and mixed sulfide-oxide ore. Johnson Camp also differs from Rosemont in that it is classified as a “disseminated bulk-mineable copper deposit” (Bikerman and others, 2007) and is a carbonate replacement deposit and not a typical porphyry copper deposit. There are no dikes or protrusions of Tqmp or granodiorite porphyry into Paleozoic meta-sediments that have been identified on surface or intersected in drilling or underground workings on the Johnson Camp property (Bikerman and others, 2007).

5.6 Other Porphyry Copper Deposits Containing Skarn in Adjacent States (Different Climate, Different Regulations)

The Central mining district in New Mexico contains several porphyry copper deposits north of Silver City. These deposits are related to Tertiary granodiorite and quartz monzonite porphyry stocks that intruded Paleozoic carbonates and sedimentary rocks and produced sulfide-rich skarn (Einaudi, 1982; McKnight and Fellows, 1978; Nielsen, 1968). These include the Chino open pit mine related to the Santa Rita stock, the Continental open pit mine related to the Hanover-Fierro intrusive stock, and the Pinos Altos underground mine related to the Pinos Altos stock. These mines are not site analogs to Rosemont because large amounts of the copper sulfide-rich Tertiary granodiorite porphyry occur in the mines (estimated 30 to 40%). In addition, these are high-sulfur systems, while the Rosemont system is a low-sulfur system as defined by the percentage of overall sulfide minerals contained in the deposit. The climate in the Central district is also different from Rosemont, in that the elevations at Santa Rita are higher, vegetation contains more piñon trees, and there is higher precipitation, both snow and rain.

The Robinson (Ely or Ruth) district in Nevada consists of three small open pits (Tripp, Veteran, and Ruth) that produce sulfide copper and gold. The Tripp and Veteran pits are not analogous to the Rosemont mine because of the abundant outcrops of the porphyry (Einaudi, 1982). The copper sulfide mineralization is a faulted sequence of porphyry copper-gold deposits that are associated with mildly acidic, monzonitic rocks of Cretaceous age (111 Ma) (Quadra, 2009). Mineralization in the Ruth pit is more analogous to Rosemont although it still contains significant Tqmp. Massive garnet skarn replaced Paleozoic Chainman Shale and Ely Limestone; the deposit is considered to be low sulfur but has more magnetite, pyrrhotite, and pyrite than does Rosemont. The region is a high sagebrush desert climate that is colder and has less rainfall and less evaporation than does Rosemont.

5.7 Porphyry Copper Deposits Not Containing Skarn

Most porphyry copper deposits in Arizona and nearby areas are not site analogs for Rosemont because they do not contain skarn deposits in Paleozoic carbonate rocks. Table 7 presents a list of those deposits that are not site analogs for Rosemont because they do not contain abundant skarn. These deposits include: Ajo, Bagdad, Bisbee, Carlota, Florence, Miami, Mineral Park, Morenci, Pinto Valley, Ray, Sacaton, Safford, San Manuel, Sierrita, and Tohono.

5.8 Environmental Comparison

EPA has requested information on deposit or operations analogs to the proposed Rosemont operation presumably to assess the potential for impacts similar to those experienced by the analog sites. One could theoretically compare the geochemical test work and groundwater quality predicted in various fate and transport models for the similar types of operations with the actual groundwater monitoring data submitted to the Arizona environmental regulatory agencies.

This type of research was done by Kuipers and others, (2006) who compared predicted and actual water quality at 25 hard rock mines in the western United States. The cases studies are dominantly gold/silver mines in host rocks and climate conditions that are not similar to those of the proposed Rosemont operation. Two case studies were selected in Arizona including the Ray porphyry copper mine[2] and the Bagdad porphyry copper-

[2] Ray is an open pit mine with copper oxide and sulfide mineralization in dominantly igneous, metamorphic, and diabase host rocks. Operations include unlined rock dump leach facilities, mill/concentrator, and one conventional slurried tailings facility.

molybdenum mine[3]. Neither of these sites are analogs for the Rosemont operation. As demonstrated in the sections above, there are no identical analogs in Arizona to the Rosemont deposit and overall operation including the proposed construction of the Dry Stack Tailings facility. Many of the Arizona operations have heritage facilities that were built 50 to 100 years ago (prior to protective measures required under the Clean Water Act and Clean Air Act) and are not analogs to the facilities proposed by Rosemont. Additionally, it could be argued that the case studies selected by Kuipers and others may not be applicable as they did not assess situations where carbonate buffering could bring the discharge leachate to a pH of 8 to 9. In SRK's experience, discrepancies at many industrial sites involving environmental contaminants are more frequently attributed to engineering or field construction-related failures rather than predictive modeling errors.

SRK does not have ready access to environmental monitoring data and modeling reports for the active and inactive properties mentioned above to compare the environmental conditions and compliance histories at these operations to what might be expected with Rosemont's operations. Environmental compliance monitoring data and modeling reports are available to the public upon request but it is outside the scope of this review to perform a case study analysis and tabulation.

[3] Bagdad is an open pit operation with dominantly copper sulfide mineralization (+molybdenum) in metamorphic and igneous host rocks. Operations include multiple unlined rock dump leach facilities and two conventional slurried tailings facilities.

Table 3 Percentage of Tqmp in Rosemont mined materials

Material Type	Total Tons of Mined Material (millions)	Tons of QMP (millions)	Percentage of QMP by Type	Percentage of QMP in All Mined Materials
Waste Rock	1,234,962	13,035	1	<1
Oxide Ore (Heap)	69,181	14,406	21	<1
Mixed Oxide/Sulfide to concentrator	13,250	12,360	1	<1
Sulfide	533,094		<1	~3
Total Materials	1,850,485			~6
Pit Wall Exposure	NA	NA	NA	0.5

Source: Production tabulation in Table 1 of Geochemical Solutions, 2012.
NA = Not applicable

Table 4 Comparison of climate conditions at selected mine facilities

Deposit	Average Elevation above Sea Level (ft)	Average Monthly Minimum Temp. (˚F)	Average Monthly Maximum Temp. (˚F)	Average Annual Precipitation (in)	Pan Evaporation (in)
Rosemont[1]	5,400	36	90	16-17	71.5
Robinson[2]	7,000	Nd	82.9	9.7	37.2
Santa Rita (Chino), New Mexico[3]	6,300	38.4	72.5	15.4	ND

Source: Compiled by SRK from various sources as noted. Measurement periods vary according to available source data that are readily available. Minimum temperatures recorded are for January; maximum temperatures recorded are for July.
1 Rosemont – Compiled from Tetra Tech, 2010k.
2 Robinson – Giroux Wash Weather Station at Robinson Site (13 years of records). Meteorological records for temperature are similar to those recorded for nearby town of Ely, Nevada over 43-year period (SRK, 2009a).
3 General historic data and in SRK files
ND = No data available

Table 5 Abbreviations used in Section 5

Abbreviation	Description	Abbreviation	Description
Ag	silver	Perm	Permian
and porph	andesite porphyry	py	pyrite
Au	gold	PZ	Paleozoic
Bi	bismuth	Qmp	quartz monzonite porphyry
bor	bornite	qtz	quartz
broch	brochantite	qtz dior	quartz diorite
bt granodior porph	biotite granodiorite porphyry	qtz dior porph	quartz diorite porphyry
bt qtz monz porph	biotite quartz monzonite porphyry	qtz feld porph	quartz feldspar porphyry
carb	carbonate	qtz lat	quartz latite
cc	chalcocite	qtz monz porph	quartz monzonite porphyry
chrys	chrysocolla	qtz porph	quartz porphyry
cov	covelite	qtzite	quartzite
cpy	chalcopyrite	Qtzt	quartzite
Cret	Cretaceous	seds	sedimentary rocks
Cu	copper	sh	shale
dacite porph	dacite porphyry	sphal	sphalerite
dig	digenite	ten-tet	tennantite-tetrahedrite
dior	diorite	Tert	Tertiary
gal	ganlena	Tqmp	Tertiary quartz monzonite porphyry
goeth	goethite	turq	turquoise
gp	group	UG	underground
gran porph	granite porphyry	up	upper
granodior porph	granodiorite porphyry	volc	volcanics
gyp	gypsum	Zn	zinc
jar	jarosite		
Jur	Jurassic		
lat	latite		
lim	limonite		
Ls	limestone		
mal	malachite		
meta	metamorphic		
metaseds	metasediments		
mid	middle		
Mn	manganese		
mo	molybdenite		
monz	monzonite		
mt	magnetite		
Mz	Mesozoic		
nat Cu	native copper		
OP	open pit		
PC gran	Precambrian granite		

Source: Compiled by SRK

Table 6 Porphyry copper deposits containing skarn in Arizona and nearby areas

Deposit	Mineralized Host Rock	Intrusive Type	Est. % QMP	Skarn Present?	Sulfide Minerals	Oxide Minerals	Mine operation type	Waste Rock Dump?	Tailings?	Heap Leach ?	Pit Lake ?	SX-EW	Reference
Rosemont	sulfide = mainly skarn of Pz carbonates [Horquilla ls] (90%), minor arkose (5%), Qmp (5%); oxide = arkose (50%), Tqmp (15%); andesite (35%)	qtz monz porph, TKp = qtz feld porph; nearby TKg granodior qtz monz stocks	5	upper Paleozoic - mainly Horquilla	cpy, py cc, bor, mo in skarn of Pz carbonates (90%); minor arkose (5%), qtz monz por (5%)	Cu-bearing lim, chrys, ten, mal, az; oxide = arkose (50%), qtz monz porph (15%); andesite (35%)	historic UG & planned OP	yes	yes	arkose, andesite, QMP	future yes	yes	Drewes, 1971; McNew, 1981; Daffron and others, 2007; Bradford & Ferguson, 2007; DEIS, 2011
Christmas	Qtz dior, Granodior porph; up PZ Naco Ls, Cret Williamson Canyon volcanics	Tert (62 Ma): and porph, dacite porph, bt granodior porph, qtz dior	40	minor: Naco marble, andradite skarn, sh=diopsidic hornfels	cpy, bor, py, sphal, minor mo, gal;	minor: shallow gossan (jar, goeth, lim, qtz, gyp); insignificant supergene - cuprite, mal, nat Cu	UG & OP (closed)	yes	yes	no	no	early	Koski & Cook 1982; Eastlick 1968; Perry, 1969
Johnson Camp	lower Pz Bolsa Abrigo	none at mine; Tert qtz monz (53Ma) nearby but unmineralized (later than deposit?)	0	Lower Paleozoic	py, cpy, bor, cc in historical vein replacement UG prod;	OP = Cu in limonite, Cu in Mn wad, chrys, mal, cc, native Cu	historic UG & current OP	no	yes	yes	no	yes	Cooper & Silver, 1964, Bikerman etc. 2007; Clayton, 1964; Romslo, 1949
Mission (Pima, San Xavier)	Pz Perm Concha Epitaph, primarily in Jurassic Rodolfo (Jvc) volcaniclastics, some Angelica arkose; nearby qtz monz porph, granodior porph	Tertiary qtz monz porph (58-56.7 Ma)	50	Upper Paleozoic	cpy , py, minor bor, mo; very minor gal, ten-tet, sphal not recovered	minor amount of remnant oxide & secondary cc	historic UG & current OP	yes	yes	no	no	no	Langlois, 1978; Jansen, 1982; Kinnison, 1966; King, 1982
Pinos Altos, NM	early dior & mid Pz ls & sh; Cret. Beartooth Qtzt & Pinos Altos qtz monz	early diorite dikes; later Pinos Altos qtz monz	30	early Zn skarn; later	cpy, sphal, py, mt, Bi, bor, cov	very minor; cov on grain boundaries	UG 1987 – 1995	none - sent to Luna mill	no	no	no	no	Osterberg & Muller, 1994; McKnight & Fellows, 1978

Deposit	Mineralized Host Rock	Intrusive Type	Est. % QMP	Skarn Present?	Sulfide Minerals	Oxide Minerals	Mine operation type	Waste Rock Dump?	Tailings?	Heap Leach ?	Pit Lake ?	SX-EW	Reference
Robinson (Ely), NV	most in qtz monz porph, minor (20%) in meta Pz ls & sh	Cret monz to qtz monz (121 Ma)	35	only 100 ft from intrusion	cpy, py; minor bor, mo; some pyrrhotite	cc, local cov	historic UG & current OP	yes	yes	no	no	no	Bauer & others. 1966; Quadra, 2009
Santa Rita (Chino), NM	mainly in the Santa Rita Stock: some in Cret Beartooth qtzite & Colorado ss & sh; some Pz seds (Miss-Perm); and volc; Dior, Qtz dior porph	qtz dior, Hanover-Fierro and Copper Flat stocks; Santa Rita stock 63 Ma; - granodior, qtz monz, qtz lat, granodior porph, qtz monz porph	35	marble; ls replacement; mainly supergene enrichment	cc, cpy, mo, 4% py, minor bor	cc, native Cu; leached cap; chrys, az	historic UG & current OP	yes	yes	yes	yes	yes	Rose & Baltosser, 1966; Hernon & Jones; 1968; Nielson, 1968
Silver Bell	low Pz, qtz monz porph, alaskite, Cret volcaniclastics	Laramide qtz monz porph,	40	skarn at contact with qtz monz porph	py, cpy, mo, lesser gal-sphal	cc, dig, cov, az, mal, chrys, wad/neotocite, broch; native Cu	historic UG & current OP	no	no	yes, plus rubbliz ation	no	yes	Graybeal, 1982; Richard & Courtright, 1966; Lopez & Titley, 1994
Twin Buttes	mostly Lara qtz monz porph; minor PC gran, Pz carbonates; Mz volc	Sierrita (60 Ma) gran porph related to Ruby Star granodiorite	50	upper Pz - Colina - Epitaph; minor Perm carbonates, Mz arkose, and Qmp	dominant cpy, py; mo; less sphal, minor bor, pyrrhotite, cc, gal, scheelite	cc, small amount cov; widespread chrys; broch, ten, cup, native Cu locally common; lesser az, mal	historic UG & closed OP	yes	yes	histori c tank leachi ng	yes	yes	Einaudi, 1982; Barter & Kelley, 1982; Stavitz etc 2009

Source: Compiled by SRK from various sources as referenced.

Table 7 Porphyry copper deposits not containing skarn in Arizona and nearby areas

Deposit	Mineralized Host Rock	Intrusive Type	Est. % QMP	Skarn Present?	Sulfide Minerals	Oxide Minerals	Mine operation type	Waste Rock Dump?	Tailings ?	Heap Leach?	Pit Lake?
Ajo	Monz, Qtz dior; PC complex metaseds & gran & gneiss	Lara Cornelia qtz monz, qtz dior	py, cpy; some bor	historic	historic UG & closed OP	yes	yes	1917193 0 vat leaching	no	no	Dixon, 1966
Bagdad	72.7 Ma porphyritic qtz monz; PC complex of metaseds, gran, diabase	76.2 qtz monz granodior; 72 Ma gran porph	cpy, mo, cc	chrys, mal, az	historic UG & current OP	yes	yes 3	dump leach	mp	yes	Anderson, 1950; Medhi, 1978; Baker & Clayton, 1968
Bisbee	Jur gran por; Pz carb & seds (Abrigo, Martin, Escabrosa)	Sacramento qtz porph	py, cpy, bor, sphal,	az, mal, cuprite, native Cu, cc, delafossite	historic UG & closed OP	yes	yes	reclamati on	no	no	Bryant, & Metz, 1966
Carlota	Pinal Schist, Lara gran, PC diabase	related to Lara Schultze granite	no	chrys, cc, mal, neotocite	open pit	no	no	yes	no	yes	Quadra, 2009 (EIS)
Miami	gran porph, qtz mona, qtz monz porph; into PC schist	Lara gran porph phase of Schultze gran	py, cpy; some bor, cc, mo	cc, chrys, az, ferric hydroxide, mal	historic UG & current OP	yes	yes	yes	no	yes	Olmstead & Johnson, 1966, Simmons & Fowells, 1966
Mineral Park	PC gran, Lara gran porph	Lara (71.6 Ma) Ithaca Peak bt qtz monz porph	cpy, mo, minor sphal gal	yes	historic UG & current OP	yes	yes	yes	no		Wilkinson etc 1982; Eidell etc. 1968
Morenci	PC gran, PZ Cret seds; gran porph, gran	qtz monz porph	py, cpy, mo, sphal, rare gal, Au, Ag	cc, cov, native Cu, cup, turq; chrys, mal; ten, cup, broch, az	historic UG & current OP	yes	yes	yes	no	no	Moolick & Durek, 1977
Pinto Valley (Castle Dome)	PC Pinal Schist, Apache Gp diabase; qtz monz, qtz monz porph, granodior	Lara gran porp 7 granodiorite (59 Ma)	cpy, py, some mo	yes	historic UG & current OP	yes	yes	yes	no	yes	SRK file data
Ray	PC Pinal schists; qtz dior, PC Lost Gulch qtz monz porph, diabase; PC Apache gp	Granite Mountain granodior porph (61 Ma)	cpy, py; minor bor, mo,; trace gal, sph	cc, chrys; minor native Cu, cup, chalcotrich ite	historic UG & current OP	yes	yes	yes	no	yes	Metz & Rose 1966; Metz & others, 1968
Safford	Cret volcanics; qtz lat, lat, qtz dior, and				historic UG & current				no		Robinson & Cook 1966; Langton &

Deposit	Mineralized Host Rock	Intrusive Type	Est. % QMP	Skarn Present?	Sulfide Minerals	Oxide Minerals	Mine operation type	Waste Rock Dump?	Tailings ?	Heap Leach?	Pit Lake?
					OP						Williams, 1982
San Manuel	PC Oracle gran: Lara qtz monz porph & granodior porph		cyp	chrys, Cu-bearing FeOx	closed UG & closed OP	yes	yes	lined	future	yes	Thomas 1966: SRK; Chaffee, 1982;
Sierrita	Tri Ox Frame volc, Cret volc; Jur Harris Ranch monz, Lara qtz monz porph, dior	Ruby Star granodiorite & qtz monz porph (53-56 Ma)	cpy, py, mo; minor gal, sphal, mt, ten-tet	cc	historic UG & current OP	yes	yes	yes	no	no	West & Aiken, 1982; Lynch, 1966, 1968
Tohono (Lakeshore)	PC Apache Gp (Mescal Ls, diabase), qtz monz, up Cret and & volc	Lakeshore granodiorite stock & bt qtz monz porph (64 Ma)	cpy, py, mo	cc, cup, native Cu, broch, chrys, Cu wad	historic block cave UG & closed OP 1974-1986	no	no	yes	no	yes	Cook, 1988

Compiled by SRK from various sources as noted in references.

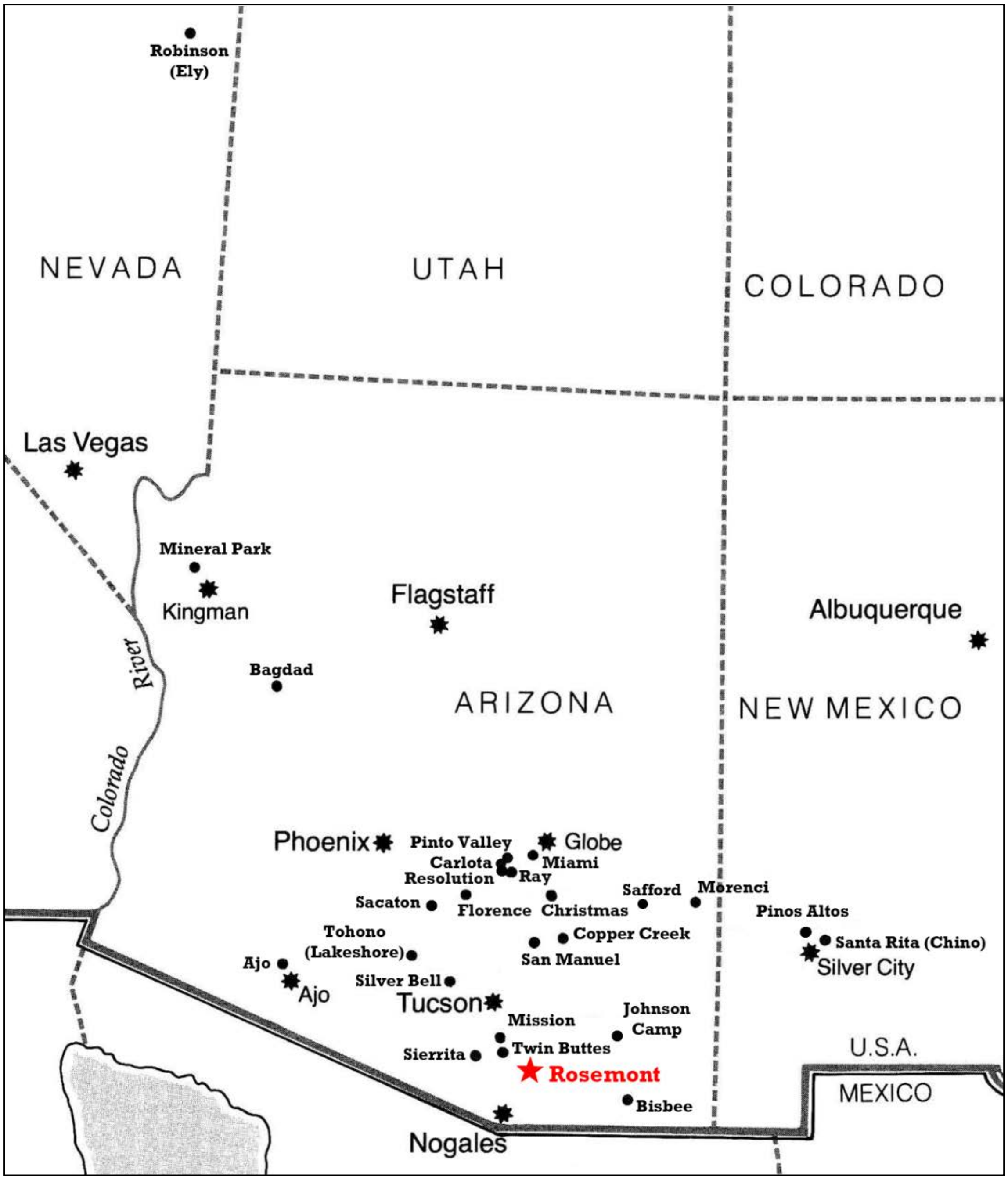
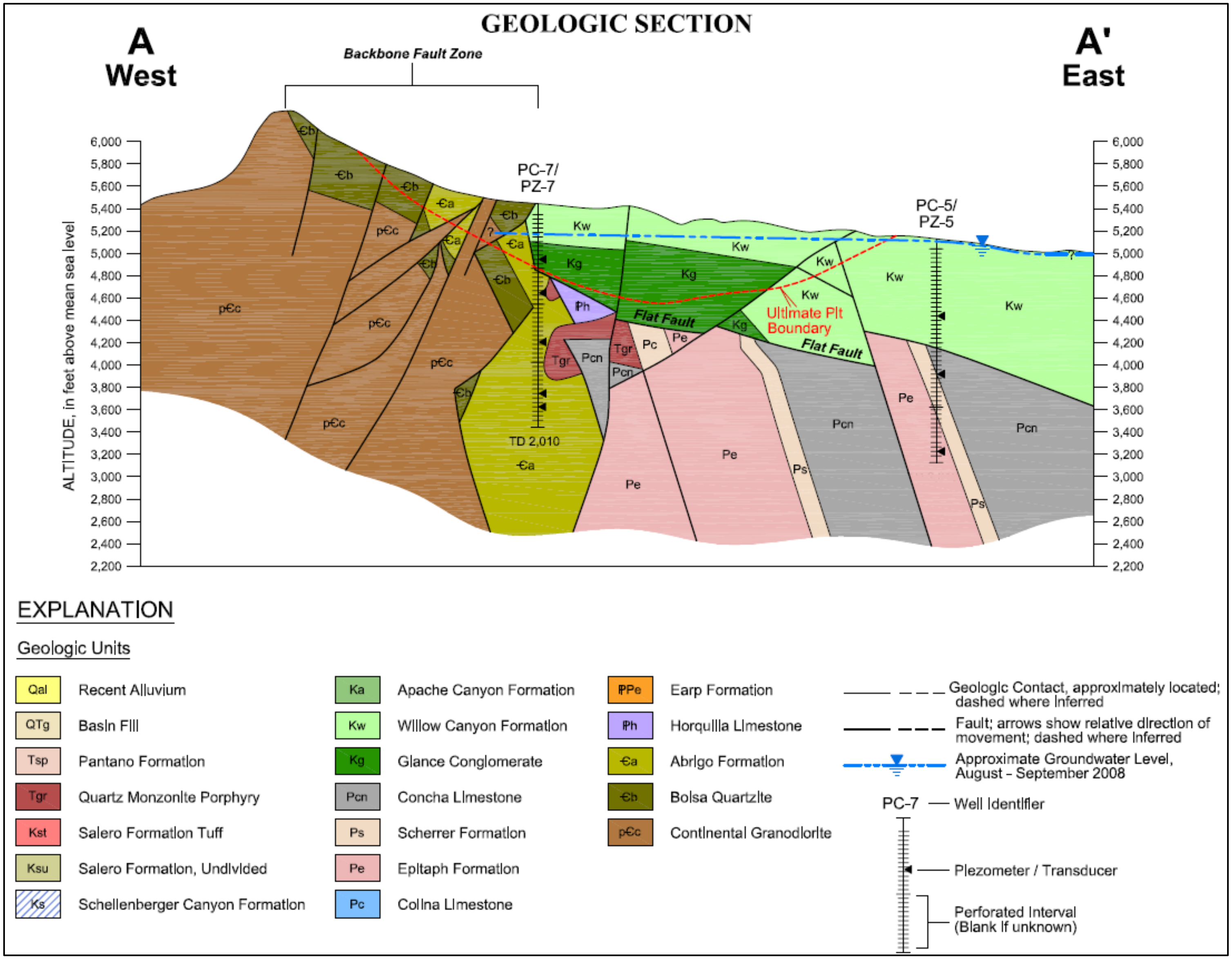
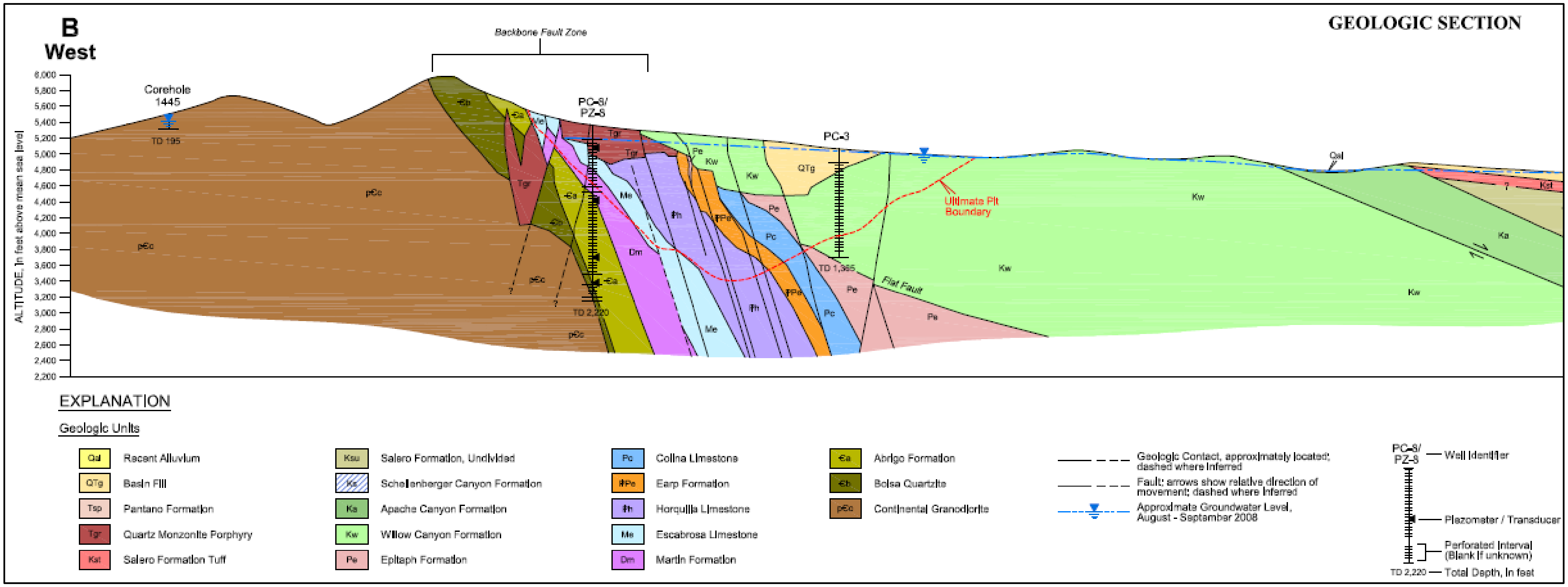


Figure 1 Porphyry copper deposits in Arizona and nearby areas



Source: Montgomery & Associates, 2009b, Figure 5

Figure 2 Cross section A-A' through north end of pit (looking north) showing the planned final pit outline at Rosemont



Source: Montgomery & Associates, 2009b, Figure 6

Figure 3 Cross section B-B' through middle of pit (looking north) showing the planned final pit outline at Rosemont

6 Heap Leach Pad Encapsulation

- *Whether encapsulation of the heap leach pad would prevent infiltration and whether encapsulation would be effective to neutralize heap leach seepage or discharge.*

Executive Summary

Tetra Tech prepared infiltration and seepage simulations for the closed Heap Leach Facility (Heap) that included capping the spent Heap ore with between 5 to 25 ft of waste rock with and without one foot of soil layer on the surface. Draindown is expected to continue at low rates after the initial 3-year draindown period and Heap capping. The draindown rate over the 217-acre lined facility is predicted to diminish from 2.5 gpm by post-cap year 15 with a residual 1 gpm within 45 years. The modeling simulations showed that 5 ft of waste rock plus 1 ft of soil cover will perform as effectively as a 20-ft thick layer of waste rock over the Heap with no soil cover (Tetra Tech, 2010c). Covering the Heap with 20 ft of waste rock is expected to reduce significantly, but not completely prevent, meteoric water infiltration and residual seepage.

The placement of a waste rock cover on the Heap will not be an effective method in neutralizing Heap seepage water quality. Limited neutralization would be expected for any heap drainage that seeps laterally and contacts calcareous waste rock. Neutralization may be expected in the limited area where draindown solutions contact the waste rock placed at the toe of the Heap upgradient of the collection pond. The surface area of the calcareous waste rock would be expected to "blind off" eventually through precipitation of gypsum and have little remaining fresh acid-neutralization surfaces.

6.1 Summary of Assumptions, Simulations, and Model Results

Tetra Tech (2010k) prepared an infiltration and seepage model for the Heap Leach Facility (during operations and closure) assuming a number of material types are present with different hydraulic properties. The materials included:

- Run-of-mine (poorly sorted gravel to large boulders) oxide ore with a permeability of 10 cm/sec;
- Semi-consolidated waste rock with a permeability of 10^{-1} cm/sec. This is poorly sorted sand to boulder size material that will be the bottom waste rock layer in the second period Tetra Tech modeled and the middle waste rock layer in the final period modeled.
- Consolidated waste rock with a permeability of 10^{-2} cm/sec. This is moderately coarse material with a poorly sorted sand to boulders

Draindown of spent solution was assumed to occur primarily during the first three years with residual draindown occurring at a much lower rate for many years post-closure as shown in Figure 4. The draindown rates were estimated to be 5 gallons per minute (gpm) within 5 years of placement of the waste rock, 2.5 gpm within 15 years, and approximately 1 gpm within 45 years.

During the time prior to placement of waste rock on the Heap, the draindown and precipitation runoff is to be collected in the double-lined process ponds for evaporation (in the pond or on top of spent ore), pumped to solvent-extraction/electrowinning plant, possible treatment, and/or incorporation into the sulfide ore circuit (Tetra Tech, 2010b). Treatment by a 1-stage or 2-stage process will improve draindown quality but will not ensure compliance with Aquifer Water Quality Standards (Tetra Tech, 2010k). Discharge of any residual draindown solution to the environment is not planned or allowed by groundwater or surface water environmental regulations.

Tetra Tech's *Heap Leach Facility Infiltration, Seepage, Fate and Transport Modeling Treatment Options* (2010d) presents the results of simulations completed with 5 ft. to 25 ft. of waste of waste rock in 5-ft additional increments, with 1-ft of soil cover, and without the soil cover. The climate assumptions included one year of average precipitation from the Nogales 6N Meteorological Station. The climate assumptions included one year of average precipitation from the Nogales 6N Meteorological Station, approximately 30 miles from the Rosemont Project site. As previously stated by SRK, the concern with using small, almost daily, precipitation amounts is that evaporation removes the precipitation. A one-year transient simulation is inadequate for a Heap draindown model and for cover designs. Tetra Tech did not perform a long-term simulation, however, to support their conclusion definitively and therefore, the current infiltration seepage model closure design is conceptual. For the final closure design of the Heap Leach Facility, a rigorous infiltration seepage model will have to be developed for the cover design. The final closure design will incorporate the actual material properties of the mined and leached materials as well as longer-term site climate data.

Comments Based on Analog Sites Elsewhere

SRK has post-closure data from a variety of covered Heap Leach Facilities in arid and semi-arid climates. Data from 20-year old covered dumps at Round Mountain, Nevada indicate that even in very arid climates, some infiltration into and through the dumps will occur regardless of cover treatment. A post-closure monitoring and contingency plan prepared prior to final closure should allow for a mechanism to monitor and manage long-term seepage (if present) or at least assess the potential consequences of an uncontrolled discharge to groundwater.

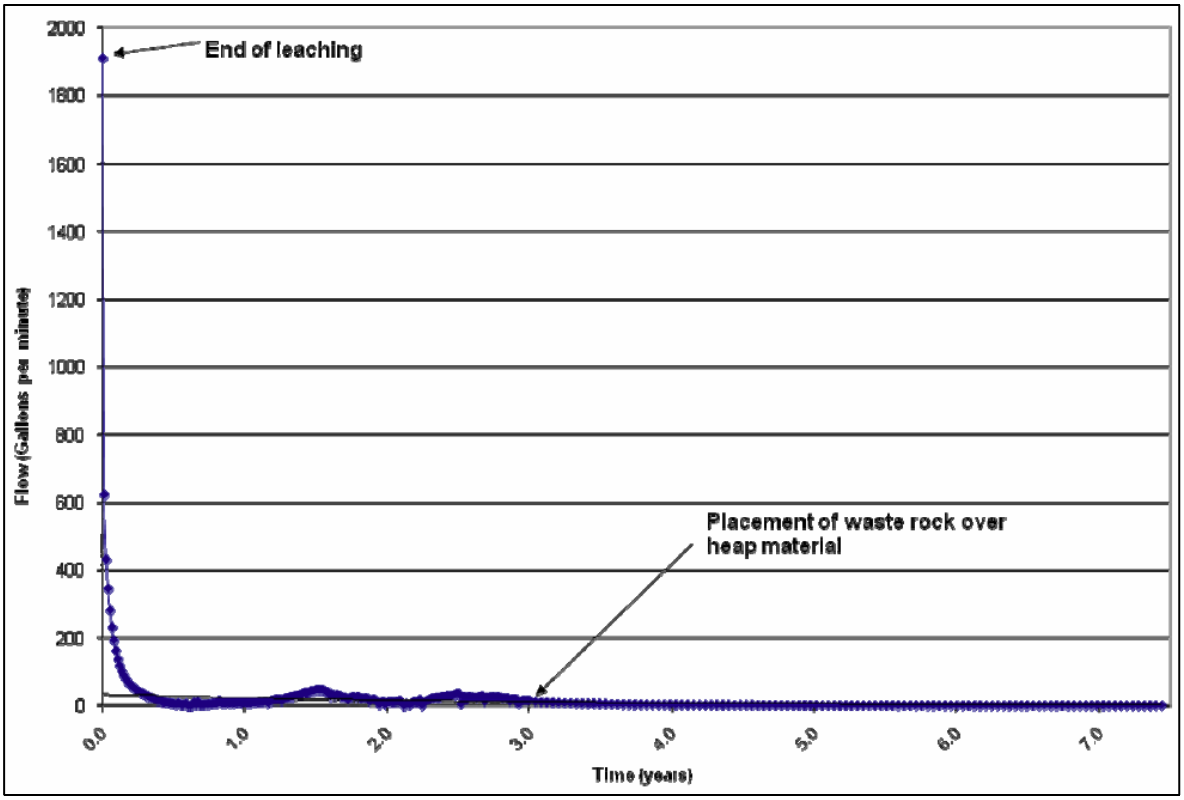


Figure 4 Draindown curve for Heap Leach Facility, Tetra Tech (2010k)

7 Capping Heap Leach with Waste Rock – Pressure on Lining

- *Whether or not burying the heap leach with waste rock could create pressure on the heap leach lining that could increase the potential for seepage and contaminant release.*

Executive Summary

The Rosemont production plan currently calls for approximately 69.2 million tons of oxide ore to be mined and placed on the lined pad during the first six years of operation (Table 1, Geochemical Solutions, 2012). Approximately 90 million tons of placed oxide ore was assumed in design criteria of the *Rosemont Heap Leach Facility – Permit Design Report* to allow for expansion capacity (Tetra Tech, 2009b). After leaching is completed, Rosemont intends to cap the spent Heap Leach Facility (Heap) with a 20-ft thick (Tetra Tech, 2010e) layer of waste rock. The waste rock has the same general material properties as the oxide leach material except that is below the 0.01% total copper cutoff grade. Burial of the Heap with waste rock is intended to minimize continued future infiltration of precipitation into the closed Heap and the generation of additional impacted draindown that will require treatment (Tetra Tech, 2010k). The planned maximum height of the Heap is 350 ft including the leach ore material and the 20-ft thick layer of waste rock.

SRK has reviewed the design criteria assumptions, design plans for the Heap, and the liner specifications (liner durability, puncture strength). Placement of the waste rock materials over the spent ore is within the design criteria established for the Heap Facility. The liner is rated to take a geostatic load of 450 ft of rock materials and a static load of 585 feet of rock materials. The additional weight from the 20-ft layer of waste rock will not place undue pressure on the liner beyond the design assumptions. One word of caution is to watch how fast the over dumping occurs or the weight may squeeze entrained water out of the Heap at a higher flow rate than was measured prior to over dumping.

Summary of Work and Calculations Performed by Tetra Tech

The liner puncture test work and settlement calculations performed by Tetra Tech provide evidence that the additional weight added by a 20-ft thick waste rock cover is within the design assumptions for the life-of-mine Heap. Tetra Tech calculated the maximum settlement in the foundation soils below the Heap pads and determined the potential differential settlement and its effect on the proposed liner system (against allowable strain). Elastic compression was assumed to occur in the top 50’ of the unconsolidated alluvial deposits; elastic compression was not expected to occur in bedrock owing to the stiffer nature of the bedrock formations.

Based on geometry of the Heap pad design, the maximum foundation loading and greatest deformation is expected to occur in the vertical column of rock below the thickest portion of the Heap. According to the design plan, the Heap is planned for a maximum height of 350 ft above the pad liner. This thickness includes approximately 330 ft of leach material and the minimum thickness of 20 feet layer intended for the Heap waste rock cap (Tetra Tech, 2010f; 2010i).

Tetra Tech’s settlement calculation shows that the differential settlement on the foundation liner system caused by the leach material will be approximately 3.4 ft over an initial length of 700 ft. This differential settlement will produce an increase in the liner system length of 0.008 ft, which is equivalent to a strain of 0.0012 percent. This strain is below the suggested allowable strain of the GCL of ten percent. Therefore, the liner system is not expected to be damaged by the settlement induced by the weight of the rock material and the liner system will maintain its integrity (Tetra Tech, 2010f).

In addition, a liner puncture testing was completed by Advanced Terra Testing, Inc. of Tucson for the Heap Leach Pad. The testing was conducted to 390 psi, which is equivalent to a geostatic load of 450 feet of stacked heap leach material. The testing used 1.5-inch minus quartz monzonite porphyry Over Liner Drain Fill (ODF), a 60-mil thick, double-sided textured, low linear density polyethylene (LLDPE) liner, a geosynthetic clay liner (GCL), and site-specific subgrade materials (Tetra Tech, 2009; 2010g). Furthermore, additional high-stress compression testing for the liner puncture was performed using a test load of 508 psi to simulate a static load of 585 feet of material on the Heap pad. The results of both tests indicated minor to moderate indentations would occur with no puncture failures (Tetra Tech, 2010i). These tests provide evidence that the liner material is resistant to static loads higher than the total maximum planned depth of 350 feet of Heap and waste rock materials.

Brief Discussion of Possible Analogous Site

Examples exist of heap leach facilities built to similar heights and construction methods as the proposed Rosemont facility. The Robinson Mine near Ely, Nevada is currently over dumping their spent gold heap leach pads with inert waste rock. This design is intended to limit meteoric recharge into the closed heap and reduce the heap draindown volume and rate. SRK is not aware of any field-based study that has tracked the potential for seepage and contaminant release from closed heap leach facilities closed with waste rock caps.

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