Technical Memorandum

To: Kathy Arnold

From: Grady O’Brien (EA) & Paul Ridlen (Tt)

Company: Rosemont Copper Company

Date: May 6, 2011

Re: Rosemont Response to FS/BLM Comments on Tetra Tech Groundwater Model

Doc #: 108/11-320878-5.3

CC: David Krizek, P.E. (Rosemont Copper)

1.0 Introduction

Rosemont Copper Company (Rosemont) received review comments on both the Montgomery & Associates (M&A) and Tetra Tech groundwater flow models in a letter titled “Groundwater Modeling for the Rosemont Copper Project Environmental Impacts Analysis”, dated April 5, 2011 (Attachment 1). This letter was the follow-up to a meeting held in February 2011 between Rosemont’s groundwater modeling consultants, the United States Forest Service (FS), the Bureau of Land Management (BLM), and their contractors. The FS letter also summarizes and reiterates comments previously submitted by SRK in a January 13, 2011 memorandum titled “Technical Review of Tetra Tech (2010i) Report: Regional Groundwater Flow Model Rosemont Copper Project” (Attachment 2).

Relevant portions of the FS Letter, including FS/BLM questions/comments, are restated in Section 2.0 and followed by responses. These responses may also be supported with figures and tables provided as attachments. Only responses pertinent to Tetra Tech are provided in this Technical Memorandum. M&A is preparing separate responses related to their groundwater modeling efforts. Comments on the “WEST SIDE GROUNDWATER MODEL (Santa Cruz River Basin)” apply only to M&A, so those comments are omitted from this Technical Memorandum.

2.0 Forest Service Comments with Tetra Tech Responses

“The Coronado National Forest has completed a review of the documents submitted by Rosemont Copper Company (RCC) in support of the groundwater quantity impacts analysis to be disclosed in the environmental impact statement (EIS) for the proposed Rosemont Copper Project (RCP). The review was to determine whether or not the data, information, and conclusions they present are sufficient for our use in preparing a complete analysis of impacts for the Draft EIS of the RCP. In February of this year, meetings to discuss final completion steps were conducted between RCC contractors and the Forest Service technical specialists, Forest Service contractors and the Bureau of Land Management (BLM). Thank you for
contributing to the resolution of a number of these steps. As we move closer to the public release of the Draft EIS, other points needing clarification have been highlighted. These items are listed below. The technical review comments are as follows: FS (Forest Service), MWH and SRK (Forest Service contractors), and BLM (Bureau of Land Management).”

EAST SIDE (ES) GROUNDWATER MODELS (Davidson Canyon and Cienega Creek), Note: comments are for both models unless specified otherwise.

ES-1 Comment. FS: Describe in detail why constant and/or general head boundaries are employed on the model periphery, why the results of the model are not affected or minimized by them, and why basin boundaries were not utilized rather than the rectangular configuration in the current models. Please provide examples and references of any other projects which have handled boundaries in a similar manner. If it is necessary to show flux out of the model boundary on the west, and it is deemed that the best way to represent this is with a general head or constant head boundary, then the use of these boundary types should be limited to the region of outflow, rather than generally applied to the model periphery.

ES-1 Response. The Tetra Tech groundwater flow model domain was consistent with the previously established M&A groundwater flow model domain (M&A, 2009; M&A, 2010). The model study area boundary was established by M&A to encompass the Project area and to extend past areas that could potentially be impacted by the Project.

Constant-head cells were used to account for flow into and out of the model domain. The steady-state potentiometric surface was used to define the hydraulic head elevations at the model boundaries. The potentiometric surface was contoured inside and outside of the model domain so that the natural hydraulic gradients and flow directions would be maintained within the model boundary cells. The majority of the boundary reaches, and particularly the reaches near sensitive areas, have water leaving the model domain. Flow rates through some of the constant-head cell reaches decreased during the mining and post-closure simulations, but the flow direction did not reverse for any reaches or simulations. Changes in inflow to the model domain were negligible during all simulations. Flow rates and directions for constant-head cell reaches for steady-state, mining, and post-closure conditions are provided in response to comment ES-3. These results indicate that the constant-head cells did not reduce the predicted impacts.

Sensitivity analyses were also performed to determine whether the constant-head cells on the western model boundary were inappropriately influencing the predicted impacts. First, the western model boundary was simulated as a no-flow boundary, but the model would not converge due to very high simulated hydraulic heads along this boundary. This simulation confirmed that groundwater flow out of the western model boundary is required to have a stable numerical simulation.

The western model boundary was also simulated with general-head cells. Predicted drawdown and western model boundary fluxes were virtually unchanged between the constant-head and general-head boundary conditions. Based on the results of the sensitivity analysis, it was determined that the use of constant-head cells was appropriate.

Additional information on boundary conditions can be found in the Tetra Tech (2010) report titled “Regional Groundwater Flow Model, Rosemont Copper Project”; Pages 18, 45, 84-85.
ES-2 Comment. FS: Provide a vector field depiction of the steady state flow regime for each of the two east-side models. The vectors should be scaled to the flow velocity. Since there is likely to be large differences in velocity depending on the aquifer type, each of these flow fields should also be shown with vectors that are not scaled to velocity shown adjacent to those that are. Descriptions should include the temporal variations post mining, at least at 20 years and 1000 years as well as the pre mining, steady state scenario.

ES-2 Response. As requested, groundwater flow direction and velocity vectors at steady-state, end of mining, post-closure 20 years, and post closure 1,000 years are provided on Figures ES-2 A, B, C, and D in Attachment ES-2.

ES-3 Comment. FS: Utilize the Zonebudget or similar program to quantify inflow and outflow at the boundaries, with something on the order of 10 zones per outside boundary. Each zone will be one cell wide along the boundary and should be about 2 miles in length. Each zone will extend from the ground surface to the model’s base. The quantification of inflow and outflow from the boundaries will be made, at a minimum, for steady state, maximum drawdown, and the 120 year stress periods. These flows will be given as rates. Provide the results of the final steady state simulation run with the only change from the initial steady state simulation being the presence of the pit.

ES-3 Response. As requested, boundary flow rates and changes in flow rates are presented for steady-state, end of operations, post-closure 150 years, and post closure 1,000 years (Table ES-3, Attachment ES-3). Boundary reaches are approximately 2-miles long and illustrated on Figure ES-3 (Attachment ES-3).

The post-closure, 1,000 year simulation represents steady-state conditions. Steady-state conditions are illustrated by the:

- lack of changes in the pit-lake water balance after 700 to 1,000 years (Tetra Tech, 2010, Figure 8-16);
- indiscernible change in drawdown at distant observation points (Tetra Tech, 2010, Figure 8-7); and
- effectively zero change in storage at 1,000 years (Tetra Tech, 2010, Table 8-3).

ES-4 Comment. FS/BLM: Describe in detail why a uniform porous media model was selected. For a fractured rock media model, describe what data is currently available and data requirements needed to build a model of this nature.

ES-4 Response. Groundwater flow modeling was performed using an equivalent porous media (EPM) assumption, which is inherent in MODFLOW. Although the groundwater flow system includes fractured geologic formations, at the regional scale it was assumed that the aquifers were accurately simulated as a porous media within MODFLOW. The EPM concept states that fluid flow through the fractured bedrock over sufficiently large volumes will be similar to that of porous media. MODFLOW is an industry standard for groundwater flow simulations and fractured rock aquifers at a regional scale are commonly simulated as equivalent porous media.
Geologic controls and hydrogeologic units were incorporated into the numerical models as appropriate. Due to the large size of the model domain, the grid spacing within the numerical models limited the resolution of the smaller geologic features. Although cell sizes within the model limited the delineation of specific hydrogeologic features, the overall, regional flow system was appropriately simulated. Since a porous media assumption was used, the selected hydraulic properties represented the average, bulk properties of the aquifers.

The EPM approach assumes that interconnected fractures exist over the large simulated model domain, when fracture connections probably exist only over much smaller areas. In practice, some fractures yielding flow to the Open Pit may initially have high flows, but then may have substantially reduced flows with time as storage is depleted and the rate of replenishment becomes lower than the hydraulic conductivity of the fracture(s). Lower than predicted inflows would equate to less pit capture and thus smaller impacts to the regional groundwater system. The porous media approach therefore provides a conservative estimate of groundwater system impacts.

Constructing a fracture flow model (i.e., discrete fracture network, dual porosity, dual permeability, or multiple interacting continua (MINC)) of the regional groundwater system requires data on the distribution and character of fractures. Discrete fracture networks can be generated by various methods based on fracture data that includes number of sets, orientation, spacing, length, density, area and shape, connectivity, aperture, coatings, and infillings. Some of these fracture data could possibly be obtained from re-analysis and examination of core from within the pit area, but these data are generally not available over the larger regional model domain. The applicability of fracture characteristics in the pit area to the larger regional area is questionable due to the unique structural features and alteration present near the ore body. The lack of fracture data would hinder development of discrete fracture network and dual porosity/dual permeability flow models. However, these types of fracture flow models have an overwhelming limitation due to their inability to simulate pit-lake formation. Prediction of post-closure impacts is largely controlled by the pit-lake water balance. Fracture flow models are therefore an inappropriate tool for evaluation of mining-related impacts.

In summary, the type of numerical model selected is dependent on the objectives of the model. Since the objective was to evaluate potential mining-related impacts to water resources several miles away (i.e., regional scale) the EPM assumption is valid for this Project.

Additional information on equivalent porous media can be found in the Tetra Tech (2010) report titled “Regional Groundwater Flow Model, Rosemont Copper Project”; Pages 1, 40-41, 69.

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**ES-5 Comment.** BLM: Describe in detail why the baseflow calibration targets for USGS gages on Cienega Creek were estimated using median flow values instead of actual baseflow values.

**ES-5 Response.** Base flow was not directly reported by the USGS for the project area gaging stations. However, previous base flow estimates have been made for other studies (M&A, 1985; PAG 1998). The stream-flow data available from two (2) USGS gaging stations in Cienega Creek and one (1) station in Davidson Canyon Wash were evaluated for use as model calibration targets. Monthly mean and median flow data from these stations show relatively consistent and small flows during October through June and a strong influence from high discharges during the July to September monsoon season.
Median stream flows were used as calibration targets to remove the influence of high flows observed during the summer monsoon season. These higher stream flows, which occur during July, August, and September, are not representative of the groundwater supported base flow. Using low flow months or other methods to estimate base flow were not used due to the relatively short period of record for these gaging stations (7 years or less).

Not including the monsoon months of July, August, and September, the range of monthly average streamflows for these gages is 0 to 1.1 cfs. This small range of monthly average streamflows results in similar base-flow estimates regardless of the method used. The M&A (1985) and PAG (1998) studies used different periods of record and the base-flow estimates ranged from 1 to 3 cfs. These small differences in base flow estimates and target streamflows would not result in changes to the predicted impacts. Additionally, streamflow impacts were evaluated as the change from simulated steady-state flows to eliminate any uncertainty in base-flow estimates.

Additional information on stream flow is available in the Tetra Tech (2010) report titled “Regional Groundwater Flow Model, Rosemont Copper Project”; Pages 51-53.

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**ES-6 Comment.** BLM: Describe in detail why existing Cienega basin-wide groundwater withdrawals and projected future growth groundwater withdrawals, primarily in the Sonoita, Elgin and Gardner Canyon areas, were not considered in the models.

**ES-6 Response.** Groundwater pumping in Sonoita, Elgin, and Gardner Canyon areas was not included in the flow model due to the pumping locations, small rates, and lack of observed water-level response. Total groundwater pumping in the Cienega Creek basin has been approximately 1,200 ac-ft/year since 1971 (ADWR, Water Atlas http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/default.htm; Attachment ES-6). Most registered groundwater wells are for minor domestic use. Larger water users (agricultural and municipal uses) that are more likely to cause an impact are south of the groundwater divide and outside of the model domain (Figure 3.3-10, Attachment ES-6).

The small and distributed domestic groundwater users within the model domain are inconsequential to the predicted impacts resulting from the Rosemont Project. Additionally, Tetra Tech reviewed the historic water-level data analysis conducted by M&A (2010, Section 4.4) and concurred with their conclusions regarding the lack of consistent water-level trends due to pumping.

Predicting impacts due to future groundwater users in the Sonoita, Elgin, and Gardner Canyon areas is speculative and not an objective of the Tetra Tech regional groundwater flow model.

Additional information on groundwater pumping can be found in the Tetra Tech (2010) report titled “Regional Groundwater Flow Model, Rosemont Copper Project”; Page 20.

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**ES-7 Comment.** SRK comment on Montgomery model.

**ES-7 Response.** See M&A Technical Memorandum.
ES-8 Comment.  SRK comment on Montgomery model.

ES-9 Comment.  SRK comment on Tetra Tech model:

1.  *Run an additional sensitivity analysis scenario for the post-mining conditions without the quartz-porphyry dike as a Horizontal Flow Barrier (HFB) to cover all possible ranges of propagation of drawdown.*

**ES-9-1 Response.**  As requested, a sensitivity simulation without the quartz-porphyry dike was completed and results are provided in Figures ES-9A and ES-9B (Attachment ES-9-1).

2.  *Prepare a better description of the data used to incorporate the quartz-porphyry dike into the hydrogeologic model as a groundwater barrier and use this dike as a very low conductive Hydrogeological Unit (HGU) for the Base Case predictive scenario.*

**ES-9-2 Response.**  The quartz-porphyry dike was incorporated into the model based on published geologic map data and field observations that verified the geologic maps. Numerous quartz-porphyry dikes have formed in the Empire Mountains (Ferguson, C.A., 2009) and Mount Fagan areas (Ferguson et al., 2001). The intrusive dikes are younger than the surrounding bedrock and therefore cut through the older bedrock. Some of these dikes appear to have been formed by intrusion into existing faults (Drewes, 1972). This intrusive nature that closes fractures can also be seen in the rocks surrounding the dike where the quartz porphyry has filled small fractures and further reduced the effective permeability. Field observations confirmed that the bedrock on either side of the dike also has very low matrix permeability and that groundwater flow would be restricted to interconnected fractures if they exist. Exposed fractures however, are typically very thin and do not show signs of any geologic processes that would tend to increase permeability.

The northwest-striking quartz-porphyry dike is roughly perpendicular to Davidson Canyon and has been mapped on the Mount Fagan and Empire Ranch 7.5’ quadrangles (Ferguson, 2009; Ferguson et al., 2001). This is one of the longest and most continuous dikes with a four (4) mile long section. There are short sections where the dike is either buried by alluvium or not present. Field investigations and geologic maps indicate that the dike thickness is commonly about 100 feet and varies from 50 to 250 feet thick. This Tertiary age geologic feature is described in Ferguson (2009) as “felsic porphyry containing 10-30% quartz and feldspar phenocrysts (1-3 mm) and sparse biotite in a fine-grained light-colored matrix, locally flow-foliated. Forms dikes and sills, and a plug-like stock in the northwest corner of the map area.”

There has been no hydraulic testing of this dike to characterize its hydraulic properties and to confirm its influence on the groundwater flow system. There is also a lack of water-level data and appropriately located wells to definitively determine the dike’s impact on the groundwater system. However, there are limited water-level data near the southeastern part of the dike and these data indicate a flattening of the hydraulic gradient, which would result from the dike impeding groundwater flow.
The dike’s crosscutting nature, width, length, low permeability, lack of fractures, and the tendency for the intrusive quartz porphyry to suture faults, fractures, and surrounding bedrock, suggests that it restricts groundwater flow. Incorporation of the dike provides an alternative to the conceptual model posed by M&A for assessing the range of potential impacts due to the Rosemont Project.

3. Show the quartz-porphyry dike simulated as a HFB in all model layers that indicate the hydraulic characteristics with the K values of the surrounding HGU.

**ES-9-3 Response.** As requested, the quartz-porphyry dike has been added to report Figures 6-4 through 6-23 and they are included as Attachment ES-9-3.

4. Add the quartz-porphyry dike to the pre-mining water level on Figures 6-1, 6-2, and 6-29 and specify in which monitoring wells the measured water levels indicate that the dike is a hydraulic barrier.

**ES-9-4 Response.** The quartz-porphyry dike has been added to report Figures 6-1, 6-2, and 6-29 as requested and are provided as Attachment ES-9-4. There is a lack of water-level data and appropriately located wells to definitively determine the dike’s impact on the groundwater system. Water-level contours based on the target wells, however, follow the dike for most of its length and the lack of wells makes it difficult to identify a large hydraulic gradient or changes in the gradient near the dike.

**ES-10 Comment.** SRK comment on Tetra Tech model: The range of simulated pit lake stage, shown on Figure 8-9, varies in elevation from 3,050 about 4,350 feet above mean sea level (amsl). This range covers the majority of completed simulations, but not all of them. For example, the pit lake elevation was predicted to be 4,429 feet amsl at 1,000 years from a sensitivity run considering a decrease of lake evaporation by 20 percent. It is not clear to SRK whether Figure 8-9 needs to be revised or the stage-area relationship in the Lake Package (LAK2) should be revised and the sensitivity predictions re-run.

**ES-10 Response.** As noted by SRK, the sensitivity simulation with a 20-percent decrease in lake evaporation resulted in the highest simulated lake stage. As requested, report Figure 8-9 has been updated to include the full range of simulated pit-lake stages, including the sensitivity analyses (Attachment ES-10).

**ES-11 Comment.** SRK comment on Tetra Tech model: It is noted that Tetra Tech applied annual precipitation of 17.37 inches to the pit lake during post-mining recovery using date from the NOAA Nogales weather station. Montgomery and Associates (M&A) in a similar study (M&A2010) used the Santa Rita weather station, which reported an annual precipitation of 22.19 inches. The Santa Rita station is located at a higher elevation compared to the NOAA Nogales (4,300 feet amsl vs. 3,560 feet amsl) and is closer to the elevation of the Rosemont site (elevation about 5,300 feet amsl). SRK did not find an explanation in the model report of Tetra Tech’s preference for the Nogales station vs. the Santa Rita station: however, use of the Nogales data, with lower annual precipitation, provides a more conservative assumption to evaluate the pit lake infilling and the impact to the groundwater system during post-mining conditions.
ES-11 Response. Precipitation estimates from the Nogales station were used consistently for all of the Tetra Tech studies, including stormwater runoff, infiltration modeling, and groundwater flow modeling. The Technical Memorandum titled *Rosemont Copper Design Storm Precipitation Data/Design Criteria* (Tetra Tech, 2009), explains why the average yearly rainfall of 17.37 inches, taken between the years 1952 and 2007 at the Nogales 6 N meteorological station, was selected for the Rosemont Project site:

- An on-site meteorological monitoring station was installed at the Project site in 2006. For the recorded years between 2006 and 2008, the average annual rainfall was 17.12 inches. This closely matched the average annual rainfall recorded at the Nogales 6 N station.
- The Nogales 6 N station is the closest meteorological station to the Project site that had recorded both precipitation and evaporation and had a large dataset (approximately 50 years). The next closest station having both data sets was the University of Arizona in Tucson. Selecting a station that provided both long-term rainfall and evaporation was deemed important for data consistency and correlation.
- The Santa Rita Experimental Range meteorological station, although closer to the Project site than the Nogales 6 N station, did not have evaporation data in addition to precipitation. Additionally, although precipitation was recorded at the Santa Rita station from 1950 to 2005 with a calculated average annual precipitation of 22.19 inches, this value was considered high for the Rosemont Project site since the average annual precipitation for the Rosemont area, estimated by Sellers (University of Arizona, 1977) for the period of 1931 to 1970, was approximately 16 inches. Also, based on available records from the Western Regional Climate Center (WRCC, 2009), the average annual precipitation for Helvetia, which was the closest recording station to Rosemont, was 19.72 inches for the period of 1916 to 1950.

3.0 Summary

Responses to questions or recommendations presented in the Forest Service’s April 5, 2011 letter were provided in Section 2.0 with supplemental or supporting information provided in the attachments. The attachments to this Technical Memorandum include the following:

- Attachment 1: Forest Service’s April 5, 2011 letter titled *Groundwater Modeling for the Rosemont Copper Project Environmental Impacts Analysis*
- Attachment ES-2: Groundwater Flow Vector Figures
- Attachment ES-3: Groundwater Flow Rates at the Model Boundary
- Attachment ES-6: Groundwater Pumping Data for Cienega Basin
- Attachment ES-9-1: Sensitivity Simulation without the Quartz-Porphyry Dike
- Attachment ES-9-3: Hydraulic Conductivity Figures including the Quartz-Porphyry Dike
- Attachment ES-9-4: Potentiometric Surface Figures including the Quartz-Porphyry Dike
- Attachment ES-10: Revised Pit-Lake Stage-Area Relationship
REFERENCES


ATTACHMENT 1

FOREST SERVICE LETTER TITLED “GROUNDWATER MODELING FOR THE ROSEMONT COPPER PROJECT ENVIRONMENTAL IMPACT STATEMENT”
Katherine Ann Arnold, PE  
Vice President, Environmental and Regulatory Affairs  
Rosemont Copper Company  
P.O. Box 35130  
Tucson, AZ 85740-5130

RE: GROUNDWATER MODELING FOR THE ROSEMONT COPPER PROJECT 
ENVIRONMENTAL IMPACTS ANALYSIS

Dear Ms. Arnold:

The Coronado National Forest has completed a review of the documents submitted by Rosemont Copper Company (RCC) in support of the groundwater quantity impacts analysis to be disclosed in the environmental impact statement (EIS) for the proposed Rosemont Copper Project (RCP). The review was to determine whether or not the data, information, and conclusions they present are sufficient for our use in preparing a complete analysis of impacts for the Draft EIS of the RCP. In February of this year, meetings to discuss final completion steps were conducted between RCC contractors and the Forest Service technical specialists, Forest Service contractors and the Bureau of Land Management (BLM). Thank you for contributing to the resolution of a number of these steps. As we move closer to the public release of the Draft EIS, other points needing clarification have been highlighted. These items are listed below. The technical review commenters are as follows: FS (Forest Service), MWH and SRK (forest service contractors), and BLM (Bureau of Land Management).

WEST SIDE GROUNDWATER MODEL (Santa Cruz River Basin)

FS/BLM: Describe in detail why extending the model time frame after pumping cessation is not possible or warranted. Presently the model drawdown contours are temporally described only at the end of pumping. The 1 foot and 10 foot cone of depression contours could extend laterally further out for years, depending on aquifer parameters.

FS: Describe in detail the feasibility of a groundwater model using seasonality. Describe what data is available and data requirements to using seasonality in the existing groundwater model such as a telescoped model focusing on the area of the cone of depression using at a minimum the 2 pumping seasons (on/off) or the 4 seasons (summer, winter etc). Such a telescoped model could include all of the appropriate seasonal variation without having to apply it to the more general, larger model, which would be used to supply boundary conditions.

MWH: Water level changes from potential Sierrita Mitigation pumping are not satisfactorily explained. The Report Addendum states that projected drawdown resulting solely from the mitigation pumping "is not provided in any reports", making the determination of Sierrita Mitigation pumping "impossible." These conclusions are not valid. First, regardless of whether
or not the drawdown caused by Sierrita Mitigation pumping has been previously reported, an estimation of mitigation pumping drawdown could be made using the Rosemont model, similar to how the estimation of CWC CAP recharge impacts were made. (MWH understands that objections were raised during the August 30, 2010 meeting regarding using the Rosemont Model to estimate water level changes from Sierrita Mitigation pumping.) Second, estimated water level changes caused by Sierrita Mitigation pumping are provided in the *Feasibility Study for Sulfate with Respect to Drinking Water Supplies in the Vicinity of Freeport-McMoRan Sierrita, Inc. Tailing Impoundment* (Hydro Geo Chem, Inc., 2008). Alternative 5 of the Feasibility Study is very similar to the Non-State Land Option presented in the Final Conceptual Wellfield Design Report (Hydro Geo Chem, Inc. and Clear Creek Associates, P.L.C, 2010). Figure 24 of the Feasibility Study (Hydro Geo Chem, Inc., 2008) should be sufficient to estimate groundwater level changes caused by Sierrita Mitigation pumping.

MWH: There appears to be an error in Figure A-6, which shows increased drawdown southeast of the Rosemont East well for the Rosemont model compared to the Rosemont model with ADWR TAMA model aquifer parameters. The explanation given in the Report Addendum, and the expectation based on the lower permeability’s of the ADWR TAMA model, is that the drawdown should be less in the Rosemont model. Please verify that the figure is correctly labeled.

MWH: The discussion of the model objectives, and the model’s ability to meet these objectives, needs to be strengthened.

MWH: The cross-section drawdown plot is provided in Figure A-3. The drawdown profiles in the figure are difficult to interpret because of the vertical scale. We recommend that the vertical exaggeration be increased. Also, Figure A-3 shows a thickness for model Layer 3, although the Rosemont model only uses a transmissivity (i.e., no explicit thickness) for Layer 3. If Layer 3 was converted to have explicit thickness and hydraulic conductivity values, then this needs to be properly documented in the modeling report.

EAST SIDE GROUNDWATER MODELS (Davidson Canyon and Cienega Creek), Note: comments are for both models unless specified otherwise.

FS: Describe in detail why constant and/or general head boundaries were employed on the model periphery, why the results of the model are not affected or minimized by them, and why basin boundaries were not utilized rather than the rectangular configuration in the current models. Please provide examples and references of any other projects which have handled boundaries in a similar manner. If it is necessary to show flux out of the model boundary on the west, and it is deemed that the best way to represent this is with a general head or constant head boundary, then the use of these boundary types should be limited to the region of outflow, rather than generally applied to the model periphery.

FS: Provide a vector field depiction of the steady state flow regime for each of the two east-side models. The vectors should be scaled to the flow velocity. Since there is likely to be large differences in velocity depending on the aquifer type, each of these flow fields should also be shown with vectors that are not scaled to velocity shown adjacent to those that are. Descriptions should include the temporal variations post mining, at least at 20 years and 1000 years as well as the pre mining, steady state scenario.
FS: Utilize the Zonebudget or similar program to quantify inflow and outflow at the boundaries, with something on the order of 10 zones per outside boundary. Each zone will be one cell wide along the boundary and should be about 2 miles in length. Each zone will extend from the ground surface to the model's base. The quantification of inflow and outflow from the boundaries will be made, at a minimum, for steady state, maximum drawdown, and the 120 year stress periods. These flows will be given as rates. Provide the results of a final steady state simulation run with the only change from the initial steady state simulation being the presence of the pit.

FS/BLM: Describe in detail why a uniform porous media model was selected. For a fractured rock media model, describe what data is currently available and data requirements needed to build a model of this nature.

BLM: Describe in detail why the baseflow calibration targets for USGS gages on Cienega Creek were estimated using median flow values instead of actual baseflow values.

BLM: Describe in detail why existing Cienega basin-wide groundwater withdrawals and projected future growth groundwater withdrawals, primarily in the Sonoita, Elgin and Gardner Canyon areas, were not considered in the models.

SRK comment on Montgomery model (M&A): M&A completed a comprehensive sensitivity analysis of two types of predicted post-mining conditions by varying: 1. hydraulic parameters (hydraulic conductivity, specific yield, and specific storage) of different hydro geological units and fault zones (26 runs), by assuming Base Case pit lake parameters; and 2. pit lake parameters (lake surface precipitation, lake evaporation, and precipitation runoff), by assuming Base Case distribution of hydraulic parameters. M&A calculated the potential impact to the Upper Cienega Creek and Davidson Canyon sub-basins for the first set of sensitivity analyses and did not present the second set of sensitivity analyses in the report. It is from the second set of sensitivity analyses that potentially greater impact to surface-water bodies can be inferred. For example, the revised report indicates that increasing lake evaporation from 50 in/yr (Base Case) to 60 in/yr would lower the ultimate pit lake elevation by 152 feet. However, any decrease of groundwater discharge to surface water streams for that scenario is not presented in the report. Additionally, the groundwater model predicts a Base Case scenario of: 1) decrease in groundwater outflow from the western boundary of 42 ac-ft/yr and, 2) five identified perennial springs (MC-1, Deering, Rosemont, Questa, and Helvetia) and seeps to be within the area of the predicted 5-foot drawdown contour. It is not clear to SRK from the revised report the magnitude of the potential impact to the decrease in groundwater outflow westward from the western model domain. No range in the outflow from a sensitivity analysis was presented. Also unclear is the range in potential impacts from that outflow to the five identified perennial springs and seeps for the sensitivity scenarios that were run. SRK recommends that these issues be clarified by presenting a summary table with the results of the second sensitivity analysis to the pit lake parameters. The new table will, at a minimum, include the other predictive parameters of ultimate pit lake elevation, decrease in groundwater outflow from western boundary, and springs within the area of projected 5-foot drawdown contour.
SRK comment on Montgomery model: Revised report could be improved and made more defensible in anticipation of future reviews by others by including the following in the document:

1. Add modeled cross section D-D' (SRK was not able to find this modeled cross section in the report).
2. Add a grid on all modeled cross sections.
3. Add the location of the Davidson Canyon fault on appropriate maps.
4. Explain why a distance of ½ mile was used to assign General Head Boundaries (GHBs) along the western boundary of the model.
5. Show simulated outflow from the western boundary of the model, modeled by GHBs at steady state conditions.
6. Show a groundwater budget at the end of the life of mine containing the components of predicted passive inflow to the pit, or otherwise state that all passive inflow would come from groundwater storage. Supply a graph of groundwater flux versus time, with a different line for every component of flux. There should be one graph for inflow and one for outflow.
7. Show a groundwater budget at long-term post-mining conditions (1,000 years after mine closure) and changes compared to pre-mining steady state condition. A table format is preferable and recommended.
8. Add the citation on Figure 94 to the Section 9 List of References that cites the location of a drain to a Tetra Tech document.

SRK comment on Tetra Tech model:

1. Run an additional sensitivity analysis scenario for the post-mining conditions without the quartz-porphyry dike as a Horizontal Flow Barrier (HFB) to cover all possible ranges of propagation of drawdown.
2. Prepare a better description of the data used to incorporate the quartz-porphyry dike into the hydrogeologic model as a groundwater barrier and use this dike as a very low conductive Hydrogeological Unit (HGU) for the Base Case predictive scenario.
3. Show the quartz-porphyry dike simulated as a HFB in all model layers that indicate the hydraulic conductivity distribution (Figures 6-4 through 6-23) for comparison of its hydraulic characteristics with the K values of the surrounding HGU.
4. Add the quartz-porphyry dike to the pre-mining water level on Figures 6-1, 6-2, and 6-29 and specify in which monitoring wells the measured water levels indicate that this dike is a hydraulic barrier.

SRK comment on Tetra Tech model: The range of simulated pit lake stage, shown on Figure 8-9, varies in elevation from 3,050 to about 4,350 feet above mean sea level (a.m.s.l). This range covers the majority of completed simulations, but not all of them. For example, the pit lake elevation was predicted to be 4,429 feet a.m.s.l at 1,000 years from a sensitivity run considering a decrease of lake evaporation by 20 percent. **It is not clear to SRK whether Figure 8-9 needs to be revised or the stage-area relationship in the Lake Package (LAK2) should be revised and the sensitivity predictions re-run.**
SRK comment on Tetra Tech model: It is noted that Tetra Tech applied annual precipitation of 17.37 inches to the pit lake during post-mining recovery using data from the NOAA Nogales weather station. Montgomery and Associates (M&A) in a similar study (M&A2010) used the Santa Rita weather station, which reported an annual precipitation of 22.19 inches. The Santa Rita station is located at a higher elevation compared to the NOAA Nogales (4,300 feet amsl vs. 3,560 feet amsl) and is closer to the elevation of the Rosemont site (elevation about 5,300 feet amsl). **SRK did not find an explanation in the model report of Tetra Tech’s preference for the Nogales station vs. the Santa Rita station**; however, use of the Nogales data, with lower annual precipitation, provides a more conservative assumption to evaluate the pit lake infilling and the impact to the groundwater system during post-mining conditions.

In order to facilitate review of your responses, please provide separate documents for each of the three groundwater models. I greatly appreciate your consistent offer to be of help to the forest as we move towards completion of the Draft EIS, followed by the Final EIS and the Record of Decision (ROD). I look forward to your responses regarding this request.

Sincerely,

JIM UPCHURCH
Forest Supervisor
ATTACHMENT 2
SRK MEMORANDUM TITLED “TECHNICAL REVIEW OF TETRA TECH (2010I) REPORT: REGIONAL GROUNDWATER FLOW MODEL ROSEMONT COPPER PROJECT”
Memorandum

To: Dale Ortman, P.E.  Date: January 13, 2011

From: Vladimir Ugorets, Ph.D.  cc: Tom Furgason, SWCA

Reviewed by: Larry Cope, M.S.  Cori Hoag, SRK


Project #: 183101/2300

This memorandum provides a technical review of the full version of the report Regional Groundwater Flow Model Rosemont Copper Project (Tetra Tech, 2010i) dated November 2010. This review was undertaken and the Technical Memorandum prepared at the request of SWCA and the Coronado National Forest, in accordance with a Technical Review Scope of Work, Request for Cost Estimate and Schedule from Mr. Dale Ortman dated December 2, 2010. This memorandum was prepared by Vladimir Ugorets and reviewed by Larry Cope of SRK Consulting (U.S.), Inc. (SRK).

1 Tetra Tech Responses to SRK Comments

Tetra Tech issued the initial sections of this report in the format of technical memoranda (Tetra Tech, 2010a through Tetra Tech 2010h). SRK’s original review comments on the Tetra Tech memoranda are presented in SRK (2010a) through SRK (2010f) and are not replicated here. The correlation between the initial Tetra Tech documents and SRK’s review memoranda is shown in Table 1.

Table 1: Correlation between Original Tetra Tech Report Sections and SRK Review Documents

<table>
<thead>
<tr>
<th>Tetra Tech Report Sections</th>
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<th>SRK Review Documents</th>
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<tbody>
<tr>
<td>Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts</td>
<td>Tetra Tech, 2010a&amp;b</td>
<td>SRK, 2010a&amp;b</td>
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<td>Hydrogeologic Framework Model</td>
<td>Tetra Tech, 2010c</td>
<td>SRK, 2010c</td>
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<td>Tetra Tech, 2010d</td>
<td>SRK, 2010d</td>
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<td>Predictive Groundwater Flow Model Construction and Calibration</td>
<td>Tetra Tech, 2010e</td>
<td>SRK, 2010e</td>
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<td>Tetra Tech, 2010f</td>
<td>SRK, 2010f</td>
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<tr>
<td>Rosemont Groundwater Flow Model Sensitivity Analyses</td>
<td>Tetra Tech, 2010g</td>
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<tr>
<td>Predictive Groundwater Flow Modeling Results</td>
<td>Tetra Tech, 2010h</td>
<td>SRK, 2010h</td>
</tr>
</tbody>
</table>

Tetra Tech’s comprehensive responses to SRK’s review comments are contained in Tetra Tech (2010j).
The purpose for this review is to confirm that the comments made in SRK’s original reviews have been addressed in the final version of the report. SRK reviewed the Tetra Tech (2010j) response to SRK’s comments and the final version of the report (Tetra Tech, 2010i) and confirms here that the pertinent issues in the SRK comments were addressed.

2 SRK Additional Comments and Recommendations

Several observations are presented below that may be outside the scope of this final review, but are made to provide insight that has been gained by the reviewers since the submittal of the individual sections of the report.

2.1 Simulation of Quartz-Porphyry Dike

The quartz-porphyry dike between the open pit and Davidson Canyon is a very important feature that restricts groundwater flow in the conceptual hydrogeological and numerical groundwater models. Tetra Tech (2010i) states that “The quartz-porphyry dike strikes sub-perpendicular to groundwater flow in the Davidson Canyon area, is over four (4) miles long, and based on a field investigation, has a low fracture density and a thickness generally greater than 100 feet. The steep hydraulic gradient from the Open Pit area to Davidson Spring in Davidson Canyon is likely due, at least in part, to this quartz-porphyry dike. However, there has been no hydraulic testing of this dike to characterize its hydraulic properties and to confirm its influence on the groundwater system. The cross-cutting nature, width, and length of the dike, however, suggest that it restricts groundwater flow.”

This dike was simulated (and finally calibrated to measured water levels) by using a Horizontal Flow Barrier (HFB) package with:

a) Hydraulic conductivity $K=3.28 \times 10^{-6}$ ft/day,
b) Width of 100 feet, and
c) Penetration within all model layers.

It should be noted that the calibrated K of the quartz-porphyry dike (simulated as a HFB) is more than three orders of magnitude lower than the horizontal hydraulic conductivity of the Upper Cretaceous and Early Tertiary intrusive rocks (KTi).

Tetra Tech concluded in their report that, “Simulating a more permeable HFB resulted in the model under predicting water levels up-gradient of the HFB and over predicting water levels down-gradient of the HFB. The calibrated HFB hydraulic characteristic improved the match to water levels on the up- and down-gradient sides of the dike and improved the match to the observed hydraulic gradient in Davidson Canyon.” However, SRK did not find any technical discussion or data to support that conclusion in the text of the report. The maps of simulated pre-mining water levels shown on Figures 6-1, 6-2, and 6-29 do not show the location of the dike. Figures 6-4 through 6-23 depicting the hydraulic conductivity distribution of the simulated Hydrogeologic Units (HGU) also do not show the location of the simulated, almost impermeable dike. This makes it difficult to compare the hydraulic conductivity of the HFB with that of the surrounding HGU and to evaluate changes in the groundwater gradient to confirm the existence of such a hydrologic barrier.

The results of the predictive simulations during post-mining conditions as shown on Figures 9-8, 9-9, 9-16, and 9-27 through 9-73 in the report, suggest that the quartz-porphyry dike as modeled serves as a hydraulic barrier to groundwater flow that limits the propagation of drawdown into Davidson Canyon.

The completed sensitivity analysis of the hydraulic conductivity of the quartz-porphyry dike (increasing and decreasing the value of K by a factor of 10) showed that this parameter is:

a) Least sensitive to simulated pre-mining water levels (normalized composite scaled sensitivity is only 0.08 (see Table 9-2 of Tetra Tech (2010i), and
b) Very sensitive to the predict propagation into the Davidson Canyon area during post mining conditions.

This means that:

a) Because of the low sensitivity for the steady state condition (to which the groundwater model was calibrated), the calibrated value of the dike hydraulic conductivity is not very defensible and as a result, the predictive simulations are not likely to be conservative; and

b) A larger range of dike hydraulic conductivity is required for the predictive sensitivity analysis to more clearly evaluate possible ranges of impact to the groundwater system within Davidson Canyon.

It should be noted that Montgomery and Associates’ groundwater flow model (M&A, 2010) does not simulate the quartz-porphyry dike. Instead, they modeled a zone of higher hydraulic conductivity in the area of the Davidson Canyon fault. They were able to obtain a steady state calibration as well. Given that a steady state calibration can be achieved from such differing approaches suggests that Tetra Tech consider further evaluation of the dike. SRK is of the opinion that the defensibility of the simulation of the dike is impacted by what is viewed as conclusions that are less than fully supported by the analyses and simulations. To improve defensibility, SRK suggests the following:

a) Run an additional sensitivity analysis scenario for the post-mining conditions without the quartz-porphyry dike as a HFB to cover all possible ranges of propagation of drawdown.

b) Prepare a better description of the data used to incorporate the quartz-porphyry dike into the hydrogeologic model as a groundwater barrier and use this dike as a very low conductive HGU for the Base Case predictive scenario.

c) Show the quartz-porphyry dike simulated as a HFB in all model layers that indicate the hydraulic conductivity distribution (Figures 6-4 through 6-23) for comparison of its hydraulic characteristics with the K values of the surrounding HGU.

d) Add the quartz-porphyry dike to the pre-mining water level on Figures 6-1, 6-2, and 6-29 and specify in which monitoring wells the measured water levels indicate that this dike is a hydraulic barrier.

2.2 Simulation of Pit Lake Stage-Volume Relationship by the Groundwater Flow Model

The range of simulated pit lake stage, shown on Figure 8-9, varies in elevation from 3,050 to about 4,350 feet above mean sea level (amsl). This range covers the majority of completed simulations, but not all of them. For example, the pit lake elevation was predicted to be 4,429 feet amsl at 1,000 years from a sensitivity run considering a decrease of lake evaporation by 20 percent. It is not clear to SRK whether Figure 8-9 needs to be revised or the stage-area relationship in the Lake Package (LAK2) should be revised and the sensitivity predictions re-run.

2.3 Precipitation to the Pit Lake

It is noted that Tetra Tech applied annual precipitation of 17.37 inches to the pit lake during post-mining recovery using data from the NOAA Nogales weather station. Montgomery and Associates (M&A) in a similar study (M&A2010) used the Santa Rita weather station, which reported an annual precipitation of 22.19 inches. The Santa Rita station is located at a higher elevation compared to the NOAA Nogales (4,300 feet amsl vs. 3,560 feet amsl) and is closer to the elevation of the Rosemont site (elevation about 5,300 feet amsl). SRK did not find an explanation in the model report of Tetra Tech’s preference for the Nogales station vs. the Santa Rita station; however, use of the Nogales data, with lower annual precipitation, provides a more conservative assumption to evaluate the pit lake infilling and the impact to the groundwater system during post-mining conditions.

The justification for the use of the NOAA Nogales weather station data was explained in Rosemont Infiltration, Seepage, Fate and Transport Response to Comments (Tetra Tech, 2010k).
explanation for using the NOAA Nogales weather station data also should be in the *Regional Groundwater Flow Model Rosemont Copper Project* (Tetra Tech, 2010i).

### 3 SRK Conclusions

The groundwater model was not calibrated to the transient conditions induced by the 30-day pumping test, and there remain some uncertainties with a simulation of such a complex natural system. Specifically, SRK suggests that a better assessment of the hydrogeological role of the quartz-porphyry dike between the open pit and Davidson Canyon be performed via additional sensitivity simulations. At a minimum, SRK suggests that an additional sensitivity run should be performed without the dike to increase the defensibility of the model predictions and to cover the possible range of potential impacts to the groundwater system and to surface-water bodies in Davidson Canyon.

Despite those uncertainties, SRK concludes that the groundwater model presented in the final version of the report was conceptualized, constructed, and presented to standard industry practices. The model addresses the comments and recommendations made by SRK in its review of the individual sections of the report. Further, SRK finds that the model generally represents hydrogeological conditions that are appropriate to the available data, is robust, and well calibrated to the pre-mining steady-state conditions. Model predictions for both mining and post-mining conditions are reasonable, are based on the results of comprehensive sensitivity analyses, and provide a range of potential impacts to the groundwater system and to surface-water bodies.

### 4 References


5 Reviewer Qualifications

Vladimir Ugorets, Ph.D., is a Principal Hydrogeologist with SRK Consulting in Denver, Colorado. Dr. Ugorets has more than 31 years of professional experience in hydrogeology, developing and implementing groundwater flow and solute-transport models related to mine dewatering, groundwater contamination, and water resource development. Dr. Ugorets’ areas of expertise are in design and optimization of extraction-injection well fields, development of conceptual and numerical groundwater flow and solute-transport models, and dewatering optimization for open-pit, underground and in-situ recovery mines. Dr. Ugorets was directly responsible for reviewing the groundwater flow model. His resume has been provided to SWCA in prior submissions.
ATTACHMENT ES-2
GROUNDWATER FLOW VECTOR FIGURES
FIGURE ES-2 B
SIMULATED FLOW DIRECTION AND VELOCITY DURING MINING

Legend

- Perennial Stream
- Ephemeral Drainage
- Railroad
- Roads
- Proposed Rosemont Open Pit
- Quartz Porphyry Dike
- Towns

Groundwater Flow Direction and Velocity (ft/d)

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- > 1

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TETRA TECH

ROSEMONT COPPER
FIGURE ES-2 C
SIMULATED FLOW DIRECTION AND VELOCITY
20 YEARS POST-MINING

Legend
- Perennial Stream
- Ephemeral Drainage
- Proposed Rosemont Open Pit
- Railroad
- Roads
- Towns
- Quartz Porphyry Dike

Groundwater Flow Direction and Velocity (ft/d)
- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1
- > 1

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April 2011
ATTACHMENT ES-3
GROUNDWATER FLOW RATES AT THE MODEL BOUNDARY
Table ES-3. Constant Head Boundary Flow and Changes Relative to the Steady-State Simulation.

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* Negative values represents flow out of the model domain, positive values represent flow into the model domain.
** Change in flow is relative to steady-state simulation.  
AF/yr = acre-feet per year
Legend

- Perennial Stream
- Ephemeral Drainage
- No Flow Cells
- Extent of Model Domain
- Railroad
- Roads
- Proposed Rosemont Open Pit
- Water-Level Contours (ft)
- Quartz Porphyry Dike
- Towns

Figure ES-3
Constant Head Boundary Reaches

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April 2011
ATTACHMENT ES-6
GROUNDWATER PUMPING DATA FOR CIENEGA BASIN
## Table 3.3-7 Cultural Water Demands in the Cienega Creek Basin\(^1\)

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Notes:
- NR = Not reported
- \(^1\) Does not include evaporation losses from stockponds and reservoirs, or effluent
- \(^2\) Includes all wells through June 1980.
Figure 3.3-10
Cienega Creek Basin
Cultural Water Demand

Demand Centers
- Agriculture
- M&I - High Intensity
- M&I - Low Intensity
- COUNTY
- Interstate Highway
- Major Road
- City, Town or Place

Primary Data Source: USGS National Gap Analysis Program, 2004
ATTACHMENT ES-9-1
SENSITIVITY SIMULATION WITHOUT THE QUARTZ-PORPHYRY DIKE
Figure ES-9A
No HFB Model with Results at 150 Years Post-Closure
Figure ES-9B
No HFB Model with Results at 1,000 Years Post-Closure
ATTACHMENT ES-9-4
POTENTIOMETRIC SURFACE FIGURES INCLUDING
THE QUARTZ-PORPHYRY DIKE
Figure 6-1
Calibration Weights for Target Water Levels
Figure 6-2
Observed Pre-Mining, Steady-State Potentiometric Surface Map and Upper Most Model Layer with Constant Head Cells

Legend

- **Perennial Stream**
- **Ephemeral Drainage**
- **No Flow Cells**
- **Railroad**
- **Roads**
- **Extent of Model Domain**
- **Proposed Rosemont Open Pit**
- **Towns**
- **Water-Level Contours (ft)**
- **Quartz Porphyry Dike**

**Constant Heads**

- **Model Layer**
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 11
  - 12
  - 13
  - 14
  - 15
  - 16
  - 17

Project No: 114-320874

April 2011
Figure 6-29
Simulated versus Observed Potentiometric Surface Map

Residual = observed minus simulated water level
ATTACHMENT ES-10
REVISED PIT-LAKE STAGE-AREA RELATIONSHIP
Figure ES-10
Stage-Area Relationship in the Lake Package