

Technical Memorandum

To:	Dale Ortman, P.E.	Date:	February 14, 2011
cc:	Tom Furgason, SWCA File, SRK	From:	Michael Sieber, P.E.
		Reviewed by:	Larry Cope Corolla K Hoag
Subject:	Technical Review of <i>Infiltration, Seepage, Fate and Transport Modeling Report–Revision 1</i> - Part 1 Infiltration and Seepage Model Components	Project #:	183101

A technical review has been undertaken and this Technical Memorandum prepared at the request of SWCA and the Coronado National Forest, in accordance with a request for a Statement of Work dated December 2, 2010 (Ortman, 2010). Provided here are comments related to the review of *Infiltration Seepage, Fate and Transport Modeling Report–Revision 1* prepared for the Rosemont Copper Company by Tetra Tech (2010a) and the Technical Memorandum *Rosemont Infiltration, Seepage, Fate and Transport Response to Comments*, (Tetra Tech, 2010b).

Michael Sieber of SRK Consulting (SRK) prepared these comments. Editorial review was provided by Larry Cope and Corolla K Hoag, also of SRK. Previous reports were reviewed and used as reference documents.

This review is organized into two parts corresponding to the two topics under review:

Part 1 - Infiltration and seepage modeling addressed in this memorandum, and

Part 2 - Fate and transport (geochemical) modeling addressed under separate cover.

With regards to the infiltration and seepage modeling discussion, the Tetra Tech (2010a) report is well presented and well written, and as supported by the appendices, it is in general comprehensive in scope. Some remaining comments and recommendations related to the infiltration and seepage model are addressed below. The report comments are related to recommendations to improve clarity and model documentation.

1 INFILTRATION AND SEEPAGE MODELING

The GEO-SLOPE VADOSE/W code used by Tetra Tech is industry standard infiltration-seepage modeling software. The information presented in *Infiltration Seepage, Fate and Transport Modeling Report–Revision 1* (Tetra Tech, 2010a) and Tetra Tech's response to comments (Tetra Tech, 2010b) satisfied most of SRK's previous comments. The requests indicated below in this section pertain to (1) the drainage estimate for the Heap Leach Facility (Heap) and (2) the Heap model results.

1.1 Input Data

This section summarizes the review of the climatic data and the saturated and unsaturated material properties used for the infiltration models.

1.1.1 Site Climatic Data

Tetra Tech's response (2010b) answered SRK's questions and comments (SRK, 2010a) with regard to the Site Climate Data and the 7-day and 24-day 100-year design storms.

Tetra Tech is using a climate dataset described in Section 5.5.1 as an average of over 50 years of daily measurements. The daily average climatic dataset is described as: "Though this is a conservative method to assess infiltration into the Project facilities, it is not representative of actual climate conditions."

- Why do infiltration simulations use this dataset if it is not representative? Other simulations are using a 10-year dataset. SRK recommends using a longer transient simulation with parts of the 50-year Nogales, which would be more defensible.

Tetra Tech's revised report provided adequate information in Section 5.8.1 concerning the sinusoidal application of daily precipitation over a 2-hour period peaking at noon.

1.1.2 Site Material-Soil Data

SRK (2010a) requested additional information for the unsaturated hydraulic properties for the rock/soils used in the infiltration model. Tetra Tech's response (2010b) was included in Section 5.5.5 (Tetra Tech, 2010a). The descriptions of the run-of-mine (ROM) material in the Tetra Tech (2010b) response to comments includes Illustration 1.0, which has the size distributions for waste rock based on Call & Nicholas studies (CNI, 2008). The illustration indicates the ROM material is estimated to range in size from 4.5 inches to 24 inches and the D50 size is about 14 inches. In regards to the material placed on the Heap Leach Facility, Tetra Tech (2010b) commented that "The oxide ore is anticipated to have a similar distribution." This statement was a response to SRK's comment (SRK, 2010a) "Consider the impacts of leaching the oxide material and its impact on the hydraulic conductivity and the use of a run-of-mine material property to model the heap".

- Could the text be revised to clarify the source of the rock size distribution used in the models? Neither the Waste Storage Facility nor the Heap Leach Facility models appear to use the Call & Nicholas waste rock size distribution as indicated in Tetra Tech's response (2010b).

Section 5.5.5.1 (Tetra Tech, 2010a) states the ROM material used for the Waste Rock simulation was andesite material tested by Advanced Terra Testing in September 2006. This material was described as poorly sorted gravel (0.1 inches) to large boulders (greater than 12 inches).

- The complete laboratory report by Advanced Terra Testing should be included as an appendix to this report.

1.2 Heap Leach Facility Conceptual Model

The Rosemont Heap Leach Facility will contain approximately 70-75 million tons of oxide ore material and will be operated for 6 years after which time the application of raffinate will cease and the spent process solutions will drain. Tetra Tech's conceptual model for the Heap (2010a) estimates draindown of the Heap to be 10 gpm for 3 years following the end of leaching.

Draindown from unnamed closed heaps in Arizona and Nevada were cited as examples (Tetra Tech, 2010b). The number of closed copper heap leaching facilities available to assess draindown rates is limited, but some examples in Arizona include the heaps at Silver Bell, Tohono, and San Manuel. The San Manuel Heap Leach Facility was a larger facility than the Rosemont facility is expected to be (90 million tons) and operated for a longer period (18 years), but the flow rate from the covered Heap after 8.5 years of closure is still greater than 10 gpm.

- What closed heap facilities were used as analogs to assess the draindown rate and flow for the Rosemont Heap Leach Facility? Would it be possible to prepare a comparison table using the other Heaps as analogs for the Rosemont Heap? Comparison items might include the approximate ROM size of material placed on the heaps, total tonnage of material leached, length of operation, total estimated inventory of residual process solution in the heaps at cessation of operations if this information is known.

As mentioned above, the Tetra Tech simulation assumed a particle size distribution similar to the ROM sent to the waste rock facilities. Oxide heap materials are typically (or frequently) shot to a smaller size than is sulfide material and/or waste rock in order to enhance the amount of surface area that is in contact with the raffinate applied to the Heap. Ore placed on the Heap differs from basin-fill or oxide/ sulfide waste rock in the concentrations of copper-bearing minerals (oxide/carbonate/silicate/sulfide) and associated gangue minerals like iron/manganese oxides/carbonates/silicates/sulfides. Heap materials will likely break into smaller size fractions than waste rock owing to the disaggregation that will occur during placement, compaction by haul trucks, and ripping in the upper layer of each lift. Lifts within the Heap will also compact with burial depth and develop localized aquitard or poor drainage zones owing to local concentrations of fines or secondary mineral precipitates. Raffinate leaching will cause the ore materials to break down to smaller particles as the fracture mineralogy holding together individual rock segments is dissolved. The leaching of calcite-bearing material will also cause the formation of secondary sulfate/oxide/hydroxide/clay minerals that may impact flow characteristics and decrease the hydraulic conductivity.

In summary, simulating the Heap Leach Facility materials as ROM waste-sized material may significantly under-estimate the duration for draindown. A conceptual closure plan for the Rosemont Heap Leach Facility has been prepared and is described in Appendices D and E of Tetra Tech (2010a). SRK cautions that it may take considerably longer than 3 years for the draindown to decrease to 10 gpm.

1.3 Waste Rock Storage Facility

Tetra Tech (2010a) improved the figures for the conceptual model and model results, and they are now easily readable.

1.4 Steady-State and Transient Solutions

Tetra Tech (2010a) Illustration 5.22 and 5.24, present the simulated water flux for various closure options for the Heap. The explanation for the illustrations on page 59 state that the contact between the spent ore and the waste rock was used as the location in the model to analyze the scenarios shown on Illustration 5.22 and 5.24. Negative flux values represent water being removed from the spent ore and waste rock through evaporation. Illustration 5.22 indicates that there is more evaporation from the spent ore through increasing thicknesses of waste rock. Rock cover acts as a mulch and from SRK's experience there is a positive flux when rock is placed over a finer grained material. Illustration 5.30 (citing a figure from AMEC, 2009) shows moisture content in tailings with depth and time.

- Could an illustration similar to Illustration 5.30 be prepared for the Heap simulations? This would assist with understanding and validation of the Heap infiltration model.

Tetra Tech states on Section 5.8, page 26 that, “Transient modeling provides a reasonable simulation of flow conditions within the Waste Rock Storage area, Heap Leach area, and the Dry Stack tailings facility.” Using average climatic conditions, the transient simulations reported in this report are 1 year in duration. However, movement of moisture through such materials may take longer than 1 year. Tetra Tech did an additional 10-year transient simulation. A reasonable approach would be to conduct a 50-year transient simulation utilizing the entire 50-year climatic data set from the Nogales 6 N weather station.

Tetra Tech provided additional descriptions for the illustrations in Section 5.9 that addressed the questions about the steady-state simulations.

1.5 Illustrations and Tables

Illustration 5.6 (Tetra Tech, 2010a) lacks numeric values for the tick marks on the X and Y axes for the graph showing unsaturated hydraulic conductivity. Illustrations 5.7 and 5.8 lack numeric values for the tick marks on the X axis of the similar graph.

2 RECOMMENDATIONS

For the infiltration and seepage components of the model report, SRK has the following recommendations:

- Results from the transient simulations do not indicate that a long-term solution has been reached at the end of 1 year. SRK recommends that transient simulations should be performed over the 50-year climatic data period of record, or at a minimum until the transient analysis demonstrates an asymptotic stabilization of results.
- Given the apparent need to extend the length of transient runs, the 1 year of averaged daily climate data may become moot. Actual climate data over the length of transient simulations should be used as input data.
- Present SWCC and unsaturated hydraulic conductivity functions on charts for all of the waste material, alluvial material, and bedrock.
- The Heap Leach Facility draindown model should use material typical of leached oxide ore and leached residue chemistry data from column tests. As actual materials are not available, a review of actual draindown data from similar closed heap leach facilities should be considered.
- Illustrations 5.6, 5.7, and 5.8 are difficult to read/understand without hydraulic conductivity units.

3 REFERENCES

- AMEC, 2009, Rosemont Copper Company, Dry stack tailings storage facility, Final design report: unpublished report prepared for Rosemont Copper Company, AMEC Project 842-1191, 54 p., 7 appendices.
- Call & Nicholas, 2008, Feasibility-level geotechnical study for the Rosemont deposit: unpublished report prepared for Augusta Resources, February 2008.
- Ortman, Dale, 2010, *Technical Review Scope of Work - Request for Cost Estimate & Schedule, Tetra Tech Mine Water Resources Reports and Technical Memoranda*: Project Memorandum, Rosemont EIS Project, 2 December, 2010, 4 p.
- SRK Consulting, 2010a, Technical review of *Infiltration, Seepage, Fate and Transport Modeling Report*: unpublished technical memorandum prepared for SWCA, April 30, 2010, 9 p.

Tetra Tech, 2010a, Infiltration, seepage, fate and transport modeling report – Revision 1, Rosemont Copper: unpublished report prepared for Augusta Resource Corporation, Tetra Tech Project No. 114-320884, August 2010, 88 p., 6 appendices.

_____, 2010b, Rosemont infiltration, seepage, fate and transport response to comments: unpublished technical memorandum prepared for Rosemont Copper Company by A. Hudson, Tetra Tech Project No. 268/10-320884-5.3, November 23, 2010, 24p.

4 REVIEWER QUALIFICATIONS

The reviewer for hydrogeology, Mike Sieber, P.E., is a Hydrogeologist with SRK Consulting in Tucson. Mr. Sieber is a professional engineer with more than 17 years of hydrogeology experience including 15 years preparing infiltration and seepage models to estimate infiltration through tailings impoundments, waste rock storage and heap leach facilities, and landfill covers. He has more than 10 years experience in the preparation of numerical groundwater flow models to predict the formation of pit lakes and potential loss of containment at open pit and underground mining operations.