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Technical Memorandum

To:	Kathy Arnold	From:	Michael Gabora, P.G.
Company:	Rosemont Copper Company	Date:	November 17, 2010
Re:	Responses to SRK's Technical Review Comments on Tetra Tech's Groundwater Flow Model Technical Memoranda	Doc #:	267/10-320874A-5.3
CC:	David R. Krizek, P.E. (Tetra Tech); Grady O'Brien (Engineering Analytics)		

Tetra Tech completed several Technical Memoranda describing the development of regional groundwater flow models for the Rosemont Copper Project (Project). These individual memoranda were technically reviewed by SRK Consulting (SRK) on behalf of the Coronado National Forest Service (CNF). Technical Memoranda reviewed by SRK included the following:

- *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts Report* (Tetra Tech, 2010a);
- *Hydraulic-Property Estimates* (Tetra Tech, 2010b);
- *Hydrogeologic Framework Model* (Tetra Tech, 2010c);
- *Groundwater Flow Model Construction and Calibration* (Tetra Tech, 2010d);
- *Steady-State Sensitivity Analyses* (Tetra Tech, 2010e);
- *Predictive Groundwater Flow Modeling Results* (Tetra Tech, 2010f); and
- *Groundwater Flow Model Sensitivity Analyses* (Tetra Tech, 2010g).

This memorandum provides responses to SRK's review comments. Cross references between this memorandum and SRK's review memoranda were simplified by maintaining consistent section titles and reiterating SRK's comments, followed by Tetra Tech's responses. SRK's review comments are included in their entirety in Attachments 1 through 5.

The reviewed Tetra Tech memoranda have been compiled into a groundwater modeling report (Tetra Tech, 2010j), which documents the entire modeling process, groundwater-system predictions, and sensitivity analysis. Modifications indicated in the responses to comments were included in the groundwater modeling report. There are no plans to reissue the reviewed individual technical memoranda with modifications based on the review comments.

1.0 Response to Comments on “Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts” (SRK, 2010a and 2010b)

The Davidson Canyon conceptual model was initially submitted in April 2010 and reissued in July 2010 (Tetra Tech, 2010a). Both of these documents were reviewed by SRK. Review of the April 2010 report was documented in the SRK memorandum dated May 11, 2010 (SRK, 2010a). These comments were incorporated into the July 2010 report. Review of the July 2010 report (Tetra Tech, 2010a) was documented in the SRK memorandum dated August 3, 2010 (SRK, 2010b; Attachment 1). The following responses address comments from both reviews by SRK, which are identified by the referenced review document. The indicated changes were incorporated into the July 2010 Davidson Canyon report (Tetra Tech, 2010a) and the groundwater modeling report (Tetra Tech, 2010j), as appropriate.

- **Comment (a):** SRK, 2010a – “*Figure 9: Local spring isolated from regional groundwater – groundwater flow lines are shown above the water table*”

Response: In the July 2010 report (Tetra Tech, 2010a), Figure 9 was modified to distinguish between “shallow localized water flow” and regional groundwater table.

- **Comment (b):** SRK, 2010a – “*Figure 15: Schematic cross section of Reach 2 spring development – what data are used for the unsaturated zone as shown between the alluvial and bedrock groundwater systems?*”

Response: In the July 2010 report (Tetra Tech, 2010a), the figure was modified to clearly illustrate surface water flows infiltrating into the unsaturated channel alluvium, which is above the regional groundwater table. The unsaturated zone was inferred from the geochemical data, geologic setting, ephemeral flow, and the nearby Pima County well that indicates hydraulically disconnected surface-water and groundwater systems. The Pima County well had the closest available groundwater-level data. These conditions also appear to be present in the Cienega Creek drainage based on several Pima Association of Governments (PAG) reports.

- **Comment (c):** SRK, 2010a – “*The water quality data described in Section 7.6 need to be added in the spring comparison table shown in Figure 8.*”

Response: In the July 2010 report (Tetra Tech, 2010a), Figure 18 was added to illustrate the general geochemistry via Stiff Diagrams, prepared by Montgomery & Associates (M&A) (M&A, 2009a), for each well and spring.

- **Comment (d):** SRK, 2010a – “*There is reference to Stiff diagrams prepared by others. It would be helpful to include these in this report.*”

Response: In the July 2010 report (Tetra Tech, 2010a), Figure 18 was added to illustrate the general geochemistry via Stiff Diagrams, prepared by M&A (2009a), for each well and spring.

- **Comment (e):** SRK, 2010a – “*A number of descriptors used in the report are relative but not quantified...*”

Response: In the July 2010 report (Tetra Tech, 2010a), an effort was made to quantify or provide data references and figures to support the relative comparison between data

at different locations. In some cases, however, data are not available for direct numerical comparison.

- **Comment (f):** SRK, 2010a – *“There are references to MC1 and MC2 differences being explained by the degree of rock alteration. Trace element characteristics could be included here as indicators. This would be a useful overall aspect to be added that could provide more in the geological context. A conclusions section should be included in the report.”*

Response: In the July 2010 report (Tetra Tech, 2010a), Figure 18 was added to illustrate the general geochemistry via Stiff Diagrams, prepared by M&A (2009a), for each well and spring, including MC1 and MC2. This figure illustrates the different geochemistry between these springs and presentation of trace elements was not needed to make this distinction.

Conclusions were added to the Executive Summary in a bulleted list to summarize the report’s (Tetra Tech, 2010a) primary findings.

- **Comment:** SRK, 2010a – *“Potential impacts to Davidson Canyon should be re-evaluated on the basis of the predictive simulations and sensitivity analyses of the 3-D numerical groundwater model currently being revised by M&A.”*

Response: The groundwater modeling report (Tetra Tech, 2010j), documenting Tetra Tech’s numerical regional groundwater flow model, discusses the potential impacts and sensitivity analyses in detail.

- **Comment:** SRK, 2010b – *“The M&A numerical groundwater flow model is being revised and Tetra Tech is currently developing a groundwater model. Once those works are complete and the final versions reviewed by SRK, the following will need to occur:*
 - *Re-evaluation of the impacts to Davidson Canyon from pit dewatering once the M&A and Tetra Tech models are reviewed and complete.*
 - *The Infiltration, Seepage, and Fate and Transport Modeling report (Tetra Tech, 2010c) was reviewed by SRK (2010c) and should be revised in light of the review comments.*
 - *Re-evaluation of the impacts of seepage from the TSF, waste rock, and heap on Davidson Canyon.*

Response: Tetra Tech’s groundwater flow models have been completed since the August 3rd review (SRK, 2010b). Impacts to Davidson Canyon and the larger regional area were subsequently evaluated in technical memoranda and in Section 8.0 of the comprehensive groundwater modeling report (Tetra Tech, 2010j).

Infiltration through and resulting seepage from the Waste Rock Storage Area and the Dry Stack Tailings Facility did not change in the updated report titled *“Infiltration, Seepage, and Fate and Transport Modeling, Revision 1”* (Tetra Tech, 2010h). There was no predicted infiltration through the Waste Rock Storage Area. The only infiltration through the Dry Stack Tailings Facility was the drain-down predicted by Amec Earth & Environmental (AMEC, 2009). Another report by Tetra Tech (2010i) documented the predicted infiltration due to the flow-through drains underneath the Dry Stack Tailings Facility. Flow-through drains pass stormwater from the up-gradient side of the Project facilities to the down-gradient side. The post-closure groundwater flow model simulations

incorporated recharge changes due to the tailings drain-down and flow-through drains (Section 5.6.3 of the comprehensive groundwater modeling report [Tetra Tech, 2010j]). In addition, a sensitivity simulation was completed using the unaltered, steady-state recharge distribution as shown in Section 9.5.8 of the comprehensive groundwater modeling report.

2.0 Response to Comments on “Hydraulic-Property Estimates” (SRK, 2010c)

Short-Term Aquifer Test Analysis

- **Comment:** *“To demonstrate that the re-analysis by Tetra Tech can be compared to the M&A analysis, SRK recommends that Attachment 1 include a column that refers the reader to the figures in the M&A report to show the particular analytical plots. Further, to make the comparisons fully defensible, it is recommended that the Tetra Tech analysis be provided as an additional attachment to the Technical Memorandum”.*

Response: References to the M&A (2009a) figures were originally included in Attachment 1 of the “Hydraulic-Property Estimates” Technical Memorandum (Tetra Tech, 2010b), but were more clearly identified and referenced in the groundwater modeling report (Tetra Tech, 2010j). The Tetra Tech short-term test analyses were added to the M&A figures for direct comparison and provided in Appendix B of the comprehensive groundwater modeling report.

Long-Term Pumping Test Analysis

- **Comment:** *“Though the configuration is implied in Attachment 1, SRK recommends that the text include a description of the configuration and some detail on how the isolation packers were deployed and monitored (given the 60 plus day deployment of the packer, if used)”.*

Response: Cross section figures (Figures 4-6, 4-7, 4-8, and 4-9) were added to the groundwater modeling report (Tetra Tech, 2010j) to illustrate the test and radial-model configurations (well completion and geologic units) for each radial-model analysis. The details of the screened intervals, hydrogeologic units, and formations are provided on these new figures. Details of the tests and procedures are provided in M&A (2009b). Isolation packers, however, were not used during the 30-day test.

- **Comment:** *“SRK would like to see a figure for that test cell similar to the Figure 2 cross section. The elevations of the screened intervals and piezometers, and the pumping rates should be listed in a text box on all plots. Tetra Tech should consider adding a right-hand Y-axis showing pumping rates over the duration of pumping. Also, the units on the time axis are not clear. They appear to be in units of “year decimal year,” which should be stated in the axis title. Actual dates may be a better presentation”.*

Response: Cross section figures (Figures 4-6, 4-7, 4-8, and 4-9) were added to the groundwater modeling report (Tetra Tech, 2010j) to illustrate the test and radial-model configurations (well completion and geologic units) for each radial-model analysis. The details of the screened intervals, hydrogeologic units, and formations are provided on these new figures. Pumping variations and average rates are discussed in the text of the

groundwater modeling report. Pump-discharge data and additional test background information are available in M&A (2009b). The time axis units on the graphs were converted to days, as suggested.

- **Comment:** *“To test the viability of the approach taken by Tetra Tech, SRK recommends a simplistic 3-D model (for the pumping area only) to re-evaluate the effects on the hydraulic parameters of the fault and truncated units for pumping test PC-5 and low permeable pre-Cambrian rock in pumping well HC-1B”.*

Response: A discussion was added to the groundwater modeling report (Tetra Tech, 2010j) on the benefits and drawbacks of alternative modeling approaches for analyzing the long-term tests (Section 4.3.4 of the report). A new model with a more refined 3D model grid could be used to overcome the limitations posed by the regional model's large cell sizes. Hydraulic properties from a refined model transient calibration, however, would ultimately have to be scaled to the same regional model grid. The additional detail and resolution required to match the test responses would be largely lost in the up-scaling process (effective hydraulic conductivity of the larger grid block), which would reduce the transient calibration's value.

Hydraulic Parameters Used In Regional Groundwater Flow Model

- **Comment:** *“It should be noted that no values for hydraulic conductivity were recommended as initial input to the regional groundwater model. Given that Tables 1 and 2 provide very different values for K_h and K_v , SRK is uncertain as to how the values will be applied. Part of our uncertainty comes from not clearly understanding the placement of the packer in PC-5, and the manner in which values for both the Concha Limestone and Scherrer Formation are provided in Table 1, even though they may have been producing at the same time from the same packer setting. Thus we are uncertain how vertical conductivities were calculated. Due to these uncertainties, SRK is not able to judge the applicability of a 2-D radial model to serve as input to, and provide transient calibration for a 3-D regional groundwater flow model.*

Response: As suggested, the initial, recommended hydraulic properties for the flow model were discussed in the Section 4.3.7 and provided in Table 4-6 of the groundwater modeling report (Tetra Tech, 2010j). Changes to these initial parameter values during model calibration were discussed in Section 6.2 and Table 6-3.

The well, test, and formation configurations for each analyzed long-term test were provided in Figures 4-6, 4-7, 4-8, and 4-9 (Tetra Tech, 2010j). Packers were not used during the long-term test and this was clarified in the report text.

3.0 Response to Comments on “Hydrogeologic Framework Model” (SRK, 2010d)

- **Comment:** *“The 10 hydrogeologic zones with individual sets of hydraulic parameters look reasonable. It should be noted that SRK did not find a description of these parameters in the reviewed document. But in as much as it presents a concept for*

modeling, we expect the parameters will be described and defended in subsequent documents.

Response: A full description of the hydrogeologic units was provided in Section 4.1 of the groundwater modeling report (Tetra Tech, 2010j). The two parameters added during model calibration are discussed in Section 6.2.1.

4.0 Response to Comments on “Groundwater Model Construction and Calibration” (SRK, 2010e)

Description of Groundwater Flow Model Setup

Comment: *“...SRK did not find an explanation of modification of the western model boundary (assumed to be C-HEAD for the steady-state conditions) for transient mining and post-mining simulations.”*

Response: The western model boundary was simulated as a constant-head boundary in the steady-state model and was not modified for transient mining and post-closure simulations. The flow-model boundaries were discussed in Section 5.10 “External Model Boundaries,” which is a subsection of 5.0 Groundwater Flow Model Construction in the groundwater modeling report (Tetra Tech, 2010j). Information in Section 5.0 of the report relates to all models unless specifically stated otherwise (e.g., post-closure recharge). Modification of the boundaries was discussed in Section 9.3 “Western Flow Model Boundary,” which is part of Section 9.0 “Sensitivity Analysis” in the groundwater modeling report (Tetra Tech, 2010j).

Simulation of Recharge

- **Comment:** *Recharge from precipitation was not applied into the pit area during transient mining simulations assuming that all water will be captured by drain cells and removed from the model. SRK agrees that this is a valid approach to simulate water levels in the vicinity of the proposed pit; however, it is our opinion that this method would underestimate dewatering requirements.*

Response: During the mining-phase simulation, the recharge distribution remained unchanged from the steady-state model. Recharge was applied to the pit area and it was removed by the drain cells and included in the pit dewatering estimates. However, recharge is less than direct precipitation and the simulated dewatering estimate does not account for this volume. Text in the groundwater modeling report (Tetra Tech, 2010j, Section 5.6.2) was modified for clarity.

- **Comment:** *Post-closure recharge from the waste rock storage area and the heap leach facility is assumed to be zero, based on the Tetra Tech (2010c) report, Infiltration, Seepage, and Fate and Transport Modeling Report. It should be noted that the review of that report by SRK (2010b) indicated that zero recharge is likely unrealistic. However, the zero value was also applied by Tetra Tech. SRK is of the opinion that recharge through the facilities should be revised or otherwise explained*

Response: Infiltration into and seepage from the Waste Rock Storage Area was re-evaluated by Tetra Tech (2010h) following SRK's review. After simulating different climate conditions as suggested, modeling resulted in the same conclusion of zero infiltration through the Waste Rock Storage Area. This finding was used in the groundwater flow models since it was considered the most reliable data available at the time the model was being constructed and calibrated.

Seepage due to heap leach drain-down after its operational period was estimated to be a maximum of 10 gpm, decreasing to 3 gpm after 10 years, and 0.5 gpm at 115 years (Tetra Tech, 2010h). At the end of operations, the drain-down seepage was predicted to be less than 5 ac-ft/yr. However, any recharge generated in the heap leach area is predicted to be within the capture zone of the Open Pit and will flow toward the pit/pit-lake. Due to the low potential seepage rate, and the short time period over which the seepage would occur, drain-down from the heap leach was not simulated in the flow models (Tetra Tech, 2010j).

Recharge was applied under the Dry Stack Tailings Facility to simulate drain-down seepage (AMEC, 2009). Recharge was also added to the areas underneath the Dry Stack Tailings Facility due to the flow-through drains (Tetra Tech, 2010i). This resulted in a net recharge increase in the Project facilities area. Sensitivity analyses were also performed on the recharge rate. Recharge rates used in the post-closure groundwater flow model is discussed in Section 5.6.3 of the groundwater modeling report (Tetra Tech, 2010j).

- **Comment:** *It is not clear from the reviewed Technical Memorandum why the recharge from the tailings is assumed to be a constant value for the entire duration of the post-closure simulation, given initial dewatering of the tailings following cessation of mining, followed by an asymptotic equilibration to average climatic conditions.*

Response: Recharge from the Dry Stack Tailings Facility varied over the post-closure period to account for the tailings drain-down as defined by AMEC (2009). The tailings will be dry stacked, so minimal drain-down was predicted. Text was added to the groundwater modeling report (Tetra Tech, 2010j) to make the recharge distribution and simulation set-up clear (see Section 5.6.3, Figures 5-5 and 5-6).

Simulation of Evapotranspiration

- **Comment:** *Assumption for extinction depth that was uniformly applied throughout the model domain (The Tetra Tech memorandum states that extinction depth varies with the types of the soil and vegetative cover, ranging from about 1.5 feet under bare conditions in sandy soil to about 27 feet under forest cover conditions in clayey soil). SRK requests an explanation of why a uniform extinction depth was applied.*

Response: In Section 5.7 of the groundwater modeling report (Tetra Tech, 2010j), the following text was added to describe the application of extinction depth: "A spatial distribution of extinction depths based on plant types was not available at the time of model construction, so the extinction depth was set uniformly to 16.4 feet (5 meters) below the land surface. This depth was a mid-range value that approximates an average extinction depth over the riparian areas." Simulated water levels in the riparian areas did

not substantially decrease, so the extinction depth did not strongly influence the simulated ET.

- **Comment:** *Distribution of maximum evapotranspiration rates along the reaches of Cienega Creek and Davidson Canyon. SRK suggests a better explanation for the basis in the data for the distribution.*

Response: As suggested, the availability of ET estimates is discussed in Section 2.6 of the groundwater modeling report (Tetra Tech, 2010j). Adoption of the M&A (2009c) ET estimates was selected as the best available ET distribution for the model domain at the time of model construction and calibration. ET is further discussed in Section 5.7 of the groundwater report.

Model Calibration and Simulated Groundwater Budget

- **Comment:** *It is not clear how the results of the interpretation of a 30-day pumping test by 2-D radial flow models (Tetra Tech, 2010d) were used for the model calibration. The comparison shown in Table 2 indicates that the hydraulic conductivity values calibrated and used in the model are less than those estimated from the 30-day pumping test data.*

Response: The hydraulic conductivity estimates from the 2D radial models and the other aquifer test analysis results were used to establish the initial model parameter values. The parameter values were subsequently modified during model calibration. The 2D model results and aquifer test data were not used explicitly due to the test limitations and scale issues, which were described in Sections 6.2 and 7.0 of the groundwater modeling report (Tetra Tech, 2010j).

- **Comment:** *Table 1 (in SRK memo) shows that the components of the groundwater budget simulated by the Tetra Tech (2010a) and M&A (2009b) numerical models both were calibrated to measured pre-mining water levels. Yet the components of the budget are substantially different. The differences in the components of the groundwater budget are as much as 2,900 ac-ft/yr for recharge and 8,800 ac-ft/yr in groundwater discharge into streams. Such differences indicate a non-unique calibration of the model to pre-mining only water levels.*

Response: The water budget differences between the M&A (2009c) and Tetra Tech models are largely explained by differences in modeling methods. Analyses to estimate the water budget components within the model domain were completed by M&A (2009c). Previous studies and M&A estimates were the best available data at the time of Tetra Tech's model construction, and they were used to the greatest extent possible. Even though similar estimates were initially used, water-budget differences remained and they were largely due to differences in model construction. The water-budget differences, however, were generally within the uncertainty of the original estimates.

SRK's calculation of water-budget differences did not consider the differences in simulation methods. Total recharge in the M&A model (2009c) was the sum of "recharge" and "groundwater recharge from streams", which was 9,182 ac-ft/yr. The difference in total recharge is only 727 ac-ft/yr or about 7 percent of Tetra Tech's simulated recharge. M&A's groundwater discharge to streams was 2,172 ac-ft/yr and Tetra Tech's net groundwater discharge to streams was 2,618 ac-ft/yr, which is a difference of 446 ac-ft/yr (10,962 ac-ft/yr – 8,344 ac-ft/yr) or 0.6 cfs. Additionally, M&A

(2009c) simulated stream flow gains and ET losses with constant-rate wells. This simulation approach did not allow the recharge and discharge rates to vary based on the simulated water levels. Tetra Tech used the SFR and EVT packages in MODFLOW which allowed the rates to vary based on the simulated water levels.

Although M&A subsequently revised their 2009 model, water-budget differences between it and the Tetra Tech model are still likely. Tetra Tech agrees with SRK that the simulated water-budget differences should be reasonable compared to the uncertainty in the water-budget component estimates. In the context of predicting impacts due to the Project, these water-balance differences appear to be acceptable since the model predictions are similar.

- **Comment:** *The Tetra Tech Technical Memorandum indicates that the streambed hydraulic conductivity of 3.28 ft/day was increased by a factor of 2 during the steady-state calibration to better match data from stream flow gauges. However, SRK was not able to find a comparison of simulated stream flows (shown in Figure 40) to measured values.*

Response: Measured flows at stream gages and simulated stream flows for each reach were presented on Figure 40 in the Technical Memorandum titled “Groundwater Flow Model Construction and Calibration” (Tetra Tech, 2010d). However, the font color was difficult to distinguish from the background. The presentation of the simulated steady-state stream flows were modified to make the results easier to see and read as illustrated on Figure 6-30 and similar figures in the groundwater modeling report (Tetra Tech, 2010j). These figures illustrate both the measured and simulated stream flows. The MODFLOW GAGE package was also used by Tetra Tech to obtain simulated flows in the model cells where the USGS gages were located. This provided a direct comparison of measured to simulated stream flow, as suggested.

- **Comment:** *Different pairs of values for recharge/vertical hydraulic conductivity can simulate the same distribution of the water levels, resulting in the same calibration to steady-state water levels. Calibrations of the model to steady-state fluxes (results have not been found) and transient conditions (not completed) are additionally required in SRK’s opinion to decrease the nonuniqueness of the parameters used for the predictive simulations.*

Response: Tetra Tech agrees that calibrating to fluxes and transient conditions improves model uniqueness. Observed stream flows at the gaging stations were discussed in Section 5.8 of the groundwater modeling report (Tetra Tech, 2010j) and their use as steady-state model calibration targets were discussed in Section 6.1. The stream-flow calibration process and results were provided in Section 6.2.6 of the groundwater report. The lack of observed regional transient water levels available for model calibration and Tetra Tech’s approach for a transient calibration was discussed in the Section 7.0 of the groundwater report.

Models to Predict Mining and Post-Mining Conditions

- **Comment:** *The specific storage parameter for bedrock units was assumed to be $S_s=9.86 \times 10^{-6} \text{ ft}^{-1}$ based on the geometric mean of the values estimated from the radial flow modeling analysis of the 30-day pumping test. SRK is of the opinion that this*

number represents the high range of specific storage values and is not conservative enough to estimate the possible maximum extent of the cone of depression during mining and post-mining conditions. Storage parameters derived from the short stress tests tend to overestimate values. Based on SRK experience for low permeability bedrock units, a more realistic and conservative value could be $S_s=1.0 \times 10^{-6} \text{ ft}^{-1}$, which is recommended for use in a Best Case, or, as the value for the transient sensitivity analysis.

Response: Additional discussion was provided to Section 7.1 of the groundwater modeling report (Tetra Tech, 2010j) to support the specific storage estimate of $9.84 \times 10^{-6} \text{ ft}^{-1}$. In addition, the sensitivity analysis used specific storage values of $9.84 \times 10^{-5} \text{ ft}^{-1}$ and $9.84 \times 10^{-7} \text{ ft}^{-1}$ to evaluate the impact of higher and lower values in mining-phase and post-closure simulations (Sections 9.4.6 and 9.5.7). While there was a difference in simulated drawdown at 150 years due to the different storage values, these differences become less important as the groundwater system approached steady-state conditions, i.e., when there was virtually no water flowing into or out of aquifer storage. The specific storage value of $9.84 \times 10^{-7} \text{ ft}^{-1}$ used in the sensitivity analysis provided the conservative value for evaluation that SRK suggested.

- **Comment:** *It is not clear how the values for conductance of the lake cells were assigned and how groundwater inflow to the pit was simulated by drain cells at the end of mining, as compared to the inflow by the lake cells at the beginning of pit lake infilling.*

Response: The lake-cell conductance was set equal to or greater than the conductance of the adjacent aquifer material. This was added to Section 8.2.1 of the groundwater modeling report (Tetra Tech, 2010j) as suggested. Pit inflows at the end of operations were approximately 400 gpm (Section 8.1.1). Pit inflows at the start of the post-closure simulation were approximately 311 gpm (Section 8.4). This difference in pit inflows was discussed in Section 8.4.1 of the groundwater report, as suggested.

In summary, the differences in pit inflows were a combination of numerical instability and changing from drain-cells to lake-cells. Hydraulic oscillations during the first 60 days of the post-closure simulation caused numerical instability that likely influenced the simulated inflow rates.

Pit inflows were likely different due to differences in drain-cell and lake-cell elevations. Simulated dewatering extended beyond the pit shell since the drain-cell elevations were set 33 feet below the pit. Lake-cell elevations, however, closely matched the pit shell elevations. Dewatered aquifer material had to re-saturate following the end of dewatering before groundwater flowed into the pit and reached the lake-cells. This resulted in a delayed inflow response following the end of dewatering. During this delay, water levels surrounding the pit were re-equilibrating and the hydraulic gradients that drove inflows were changing. This likely contributed to the simulated decrease in pit groundwater inflows exactly at the end of operations relative to inflows several time steps into the post-closure simulation.

- **Comment:** *It is not clear what boundary conditions are along the western model boundary for mining and premining simulation. SRK requests an explanation of how the boundary conditions were constructed for mining and post-mining conditions.*

Response: Clarifying text was added to the groundwater modeling report (Tetra Tech, 2010j) to indicate that the external boundary conditions, including the western model

boundary, were constant for the steady-state, mining-phase, and post-closure simulations (Section 5.10). The western boundary was altered during the sensitivity analysis and is discussed in Section 9.3 of the groundwater report.

- **Comment:** *It was assumed that the pit lake will reach a steady-state elevation 1,000 years after mining has ceased. This was estimated by extending the predicted post-mining conditions estimated in the 100-year prediction in M&A (2009b). It is not clear whether the assumption is appropriate and representative. SRK recommends completing an assessment of timing to reach steady-state post-mining conditions by using the Tetra Tech model, not M&A model.*

Response: The steady-state elevation of the pit-lake and the groundwater system as a whole is discussed in Section 8.4.1 of the groundwater modeling report (Tetra Tech, 2010j). Figure 8-16 illustrates the pit-lake water balance over the 1,000-year post-closure period. Steady-state conditions were reached after approximately 700 years. As suggested, steady-state conditions were confirmed by an additional figure (Figure 8-14) that illustrates that drawdown did not change between 1,000 and 1,500 years.

Results of Model Calibration and Steady State Sensitivity Analysis

- **Comment:** *Based on the completed analyses, Tetra Tech concluded that the steady-state calibration has a “nearly optimal parameter value for matching water level in the model.” SRK agrees that mathematically this statement is correct. However, as mentioned above, the model should be calibrated to both water level and flow data. It should be noted that SRK did not find the results of the sensitivity analyses of model parameters to the data for groundwater/stream flow interaction.*

Response: Tetra Tech agrees that model calibration to water level and flow data is preferred. Stream flows at the gaging stations were used as steady-state model calibration targets and are discussed in Section 6.1 of the groundwater modeling report (Tetra Tech, 2010j). The stream-flow calibration process and results are provided in Section 6.2.6. The lack of observed regional transient water levels available for model calibration and Tetra Tech’s approach for a transient calibration was discussed in Section 7.0 of the groundwater report. Sensitivity analyses are included in Section 9.0.

5.0 Response to Comments on “Predictive Groundwater Modeling Results” (SRK, 2010f)

Mining Conditions

- **Comment:** *The simulations were made using 3 models – pre-mining, mining, and post – mining. The results of the simulations are presented in Table 7 in Tetra Tech (2010a) and Tables 1 and 3 in Tetra Tech (2010b). The component of the pre-mining steady state water balance should be exactly the same in these three tables.*

Response: In the groundwater modeling report (Tetra Tech, 2010j), Table 8.3 presents the water-balance data as suggested.

Post-Mining Conditions

- **Comment:** *Constant head (CHEAD) boundary condition at the Western boundary likely significantly limits propagation of drawdown to the east. SRK strongly recommends that the influence of the CHEAD boundary be investigated with a General Head Boundary (GHB) along the Western boundary of the model using a sensitivity analysis or post-mining conditions. The GHD utilizes a constant head at a defined distance that would be beyond the current western boundary, thereby mitigating the synthetic effect of a constant head so close to the pit.*

Response: As suggested, the western boundary was simulated as a General Head Boundary (GHB) and as a no-flow boundary in the sensitivity analysis (Section 9.3 of the groundwater modeling report [Tetra Tech, 2010j]). A description of GHB conductance and heads was included. Simulated changes in flows out of the model domain and drawdown propagation were also discussed. Under all simulated conditions, except the no flow boundary sensitivity simulation, there was groundwater flow out of the western boundary. Water was not simulated to flow from the western boundary to the pit. The flux out of the model decreased by approximately 2 percent between the post-closure constant head simulation and the GHB sensitivity simulation, but drawdown propagation was relatively insensitive to these changes.

- **Comment:** *It is not clear why the extent of drawdown cone at steady-state post mining conditions (run by steady-state model) is smaller than the extent at 1000 years after mining ceased. An explanation is required. If the difference has a numerical origin (i.e., steady-state vs. transient simulations), SRK recommends that the transient model be run sufficiently long to demonstrate equilibration with steady-state results.*

Response: As suggested, the post-closure simulation was extended to 1,500 years and drawdown was compared to the 1,000 year simulation (Figure 8-14 of the groundwater modeling report [Tetra Tech, 2010j]). These simulations confirmed that the predicted groundwater system had reached steady-state conditions by 1,000 years.

6.0 Response to Comments on “Results of Sensitivity Analyses” (SRK, 2010f)

Conclusions

- **Comment:** *Include influence of the Western model boundary into the sensitivity analysis. The model predictions indicate that an assigned CHEAD boundary condition limits and, most likely, under-predict propagation of cone of drawdown (and at a minimum, deforms the cone) during post-mining conditions. It is recommended that GHB condition be applied at differing distances from the Western model boundary to evaluate its effect on predictive simulations, especially during post-mining conditions.*

Response: As suggested, the western boundary was simulated as a General Head Boundary (GHB) and as a no-flow boundary in the sensitivity analysis (Section 9.3 of the groundwater modeling report [Tetra Tech, 2010j]). A description of GHB conductance and heads was included. Simulated changes in flows out of the model domain and drawdown propagation were also discussed. Under all simulated conditions, except the

no flow boundary sensitivity simulation, there was groundwater flow out of the western boundary. Water was not simulated to flow from the western boundary to the pit. The flux out of the model decreased by approximately 2 percent between the post-closure constant head simulation and the GHB sensitivity simulation, but drawdown propagation was relatively insensitive to these changes.

- **Comment:** *Though graphs and tables are present the results of the sensitivity analysis, SRK recommends that additional results be included as tables and/or graphs, showing:*
 - a) *Predicted pit inflow in time (for mining phase, graphs);*
 - b) *Pit-lake infilling curves in time (for post-mining, graphs);*
 - c) *Drawdown propagation (for both mining and post-mining, table); and*
 - d) *Impact to surface bodies – cumulative change in stream flow (for both mining and post-mining, table).*

Response: The following figures in the comprehensive groundwater modeling report (Tetra Tech, 2010j) present the suggested results:

- a) **Figure 8-3:** Predicted pit inflow in time (for mining-phase, graphs);
 - b) **Figure 8-16:** Pit-lake infilling curves in time (for post-closure, graphs);
 - c) **Numerous figures were provided with drawdown contours and graphs, presentation in table format was deemed less informative based on the spatial nature of the results:** Drawdown propagation (for both mining-phase and post-closure, table); and
 - d) **Figures 8-6 and 8-15 (tables included on figures):** Impact to surface bodies – cumulative change in stream flow (for both mining-phase and post-closure, table).
- **Comment:** *Explain the difference seen in Figure 23 between the drawdown contours from transient predictions at 1,000 years post mining, and for the steady-state post-mining conditions. Unless otherwise explained, it is SRK’s opinion that steady-state contours of drawdown should not be closer to the pit than the 1,000-year contour generated by the transient predictive runs.*

Response: As suggested, the post-closure simulation was extended to 1,500 years and drawdown was compared to the 1,000 year simulation (Figure 8-14 of the groundwater modeling report [Tetra Tech, 2010j]). These simulations confirm that the predicted groundwater system had reached steady-state conditions by 1,000 years.

- **Comment:** *Add the extent of the steady-state post-closure drawdown to Figure 24 for purposes of comparison. The Figure currently compares drawdown contours at end of mining and after 150 and 1,000 years post closure. Adding the steady-state contour to the figure may shed insight into the differences mentioned in the previous bullet.*

Response: As suggested, Figure 8-14 was added to the groundwater model report (Tetra Tech, 2010j) to illustrate that the 1,000-year and 1,500-year drawdown were the same and represented steady-state conditions. The comparison between end of operations, 150-years post-closure, and 1,000-years post-closure was presented on Figure 9-27. In the groundwater report, the text and figures indicate that the 1,000-year post closure drawdown represented steady-state conditions, so the intent of the comment was addressed.

7.0 References

- AMEC Earth & Environmental, Inc. (2009). *Dry Stack Tailings Storage Facility, Final Design Report*. Prepared for Rosemont Copper Company. Report Dated April 15, 2009.
- Montgomery & Associates, Inc. (M&A) (2009a). *Results of Phase 2 Hydrogeologic Investigations and Monitoring Program, Rosemont Project, Pima County, Arizona*. Prepared for Rosemont Copper Company. Report Dated February 26, 2009.
- M&A (2009b). *Analysis of Long-Term, Multi-Well Aquifer Test – November 2008 through January 2009, Rosemont Project, Pima County, Arizona*. Prepared for Rosemont Copper Company. Report Dated October 28, 2009.
- M&A (2009c). *Groundwater Flow Modeling Conducted for Simulation of Proposed Rosemont Pit Dewatering and Post-Closure, Rosemont Project, Pima County, Arizona*. Prepared for Rosemont Copper Company. Report dated October 28, 2009.
- Tetra Tech (2010a). *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts Report*. Prepared for Rosemont Copper Company. Report Dated July 2010.
- Tetra Tech (2010b). *Hydraulic-Property Estimates*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 9, 2010.
- Tetra Tech (2010c). *Hydrogeologic Framework Model*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 9, 2010.
- Tetra Tech (2010d). *Groundwater Flow Model Construction and Calibration*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 26, 2010.
- Tetra Tech (2010e). *Steady-State Sensitivity Analyses*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 26, 2010.
- Tetra Tech (2010f). *Predictive Groundwater Flow Modeling Results*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 30, 2010.
- Tetra Tech (2010g). *Rosemont Groundwater Flow Model Sensitivity Analyses*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated August 17, 2010.
- Tetra Tech (2010h). *Infiltration, Seepage, Fate, and Transport Modeling Report, Revision 1*. Prepared for Rosemont Copper Company. Report Dated August 2010.
- Tetra Tech (2010i). *Rosemont Infiltration Analysis*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated April 5, 2010.



- Tetra Tech (2010j). *Regional Groundwater Flow Model, Rosemont Copper Project*. Prepared for Rosemont Copper Company. Report Dated November 2010.
- SRK Consulting (SRK) (2010a). *Technical Review of Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project (Tetra Tech, 2010a)*. Technical Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated May 11, 2010.
- SRK (2010b). *Technical Review of Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project (Tetra Tech, 2010a)*. Technical Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated August 3, 2010.
- SRK (2010c). *Review of Tetra Tech (2010) Hydraulic Property Estimates*. Draft Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated August 2, 2010.
- SRK (2010d). *Technical Review of Hydrogeologic Framework Model (Tetra Tech, 2010)*. Draft Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated July 30, 2010.
- SRK (2010e). *Review of Tetra Tech Documents "Groundwater Flow model Construction and Calibration" and "Steady-State Sensitivity Analyses."* Draft Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated August 17, 2010.
- SRK (2010f). *Technical Review of Predictive Groundwater Flow Modeling Results (TT, 2010a) and Rosemont Groundwater Flow Model Sensitivity Analyses (TT, 2010b)*. Technical Memorandum to Dale Ortman (SWCA). Technical Memorandum Dated September 27, 2010.

ATTACHMENT 1
SRK REVIEWS OF TETRA TECH (2010A)
DAVIDSON CANYON HYDROGEOLOGIC
CONCEPTUAL MODEL AND ASSESSMENT OF
SPRING IMPACTS REPORTS

Technical Memorandum

To:	Dale Ortman, P.E.	Date:	May 11, 2010
cc:	Tom Furgason, SWCA File, SRK	From:	Vladimir Ugorets, PhD, SRK Michael Sieber, P.E., SRK Stephen J. Day, P.Geo., SRK
Subject:	Technical Review of <i>Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project</i> (Tetra Tech, 2010a) and <i>Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine</i> (Montgomery & Associates, 2010)	Project #:	183101/1700

A technical review was undertaken and this Technical Memorandum was prepared at the request of SWCA and the Coronado National Forest, in accordance with a statement of work from Mr. D. Ortman dated March 15, 2010. Provided here are comments related to the review of the following two reports:

- (a) *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project* (Tetra Tech, 2010a), and
- (b) *Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine* (Montgomery & Associates, 2010)

These comments were prepared by Vladimir Ugorets, Michael Sieber, and Stephen Day of SRK Consulting, Inc. (SRK). Review was performed by Larry Cope, also of SRK.

This memorandum is organized into two sections, per the two reviewed documents listed above.

1 Davidson Canyon Hydrogeological Conceptual Model and Assessment of Spring Impacts

The report is relatively comprehensive, well presented, and well written. The report describes the most likely hydrologic dynamics and key physical processes that are governing groundwater-surface water interactions in Davidson Canyon. It includes a discussion of creeks and springs and their interface with the groundwater system (Tetra Tech, 2010a).

This document is a good compilation of available groundwater, surface water, local geology, and water chemistry data indicating that:

- (a) The Rosemont Project will have some effect on Davidson Canyon due to the changes in the surface and groundwater flow patterns at the Project site.
- (b) The estimated area affected by the Rosemont Project comprises about 16 percent of the Davidson Canyon watershed.
- (c) In average annual conditions, Tetra Tech (2010a) estimated that most of the stormwater entering the flow-through drains will result in infiltration and likely will reduce flows to downstream receptors.

- (d) The areas with the most for potential groundwater-surface water interactions are in topographically lower areas of Davidson Canyon (Reach 4), which are the furthest from the proposed Rosemont Project.
- (e) Changes to baseline conditions in Davidson Canyon and Cienega Creek as a result of open pit dewatering operations will not occur unless the cone of depression extends to an aquifer that is hydraulically connected to surface water.
- (f) Three springs (Questa, Rosemont, and Davidson) are potentially hydraulically connected with the regional bedrock groundwater system and might be impacted by in-pit dewatering, if drawdown propagates to their location. Other local (or perched-water) springs would be less likely to be affected by mine activities, unless they are proximate to the pit where the pit may alter the local flow system that is yielding water to the springs.
- (g) The long term impacts to the water resources in Davidson Canyon and the larger Cienega Creek basin will not exceed the predicted rate of pit inflow (300 to 400 gallons per minute (gpm) during mining, and will continuously decrease to 120 gpm after 100 years of pit lake infilling (M&A, 2009). This model is currently being revised and the impact on Davidson Canyon should be re-examined when the revisions are complete.

Mine Impacts

The mining operations that could potentially impact the Davidson Canyon and Cienega Creek watersheds are the open pit dewatering (M&A, 2009 and Tetra Tech, 2010b) and seepage from the Dry Stack Tailings Storage Facility (TSF) (AMEC, 2009, Tetra Tech, 2010b), the Waste Rock storage area (waste rock), and Heap Leach facility (heap) (Tetra Tech, 2010b). The M&A numerical groundwater flow model is currently being revised and the impacts to Davidson Canyon from pit dewatering should be re-evaluated once the revisions are complete. Should the Infiltration and Seepage Model (Tetra Tech, 2010b) that was reviewed by SRK (2010) be revised, the impacts of seepage from the TSF, waste rock, and the heap also should be re-evaluated.

SRK found Tetra Tech's conceptual model of Davidson Canyon and their conclusions regarding possible impacts from the mining operations to be reasonable. The isotopic interpretations they presented seem reasonable based on the information provided in the report. However, we feel that it should be considered preliminary due to limited available data and uncertainties in the groundwater modeling predictions (discussed in SRK (2010)). Our specific comments are:

- (a) Figure 9: Local spring isolated from regional groundwater—groundwater flow lines are shown above the water table.
- (b) Figure 15: Schematic cross section of Reach 2 spring development—what data are used for the unsaturated zone as shown between the alluvial and bedrock groundwater systems?
- (c) The water quality data described in Section 7.6 need to be added in the spring comparison table, shown in Figure 8.
- (d) There is reference to Stiff diagrams prepared by others. It would be helpful to include these in this report.
- (e) A number of descriptors used in the report are relative but not quantified. Waters are described as “different,” “very similar,” and “dissimilar,” Inclusion of charts showing the data or more statistics would illustrate these differences.
- (f) There are references to MC1 and MC2 differences being explained by the degree of rock alteration. Trace element characteristics could be included here as indicators. This would be a useful overall aspect to be added that could provide more in the geological context. A conclusions section should be included in the report.

Potential impacts to Davidson Canyon should be re-evaluated on the basis of the predictive simulations and sensitivity analyses of the 3-D numerical groundwater model currently being revised by M&A.

2 Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections, Rosemont Mine

This section presents the results of our review of the report on short-term and long-term groundwater fluctuations as compared to projected drawdown 100 years after closure of the proposed Rosemont mine (M&A, 2009). The document provides a thorough compilation of available groundwater level data that indicate that:

- (a) Calculated short-term (2 to 3 years) groundwater level fluctuations measured in 52 wells range from 0.7 to 33 feet, with an averaged value of 7 feet.
- (b) Calculated long-term (37 to 55 years) groundwater level fluctuations measured in 14 wells range from 0.7 to 69 feet, with an averaged value of about 20 feet.
- (c) The projected drawdown at existing non-Rosemont wells east of the mine area, 100 years after closure of the proposed Rosemont mine, is generally of similar magnitude to the natural short-term fluctuation in groundwater levels observed during a 2- to 3-year period and is generally less than the long-term natural fluctuation in groundwater levels observed during the long-term 37- to 55-year period.
- (d) The projected drawdown at existing non-Rosemont wells west of the Santa Rita ridge and at livestock wells in the immediate mine area, 100 years after closure of the proposed Rosemont mine, appears to exceed the natural short-term groundwater fluctuation (2-year period). No data are available concerning long-term groundwater fluctuation west of the Santa Rita ridge.

SRK has the following specific comments:

- (1) It is not clear why the simulated drawdown of 100 years after closure was chosen for comparison with measured natural groundwater fluctuations. In SRK's opinion, the comparison should be made with the time of maximum drawdown (during the early or intermediate stage of pit-lake infilling) and at steady state, post-mining conditions, which will be significant after 100 years of pit lake infilling. The existing groundwater model (M&A, 2009) did not simulate full pit lake recovery and did not clearly indicate when maximum drawdown occurs at particular locations.
- (2) Surface water bodies (such as creeks and springs) that show the propagation of drawdown need to be added to Figures 1 and 2.
- (3) This comparison analysis should be repeated after existing numerical groundwater model is revised based on the transient calibration (recommendation by SRK (2010)) and to incorporate the revised model simulations.

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.
- Montgomery & Associates, 2009, *Groundwater-flow modeling conducted for simulation of proposed Rosemont pit dewatering and post-closure*: unpublished report prepared for Rosemont Copper by Errol L. Montgomery & Associates, Inc., October 28, 2009, 73 p.
- _____, 2010, *Comparison of natural fluctuation in groundwater level to provisional drawdown projections, Rosemont Mine*: Technical Memorandum prepared for Rosemont Copper by Errol L. Montgomery & Associates, Inc., March 1, 2010.
- SRK, 2010, *Technical review of M & A (2009) groundwater flow model report prepared Rosemont Copper*: Technical Memorandum prepared for SWCA, February 9, 2010, 6 p.
- Tetra Tech, 2010a, *Davidson Canyon Hydrogeologic Conceptual Model and assessment of Spring Impacts*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320869, April 2010, 72 p, 1 appendix.
- _____, 2010b, *Infiltration, Seepage, Fate and Transport Modeling Report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320794, February 2010, 68 p., 6 appendices.

4 QUALIFICATIONS OF KEY TECHNICAL REVIEWER

The Senior Reviewer for Hydrogeology, Vladimir Ugorets, Ph.D., is a Principal Hydrogeologist with SRK Consulting in Denver, Colorado (résumé attached). 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's 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.

Technical Memorandum

To:	Dale Ortman, P.E.	Date:	August 3, 2010
cc:	Tom Furgason, SWCA File, SRK	From:	Vladimir Ugorets, PhD, SRK Michael Sieber, P.E., SRK Larry Cope, SRK
Subject:	Technical Review of <i>Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project</i> (Tetra Tech, 2010a)	Project #:	183101/1800(3)

A technical review was undertaken and this Technical Memorandum was prepared at the request of SWCA and the Coronado National Forest, in accordance with a statement of work from Mr. D. Ortman dated July 18, 2010. Provided here are comments related to the review of the following report:

- (a) *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project* (Tetra Tech, 2010a)

These comments were prepared by Michael Sieber and Vladimir Ugorets of SRK Consulting, Inc. (SRK). Review was performed by Larry Cope, also of SRK.

The first draft of *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts, Rosemont Copper Project*, April 2010 (Tetra Tech, 2010b) was reviewed by SRK (2010a) on May 11, 2010.

1 Davidson Canyon Hydrogeological Conceptual Model and Assessment of Spring Impacts

The report is relatively comprehensive, well presented, and well written. The report describes the most likely hydrologic dynamics and key physical processes that are governing groundwater-surface water interactions in Davidson Canyon. It includes a discussion of creeks and springs and their interface with the groundwater system (Tetra Tech, 2010b).

This document is a good compilation of available groundwater, surface water, local geology, and water chemistry data indicating that:

- (a) The Rosemont Project will have some effect on Davidson Canyon due to the changes in the surface and groundwater flow patterns at the Project site.
- (b) The estimated area affected by the Rosemont Project comprises about 16 percent of the Davidson Canyon watershed. Stormwater flow diversions will likely result in reduced flows to downstream receptors.
- (c) In average annual conditions, Tetra Tech (2010a) estimated that most of the stormwater entering the flow-through drains will result in infiltration and likely will reduce flows to downstream receptors.

- (d) The areas with the greatest potential for groundwater-surface water interactions are along the narrow riparian zones of Reaches 2 and 4, and potentially Reach 3.
- (e) Changes to baseline conditions in Davidson Canyon and Cienega Creek as a result of open pit dewatering operations will not occur unless the cone of depression extends to an aquifer that is hydraulically connected to surface water, Reach 4.
- (f) Three springs (Questa, Rosemont, and Helvetia) are potentially hydraulically connected with the regional bedrock groundwater system and might be impacted by in-pit dewatering, if drawdown propagates to their location. Other local (or perched-water) springs would be less likely to be affected by mine activities, unless they are proximate to the pit where the pit may alter the local flow system that is yielding water to the springs.
- (g) The long term impacts to the water resources in Davidson Canyon and the larger Cienega Creek basin will not exceed the predicted rate of pit inflow (300 to 400 gallons per minute (gpm) during mining, and will continuously decrease to 120 gpm after 100 years of pit lake infilling (M&A, 2009). This model is currently being revised and the impact on Davidson Canyon should be re-examined when the revisions are complete.
- (h) Tetra Tech is currently developing a regional groundwater model to simulate mining and post-mining conditions. The impacts on Davidson Canyon should be re-examined when this model is complete.

Mine Impacts

Open pit dewatering (M&A, 2009) and infiltration, seepage, and transport from the Waste Rock Storage area (waste rock), Heap Leach facility (heap), and the Dry Stack Tailings Storage Facility (TSF) (Tetra Tech, 2010c), and seepage from the TSF (AMEC, 2009, Tetra Tech, 2010c) are the mining operations that could potentially impact the Davidson Canyon and Cienega Creek watersheds. A large amount of work is currently being conducted by M&A and Tetra Tech. The M&A numerical groundwater flow model is being revised and Tetra Tech is currently developing a groundwater model. Once those works are complete and the final versions reviewed by SRK, the following will need to occur:

- Re-evaluation of the impacts to Davidson Canyon from pit dewatering once the M&A and Tetra Tech models are reviewed and complete.
- The Infiltration, Seepage, and Fate and Transport Modeling report (Tetra Tech, 2010c) was reviewed by SRK (2010c) and should be revised in light of the review comments.
- Re-evaluation of the impacts of seepage from the TSF, waste rock, and heap on Davidson Canyon.

SRK found Tetra Tech's conceptual model of Davidson Canyon and their conclusions regarding possible impacts from the mining operations to be defensible and supported by the data provided. The isotopic interpretations that were presented are also defensible and supported by the information provided in the report. However, we feel that it should be considered preliminary due to limited available data and uncertainties in the groundwater modeling predictions and infiltration and seepage modeling predictions (discussed in SRK (2010c)). Specifically, we consider a number of descriptors used in the report are relative and not quantified. Waters are described as "different," "very similar," and "dissimilar." Inclusion of charts showing the data or a more complete presentation of the data and summary statistics would illustrate the differences.

Potential impacts to Davidson Canyon should be re-evaluated on the basis of the predictive simulations and sensitivity analyses of the 3-D numerical groundwater model currently being revised by M&A and the completion of the Tetra Tech numerical groundwater flow model.

2 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.
- Montgomery & Associates, 2009, *Groundwater-flow modeling conducted for simulation of proposed Rosemont pit dewatering and post-closure*: unpublished report prepared for Rosemont Copper by Errol L. Montgomery & Associates, Inc., October 28, 2009, 73 p.
- SRK, 2010a, *Technical review of Tetra Tech (2010) Davidson Canyon hydrogeologic conceptual model and assessment of spring impacts*: Technical Memorandum prepared for SWCA, May 11 2010, 4 p.
- _____ 2010b, *Technical review of Tetra Tech (2010) Infiltration, seepage, fate and transport modeling report*: Technical Memorandum prepared for SWCA, April 30, 2010, 9 p.
- _____ 2010c, *Technical review of M & A (2009) groundwater flow model report prepared Rosemont Copper*: Technical Memorandum prepared for SWCA, February 9, 2010, 6 p
- Tetra Tech, 2010a, *Davidson Canyon hydrogeologic conceptual model and assessment of spring impacts*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320869, April 2010, 72 p, 1 appendix.
- _____ 2010b, *Infiltration, seepage, fate and transport modeling report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320794, February 2010, 68 p., 6 appendices.

3 QUALIFICATIONS OF KEY TECHNICAL REVIEWER

The Senior Reviewer for Hydrogeology, 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's 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's resume was submitted to SWCA previously.

ATTACHMENT 2
SRK REVIEW OF TETRA TECH (2010B)
HYDRAULIC PROPERTY ESTIMATES

Memorandum - DRAFT

To:	Dale Ortman, P.E.	Date:	August 2, 2010
cc:	Tom Furgason, SWCA Cori Hoag, SRK File	From:	Vladimir Ugorets, Ph.D. Larry Cope, M.S. Mike Sieber, P.E.
Subject:	Review of Tetra Tech (2010) <i>Hydraulic Property Estimates</i>	Project #:	183101/1800

This memorandum provides a technical review of the Technical Memorandum, *Hydraulic Property Estimates* (Tetra Tech, 2010) dated July 9, 2010, hereafter referred to as the "Technical Memorandum." This review was undertaken, and our Memorandum prepared by Vladimir Ugorets, Larry Cope, and Mike Sieber of SRK Consulting (U.S.), Inc. (SRK), at the request of SWCA and the Coronado National Forest, and in accordance with a Statement of Work and Request for Cost Estimated from Mr. Dale Ortman dated July 18, 2010.

The comments in the present review are grouped into three topics: (1) short-term aquifer test analysis, (2) long-term pumping test analysis, and (3) hydraulic parameters used in the regional groundwater flow model. The Technical Memorandum is well written and the thinking of the authors can be followed in a straight forward manner. The comments presented below are, in general, requests for clarifications and additional detail related to the data applied and the configuration of the radial flow models.

1 Short-Term Aquifer Test Analysis

Tetra Tech re-evaluated the short-term aquifer tests completed by Montgomery & Associates (M&A) in 2007 and 2008 (M&A, 2007, 2009a, 2009b) by using standard straight-line solutions: Copper-Jacob or Theis Recovery. The results of this re-evaluation produced an arithmetic mean of all K values that was 90.9 percent of the M&A values calculated for the same subset of wells. Although there are some significant differences (by factors of up to 5) for several analyses, SRK considers the brief explanations in Attachment 1 (Tetra Tech, 2010) provide adequate rationale for the differences. With the 10 values of greater than a factor of two removed from the mean calculation, the Tetra Tech mean is 94.1 percent of the M&A mean. Given that the large differences do not have much impact on the mean of all the values, further refinement of the some values is not viewed here as warranted. It may be noteworthy that four of the 10 values with large differences used data from the multiple-level vibrating wire piezometers, which can be very interpretive given the difficulty in quantifying how the point pressure measurements relate to the larger (thicker) flow field.

To demonstrate that the re-analysis by Tetra Tech can be compared to the M&A analysis, SRK recommends that Attachment 1 include a column that refers the reader to the figures in the M&A report to show the particular analytical plots. Further, to make the comparisons fully defensible, it is recommended that the Tetra Tech analysis be provided as an additional attachment to the Technical Memorandum.

2 Long-Term Pumping Test Analysis

Tetra Tech completed re-evaluation of three long-term pumping tests (from wells PC-5, HC-1B, and HC-5A) using detailed 2-D radial numerical groundwater models. Their results are shown in their report Tables 1 through 4.

SRK agrees that a 2-D radial model is an appropriate way to evaluate vertical hydraulic conductivity values when pumping from one tested interval, and water levels are monitored in the same interval and in intervals below or above. However, no discussion is provided on the intervals pumped relative to the piezometers being monitored. Though the configuration is implied in Attachment 1, SRK recommends that the text include a description of the configuration and some detail on how the isolation packers were deployed and monitored (given the 60 plus day deployment of the packer, if used).

Figures 3 through 8 show reasonably good agreement between observed and modeled drawdowns in the grouted-in piezometer PZ5 and the stand-pipes in PC2, HC-1A, and HC-5B. SRK would like to see a figure for that test cell similar to the Figure 2 cross section. The elevations of the screened intervals and piezometers, and the pumping rates should be listed in a text box on all plots. Tetra Tech should consider adding a right-hand Y-axis showing pumping rates over the duration of pumping. Also, the units on the time axis are not clear. They appear to be in units of “year decimal year,” which should be stated in the axis title. Actual dates may be a better presentation.

As pointed out in the Technical Memorandum, faults and discrete linear features are often difficult to represent in a radial model due to the possibility of their incorporation by using a cylindrical shape. It should be noted that such features as a fault and fault-truncated strata are present in the area of pumping well PC-5 and the contact with low permeable pre-Cambrian rocks is present in the vicinity of pumping well HC-1B. To present geological variation between PZ-5 and PC-2 (shown in Figure 2), it appears the model was run for scenarios with and without the Permian formations (Concha, Scherrer, and Epitaph/Colina). The estimated hydraulic parameters for both models are shown in Tables 1 and 2 (by using water level data from piezometers PZ-5 and PC-2, respectively). The results of the estimates for the Willow Canyon Formation (K_{sd}) are very different ($K_h=0.16$ feet per day (ft/day) and $K_v=2.8$ ft/day for piezometer PZ-5, and $K_h=0.1$ ft/day and $K_v=0.006$ ft/day for piezometer PC-2). The differences likely indicate the inapplicability of a 2-D radial flow analysis to simulate responses at PC-2 from the pumping of PC-5. To test the viability of the approach taken by Tetra Tech, SRK recommends a simplistic 3-D model (for the pumping area only) to re-evaluate the effects on the hydraulic parameters of the fault and truncated units for pumping test PC-5 and low permeable pre-Cambrian rock in pumping well HC-1B.

From the foregoing discussion, SRK’s specific requests are summarized as follows:

1. Include details to show how values for K_v and K_h varied with the placement of packers in pumping well PC-5.
2. List test parameters on Figures 3 through 8 (Q , packer/tested interval).
3. Include figures showing the numerical model grid used to simulate the cross section shown on Figure 2 and the pumping test from well HC-1B.
4. Complete an analysis of the pumping tests from wells PZ-5 and HC-1B by using a simplified 3-D numerical groundwater flow model.

3 Hydraulic Parameters Used in the Regional Groundwater Flow Model

The results of the interpretation of long-term pumping tests by using 2-D radial models indicate that:

- a) Horizontal hydraulic conductivity varies from 0.00017 ft/day to 761 ft/day,

- b) Vertical hydraulic conductivity varies from 0.0005 ft/day to 0.28 ft/day, and
- c) Specific storage was estimated to range from 7×10^{-7} 1/ft to 0.0004 1/ft, with a geometric mean of 9×10^{-6} 1/ft (this number was recommended to be applied to all bedrock units within a regional groundwater model).

It should be noted that no values for hydraulic conductivity were recommended as initial input to the regional groundwater model. Given that Tables 1 and 2 provide very different values for K_h and K_v , SRK is uncertain as to how the values will be applied. Part of our uncertainty comes from not clearly understanding the placement of the packer in PC-5, and the manner in which values for both the Concha Limestone and Scherrer Formation are provided in Table 1, even though they may have been producing at the same time from the same packer setting. Thus we are uncertain how vertical conductivities were calculated. Due to these uncertainties, SRK is not able to judge the applicability of a 2-D radial model to serve as input to, and provide transient calibration for a 3-D regional groundwater flow model.

4 References

Errol L. Montgomery & Associates, Inc. (M&A), 2007, Results of drilling, construction, and testing of four pit characterization wells, Rosemont Project, Rosemont Copper Company, Pima County, Arizona: report prepared for Rosemont Copper Company, September 6, 2007, 108 p., 2 appendices.

____ 2009a, Results of Phase 2 hydrogeologic investigations and monitoring program, Rosemont Project, Pima County, Arizona, Volume 2: Appendices: unpublished report prepared for Rosemont Copper Company, February 26, 2009, variously paginated.

____ 2009b, Analysis of long-term, multi-well aquifer test, November 2008 through January 2009, Rosemont Project, Pima County, Arizona: unpublished report prepared for Rosemont Copper Company, May 21, 2009, 59 p, 2 appendices.

Tetra Tech, 2010, Technical Memorandum, Hydraulic property estimates, July 9, 2010, 12 p., 1 attachment.

5 Reviewer Qualifications

The Senior Reviewer, 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 preparation of this memorandum. His resume has been provided to SWCA in prior submissions.

ATTACHMENT 3
SRK REVIEW OF TETRA TECH (2010C)
HYDROGEOLOGIC FRAMEWORK MODEL

Memorandum - DRAFT

To:	Dale Ortman, P.E.	Date:	July 30, 2010
cc:	Tom Furgason, SWCA Cori Hoag, SRK File	From:	Vladimir Ugorets, Ph.D. Larry Cope, M.S. Mike Sieber, P.E.
Subject:	Technical Review of Hydrogeologic Framework Model (Tetra Tech, 2010)	Project #:	183101/1800

This memorandum provides a technical review of the Technical Memorandum, *Hydrogeologic Framework Model* (Tetra Tech, 2010) dated July 9, 2010. This review was undertaken and the Technical Memorandum prepared at the request of SWCA and the Coronado National Forest, in accordance with a Statement of Work and Request for Cost Estimate from Mr. Dale Ortman dated July 18, 2020. This memorandum was prepared by Vladimir Ugorets, Larry Cope, and Mike Sieber of SRK Consulting (U.S.), Inc. (SRK).

1 Description of Hydrogeologic Framework Model

The hydrogeologic framework model was constructed using Mining Visualization System and hydrogeologic data at 200-foot intervals between 5,400 and 2,400 feet above mean sea level (amsl). These horizontal slices, representing the subsurface hydrogeologic units, were developed by Montgomery & Associates (M&A, 2009) and were created from a combination of publically available surface geology maps, borehole lithology data, and cross sections. The geologic formations were grouped into ten (10) hydrogeologic units, based on their age and material properties as follows:

1. Quaternary and Recent alluvium (Qal)
2. Late Tertiary to Early Quaternary basin-fill deposits - higher permeability (QTg)
3. Late Tertiary to Early Quaternary basin-fill deposits - lower permeability (QTg1)
4. Late Tertiary to Early Quaternary basin-fill deposits - lowest permeability (QTg2)
5. Early to Mid-Tertiary sedimentary and volcanic units (Pantano Formation - Tsp)
6. Upper Cretaceous and Early Tertiary intrusive rocks (Kti)
7. Upper Cretaceous volcanic rocks (Kti)
8. Lower Cretaceous sedimentary units (Bisbee Group – Ksd)
9. Paleozoic sedimentary and metamorphic formations (Pz)
10. Precambrian igneous and metamorphic (pCb)

The process used by Tetra Tech to transform the two-dimensional data sets into the three-dimensional block model consisted of three steps: (1) data sampling, (2) hydrogeologic unit interpretation, and (3) consistency check. The steps are described in detail in their technical memorandum.

The developed regional groundwater flow model has a telescoping grid in plain view, with the grid ranging from a cell width of 800 feet at the model domain edges to a cell width of 200 feet in the vicinity of the pit. Vertically, the grid was constructed using a total of 20 horizontal model layers with consistent thicknesses. Flow model layers intersecting the pit were assigned a cell thickness of

approximately 150 feet and model cells above and below the pit were assigned thicknesses between 200 and 430 feet. The uppermost elevation of the flow model was placed at an elevation of 5,500 feet amsl, and the base of the model was placed at an elevation of 1,000 feet amsl.

2 SRK Conclusions

SRK concludes that:

1. The geologically based approach used in the Hydrogeologic Framework Model by Tetra Tech is reasonable and is an accepted practice for groundwater modeling of mine dewatering projects. The geology incorporated into the numerical model matches the geology slice at 3,600 ft elevation (Figure 1) and cross sections A-A' and B-B' (Figures 5 and 6, respectively).
2. The 10 hydrogeologic zones with individual sets of hydraulic parameters look reasonable. It should be noted that SRK did not find a description of these parameters in the reviewed document. But in as much as it presents a concept for modeling, we expect the parameters will be described and defended in subsequent documents.
3. Proposed grid discretization (telescoping in plan view and detailed in cross section, shown in Figure 3) is considered adequate for the required predictive simulations and corresponds to standards in 3-D numerical groundwater modeling.

3 Reviewer Qualifications

The Senior Reviewer, 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 hydrogeology of the pit lake predictive model. His resume has been provided to SWCA in prior submissions.

ATTACHMENT 4
SRK REVIEW OF TETRA TECH (2010D)
GROUNDWATER FLOW MODEL CONSTRUCTION AND
CALIBRATION
AND
TETRA TECH (2010E)
STEADY-STATE SENSITIVITY ANALYSES

Memorandum - DRAFT

To:	Dale Ortman, P.E.	Date:	August 17, 2010
cc:	Tom Furgason, SWCA Cori Hoag, SRK File	From:	Vladimir Ugorets, Ph.D. Larry Cope, M.S. Mike Sieber, P.E.
Subject:	Review of Tetra Tech Documents <i>Groundwater Flow Model Construction and Calibration and Steady-State Sensitivity Analyses</i>	Project #:	183101/2000

This memorandum provides a technical review of the two Technical Memoranda, *Groundwater Flow Model Construction and Calibration* dated July 26, 2010 (Tetra Tech, 2010a) and *Calibration and Steady-State Sensitivity Analyses* dated July 30, 2010 (Tetra Tech, 2010b). This review was undertaken, and our Memorandum prepared by Vladimir Ugorets, Larry Cope, and Mike Sieber of SRK Consulting (U.S.), Inc. (SRK), at the request of SWCA and the Coronado National Forest, as transmitted to SRK by Mr. Dale Ortman in email requests dated August 5 and August 9, 2010.

1 Description of Groundwater Flow Model Setup

Tetra Tech has developed a 3-D numerical regional groundwater flow model based on a framework model that was reviewed by SRK previously (SRK, 2010a). The geologic formations were grouped by Montgomery & Associates (2009a) into ten (10) hydrogeologic units on the basis of their age and material properties. The following four additional units were incorporated into the model by Tetra Tech (2010a):

1. Paleozoic units in the western side of the pit area (Zone 11 – Pz_Pit) that cover the Backbone Fault along the ridge of the Santa Maria Mountains,
2. Quaternary-Tertiary gravel in the Tucson Basin (Zone 15 – QTg_TB),
3. Quartz-Porphry Dike (simulated as the HFB package in MODFLOW), and
4. Streambed material (simulated by the SFR package of MODFLOW).

The model domain and the external lateral model boundaries are the same as those applied by M&A (2009b).

The description of the model development in the reviewed document is detailed, comprehensive, and easy to follow. However, it should be noted that SRK did not find an explanation of modification of the western model boundary (assumed to be C-HEAD for the steady-state conditions) for transient mining and post-mining simulations.

2 Simulation of Recharge

Tetra Tech (2010a) methodology for building recharge into the model used a combination of Geographic Information System (GIS) analysis, empirical surface-runoff modeling, and water balance calculations. The model domain was divided into 21 sub-watersheds based on topography. The sub-watersheds were further divided into bedrock, alluvial fan, and valley floor. Precipitation distribution data obtained from the PRISM Group at Oregon State University were applied to each sub-basin using GIS methods. Precipitation data from

the Santa Rita Experimental Range were used to simulate precipitation events and to develop runoff estimates for each sub-basin. Water balance calculations were performed to normalize the recharge rates for each sub-basin; the total recharge for all of the sub-basin was 10,100 acre-feet per year (ac-ft/yr), which is approximately 5.4 percent of annual precipitation. Six recharge zones were incorporated into the model with rates that varied from 0.33 inch per year (in/yr) to 1.31 in/yr. The total recharge calculated by the steady-state model was 9,909 ac-ft/yr.

The simulation of mining impacts and post-closure changed the recharge that was used in the steady-state calibration. SRK provides the following observations about these changes:

- Recharge from precipitation was not applied into the pit area during transient mining simulations assuming that all water will be captured by drain cells and removed from the model. SRK agrees that this is a valid approach to simulate water levels in the vicinity of the proposed pit; however, it is our opinion that this method would underestimate dewatering requirements.
- Post-closure recharge from the waste rock storage area and the heap leach facility is assumed to be zero, based on the Tetra Tech (2010c) report, *Infiltration, Seepage, and Fate and Transport Modeling Report*. It should be noted that the review of that report by SRK (2010b) indicated that zero recharge is likely unrealistic. However, the zero value was also applied by Tetra Tech. SRK is of the opinion that recharge through the facilities should be revised or otherwise explained.
- It is not clear from the reviewed Technical Memorandum why the recharge from the tailings is assumed to be a constant value for the entire duration of the post-closure simulation, given initial dewatering of the tailings following cessation of mining, followed by an asymptotic equilibration to average climatic conditions.

3 Simulation of Evapotranspiration

Tetra Tech simulated groundwater losses to evapotranspiration (ET) along the reaches of Cienega Creek and Davidson Canyon where riparian vegetation is present. ET was simulated with MODFLOW's evapotranspiration (EVT) package. Maximum ET rates were assigned to each model cell, and simulated ET varied with groundwater level. The extinction depth was set to a constant depth of 16.4 ft (5 meters) below land surface. Simulated maximum evapotranspiration rates are shown in Figure 7 of the reviewed Technical Memorandum and vary from 10.9 in/yr to 39 in/yr. The bases for the following two model decisions are not clear to SRK:

- Assumption for extinction depth that was uniformly applied throughout the model domain (The Tetra Tech memorandum states that extinction depth varies with the types of the soil and vegetative cover, ranging from about 1.5 feet under bare conditions in sandy soil to about 27 feet under forest cover conditions in clayey soil). SRK requests an explanation of why a uniform extinction depth was applied.
- Distribution of maximum evapotranspiration rates along the reaches of Cienega Creek and Davidson Canyon. SRK suggests a better explanation for the basis in the data for the distribution.

4 Simulation of Groundwater—Stream Flow Interaction

Cienega Creek has two U.S. Geological Survey (USGS) stream gauges and there is one USGS gauge in Davidson Canyon with historical stream flow data between 1968 and 1981. Tetra Tech simulated the interaction between surface water and groundwater along Cienega Creek and Davidson Canyon with MODFLOW's Stream Flow Routing Package. Stream boundaries were assigned to model layers corresponding to the stream elevation. Stream flows were used as calibration targets in a qualitative manner due to the regional model scale that limits the accuracy of stream-channel aquifers.

5 Model Calibration and Simulated Groundwater Budget

Tetra Tech calibrated the groundwater model to measured steady-state pre-mining water levels by using a weighting approach. All water-level targets (377 wells, 12 piezometers, and 67 springs) were assigned calibration weights (ranging from 0 to 1) based on:

- Availability and completeness of well construction information;
- Well completion interval depth and screen length;
- Water level trends; and
- Period of water-level data.

Simulated groundwater budgets for the pre-mining steady-state conditions are shown in Table 1. The process of steady-state model calibration to the measured water levels is well described.

Table 1: Comparison of Component of Groundwater Budget Simulated by Tetra Tech (2010a) and M&A (2009b) Models.

Components of Groundwater Budget	M&A, 2009b	Tetra Tech, 2010a	Difference
	Rate [ac-ft/yr]	Rate [ac-ft/yr]	Rate [ac-ft/yr]
Recharge	7,010	9,909	2,899
Groundwater recharge from streams	2,172	8,344	6,172
Evapotranspiration	4,240	5,638	1,398
Groundwater discharge to streams	2,172	10,962	8,790
Net of boundary outflow	2,770	1,653	-1,117

SRK comments regarding the model calibration are:

1. It is not clear how the results of the interpretation of a 30-day pumping test by 2-D radial flow models (Tetra Tech, 2010d) were used for the model calibration. The comparison shown in Table 2 indicates that the hydraulic conductivity values calibrated and used in the model are less than those estimated from the 30-day pumping test data.

Table 2: Comparison of Hydraulic Conductivity Values for Lower Cretaceous Sedimentary Unit Used in Model and Derived from 30-Day Pumping Test.

Hydraulic Conductivity of Lower Cretaceous Sedimentary Unit	K_h (ft/d)	K_v (ft/d)
Used in Model	0.066	0.005
Estimated from PC-5 pumping test (piezometer PZ-5)	0.16	2.8
Estimated from PC-5 pumping test (piezometer PC-2)	0.1	0.006

2. Table 1 shows that the components of the groundwater budget simulated by the Tetra Tech (2010a) and M&A (2009b) numerical models both were calibrated to measured pre-mining water levels. Yet the components of the budget are substantially different. The differences in the components of the groundwater budget are as much as 2,900 ac-ft/yr for recharge and 8,800 ac-ft/yr in groundwater discharge into streams. Such differences indicate a non-unique calibration of the model to pre-mining only water levels.

3. The Tetra Tech Technical Memorandum indicates that the streambed hydraulic conductivity of 3.28 ft/day was increased by a factor of 2 during the steady-state calibration to better match data from stream flow gauges. However, SRK was not able to find a comparison of simulated stream flows (shown in Figure 40) to measured values.
4. Different pairs of values for recharge/vertical hydraulic conductivity can simulate the same distribution of the water levels, resulting in the same calibration to steady-state water levels. Calibrations of the model to steady-state fluxes (results have not been found) and transient conditions (not completed) are additionally required in SRK's opinion to decrease the non-uniqueness of the parameters used for the predictive simulations.

6 Models to Predict Mining and Post-Mining Conditions

Both models used for prediction of mining and post-mining conditions are very clearly described in the reviewed documents with the exceptions described below. SRK has the following observations and questions:

- a) The specific storage parameter for bedrock units was assumed to be $S_s=9.86 \times 10^{-6} \text{ ft}^{-1}$ based on the geometric mean of the values estimated from the radial flow modeling analysis of the 30-day pumping test. SRK is of the opinion that this number represents the high range of specific storage values and is not conservative enough to estimate the possible maximum extent of the cone of depression during mining and post-mining conditions. Storage parameters derived from the short stress tests tend to overestimate values. Based on SRK experience for low permeability bedrock units, a more realistic and conservative value could be $S_s=1.0 \times 10^{-6} \text{ ft}^{-1}$, which is recommended for use in a Best Case, or, as the value for the transient sensitivity analysis.
- b) It is not clear how the values for conductance of the lake cells were assigned and how groundwater inflow to the pit was simulated by drain cells at the end of mining, as compared to the inflow by the lake cells at the beginning of pit lake infilling
- c) It is not clear what boundary conditions are along the western model boundary for mining and pre-mining simulation. SRK requests an explanation of how the boundary conditions were constructed for mining and post-mining conditions.
- d) It was assumed that the pit lake will reach a steady-state elevation 1,000 years after mining has ceased. This was estimated by extending the predicted post-mining conditions estimated in the 100-year prediction in M&A (2009b). It is not clear whether the assumption is appropriate and representative. SRK recommends completing an assessment of timing to reach steady-state post-mining conditions by using the Tetra Tech model, not M&A model.

7 Results of Model Calibration and Steady-State Sensitivity Analyses

Tetra Tech has completed a sensitivity analyses of model parameters to the steady-state pre-mining water levels by varying 13 parameters (recharge values in 6 model zones and horizontal/vertical hydraulic conductivity values in 6 hydrogeologic units), plus the horizontal flow barrier and streambed hydraulic conductivities values. Based on the completed analyses, Tetra Tech concluded that the steady-state calibration has a "nearly optimal parameter value for matching water level in the model." SRK agrees that mathematically this statement is correct. However, as mentioned above, the model should be calibrated to both water level and flow data. It should be noted that SRK did not find the results of the sensitivity analyses of model parameters to the data for groundwater/stream flow interaction.

8 References

- Montgomery & Associates, Inc. (M&A), 2009a, *Results of Phase 2 Hydrogeologic investigations and monitoring program, Rosemont Project, Pima County, Arizona*: unpublished report prepared for Rosemont Copper Company, February 26, 2009.
- _____ 2009b, *Groundwater-flow modeling conducted for simulation of proposed Rosemont pit dewatering and post-closure*: unpublished report prepared for Rosemont Copper, October 28, 2009, 73 p.
- SRK, 2010a, *Technical review of Tetra Tech (2010) Hydrogeologic framework model report*: Technical Memorandum prepared for SWCA, July 30, 2010, 2 p.
- _____ 2010b, *Technical review of Tetra Tech (2010) Infiltration, seepage, fate and transport modeling report*: Technical Memorandum prepared for SWCA, April 30, 2010, 9 p.
- Tetra Tech, 2010a, *Groundwater flow model construction and calibration*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 198-10-320874-5.3, July, 26 2010, 100 p, 2 attachments.
- _____ 2010b, *Steady-state analysis report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 202/10-320874-5.3, July 30, 2010, 12 p.
- _____ 2010c, *Infiltration, seepage, fate and transport modeling report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320794, February 2010, 68 p., 6 appendices.
- _____ 2010d, *Hydraulic-property estimates report*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 1741/10-320874-5.3, July, 9 2010, 25 p.

ATTACHMENT 5
SRK REVIEW OF TETRA TECH (2010F)
PREDICTIVE GROUNDWATER FLOW MODELING
RESULTS
AND
TETRA TECH (2010G)
GROUNDWATER FLOW MODEL SENSITIVITY
ANALYSES

Technical Memorandum

To:	Dale Ortman, P.E.	Date:	September 27, 2010
cc:	Tom Furgason, SWCA Cori Hoag, SRK File	From:	Vladimir Ugorets, Ph.D. Larry Cope, M.S. Mike Sieber, P.E.
Subject:	Technical Review of <i>Predictive Groundwater Modeling Results</i> (TT, 2010a) and <i>Rosemont Groundwater Flow Model Sensitivity Analyses</i> (TT, 2010b)	Project #:	183101/2000

This memorandum provides a technical review of the two Technical Memorandums, *Predictive Groundwater Modeling Results* (Tetra Tech, 2010b) dated July 30, 2010 and *Rosemont Groundwater Flow Model Sensitivity Analyses* (Tetra Tech, 2010c) dated August 17, 2010. This review was undertaken, and our Memorandum prepared by, Vladimir Ugorets, Larry Cope, and Mike Sieber of SRK Consulting (U.S.), Inc. (SRK), at the request of SWCA and the Coronado National Forest, and in accordance with the Statement of Work and Request for Cost Estimated from Mr. Dale Ortman dated July 28, 2010.

These two reviewed technical memoranda describe result of predictive simulation and sensitivity analyses for the Rosemont project by using a 3-D regional groundwater flow model developed by Tetra Tech as described in Tetra Tech (2010a). It should be noted that SRK reviewed the construction and calibration of the model and presented the results of that review in our Technical Memorandum dated August 17, 2010 (SRK, 2010). The conclusions and recommendations presented in that memorandum are related to model setup and calibration, and are not repeated in this document.

1 Results of Predictions

The predictions were conducted for mining and post-mining conditions using the model construction and calibration described in Tetra Tech (2010a).

1.1 Mining Conditions

Mining conditions were simulated by excavation of a proposed open pit using drain cells and parameters were predicted for the Base Case scenario in which the following were tracked over time:

- Passive groundwater inflows to the pit during 22 years of mining;
- Groundwater levels and drawdowns;
- Groundwater discharge into the streams; and the,
- Water balance during mining.

Predictions for the Base Case scenario are:

- 1) Passive inflow to the pit ranges from 400 to 500 gpm (about 400 gpm during last 10 years of pit expansion).
- 2) Maximum extent of drawdown of about 4-4.5 miles to the northeast. Cone of drawdown will not reach the Western boundary of the model, as simulated by Constant Head boundary conditions.
- 3) Significant impact to Rosemont Spring, which would be located within the 100-foot drawdown contour, and possible decrease in flow from Questa Spring, which would be within 10-foot drawdown contour.
- 4) No changes of stream flows in the Cienega Creek and Davidson Canyon. The 5-foot drawdown contour would not reach the vicinity of Cienega Creek or perennial reach of Davidson Canyon during the 22-year mining period.

The results of the predictions look reasonable and correspond to assumptions currently used in conceptual groundwater model.

SRK has one comment relative to the water balance simulations for pre-mining steady state conditions. The simulations were made using 3 models – pre-mining, mining, and post –mining. The results of the simulations are presented in Table 7 in Tetra Tech (2010a) and Tables 1 and 3 in Tetra Tech (2010b). The component of the pre-mining steady state water balance should be exactly the same in these three tables. However there is a difference up to 660 acre-ft/yr reported in Table 1 (Tetra Tech, 2010b) versus Table 7 (Tetra Tech, 2010a). About the same difference can be observed between Table 3 (Tetra Tech, 2010b) and Table 7 (Tetra Tech, 2010a). The difference needs to be understood and should be explained.

1.2 Post- Mining Conditions

Post-mining conditions were simulated by the inflow of groundwater to the open pit and corresponding changes to groundwater flow system using the LAK2 Package. Simulation of the creation of the pit lake included as output a detailed water balance.

The model predicts that a terminal hydraulic sink pit lake will equilibrate at 4,279 feet amsl after about 700 years of refilling . That elevation is approximately 700 feet below pre-mining water levels. The groundwater divide east of the open pit is predicted to occur at an elevation about 4,600 feet amsl. The predicted steady-state stage of the pit lake would thus need to rise about 320 feet before a flow-through condition would occur. Steady-state groundwater inflow to the terminal pit lake is predicted to be about 230 gpm, which by the interaction of groundwater gradient and formation permeabilities balances with the water lost by evaporation from the pit lake.

The 1,000 year model simulation predicts modest decreases to the base flows in Cienega Creek and Davidson Creek. A stream flow decrease of 0.09 cfs is predicted in the upper reach of the Cienega Creek, which is less than 3 percent of the base flow. In Davidson Canyon, base flow is predicted to decrease 0.01 cfs.

SRK comments related to the results to the prediction modeling are:

- Constant head (CHEAD) boundary condition at the Western boundary likely significantly limits propagation of drawdown to the east. SRK strongly recommends that the influence of the CHEAD boundary be investigated with a General Head Boundary (GHB) along the Western boundary of the model using a sensitivity analysis or post-mining conditions. The GHD utilizes a constant head at a defined distance that would be beyond the current western boundary, thereby mitigating the synthetic effect of a constant head so close to the pit.

- It is not clear why the extent of drawdown cone at steady-state post mining conditions (run by steady-state model) is smaller than the extent at 1000 years after mining ceased. An explanation is required. If the difference has a numerical origin (i.e., steady-state vs. transient simulations), SRK recommends that the transient model be run sufficiently long to demonstrate equilibration with steady-state results.

2 Results of Sensitivity Analyses

Tetra Tech conducted a comprehensive sensitivity analyses for pre-mining, mining, and post-mining conditions. The analysis investigated variations in key model parameters and their influence on the range of predictive results.

2.1 Steady state pre-mining conditions

Parameters that were varied:

- Horizontal hydraulic conductivity of QTg1, QTb_TB (± 30 percent),
- Horizontal hydraulic conductivity of Pz_Pit (-30, -50, -90 percent; +30 percent, +5x, +10x),
- Horizontal hydraulic conductivity of Basin Fill (± 30 percent),
- Horizontal hydraulic conductivity of Bedrock (-10 percent; +30 percent),
- Vertical hydraulic conductivity of Kv, Ksd, Pz, Pz_Pit (-30, -50, -90 percent; +30 percent, +5x, +10x),
- Vertical hydraulic conductivity of Basin Fill (± 30 percent),
- Vertical hydraulic conductivity of Bedrock (± 30 percent),
- Recharge (± 20 percent; ± 40 percent),
- Hydraulic conductivity of Quartz-Porphry Dike (-90 percent; +10x), and
- Hydraulic conductivity of streambed sediments (-90 percent; +10x).

Evaluation of sensitivity of listed above parameters was limited to the effect on the sum of square weighted residuals (SOSWR), a measure of how closely the model matches target measured water levels.

2.2 Mining conditions

Parameters that were varied:

- Horizontal hydraulic conductivity of Basin Fill (± 30 percent),
- Horizontal hydraulic conductivity of Bedrock (-10 percent; +30 percent),
- Vertical hydraulic conductivity of Basin Fill (± 30 percent),
- Vertical hydraulic conductivity of Bedrock (-10 percent; +30 percent),
- Hydraulic conductivity of Quartz-Porphry Dyke (\pm order of magnitude),
- Specific storage of all HGU's (\pm order of magnitude),
- Specific yield of Basin Fill (± 50 percent), and
- Specific yield of Bedrock (\pm factor of 2).

The report concluded that:

- a) The most sensitive mining-phase parameters are specific storage and specific yield. Simulated variation in propagation of the drawdown is about 3 mi.
- b) The low permeability the pCb unit and the constant-head boundary west of the open pit function to limit the propagation of drawdown propagation in the area immediately west of the pit.
- c) Drawdown tends to propagate toward Davidson Canyon and southeast of the open pit.
- d) Drawdown is not predicted to reach the quartz-porphry dike to the northwest of the pit at end of mining.

2.3 Post-Mining conditions

Parameters that were varied:

- Pit lake precipitation (± 30 percent)
- Pit lake evaporation (± 20 percent)
- Pit runoff into pit lake (20 and 40 percent)
- Hydraulic conductivity of Quartz-Porphyry Dyke (\pm order of magnitude)
- Specific storage of all HGUs (\pm order of magnitude)
- Specific yield of Basin Fill (± 50 percent)
- Specific yield of Bedrock (\pm factor of 2)
- Horizontal hydraulic conductivity of Basin Fill (± 30 percent)
- Horizontal hydraulic conductivity of Bedrock (-10 percent; +30 percent)
- Vertical hydraulic conductivity of Basin Fill (± 30 percent)
- Vertical hydraulic conductivity of Bedrock (-10 percent; +30 percent)
- Recharge at facility area.

The report concluded that:

- a) The extent and magnitude of drawdown in the post-closure model was sensitive to changes in storage parameters over the first 100 to 200 years post mining period. However, after 1,000 years, the groundwater system was close to steady-state and storage parameters were not significant.
- b) The post-closure model is relatively sensitive to the hydraulic conductivity of the quartz-porphyry dike (simulated as an HFB). However, the extent of drawdown remained six miles or more from the perennial reaches in Davidson Canyon using the range of values for hydraulic conductivity.
- c) The most sensitive parameters in the post-closure model are the 20% decrease in pit-lake evaporation and steady-state recharge distribution.
- d) Drawdown tends to propagate toward Davidson Canyon and southeast of the open pit.

SRK concludes that Tetra Tech has completed comprehensive sensitivity analysis for pre-mining, mining, and post-mining conditions to evaluate the most sensitive key hydrogeological parameters used in the models (three models were used) and possible range of predictive characteristics (propagation of drawdown, pit lake stage, impact to the surface-water bodies).

3 Conclusions

From the review of the two documents, SRK recommends:

- 1) Include influence of the Western model boundary into the sensitivity analysis. The model predictions indicate that an assigned CHEAD boundary condition limits and, most likely, under-predict propagation of cone of drawdown (and at a minimum, deforms the cone) during post-mining conditions. It is recommended that GHB condition be applied at differing distances from the Western model boundary to evaluate its effect on predictive simulations, especially during post-mining conditions.
- 2) Though graphs and tables are present the results of the sensitivity analysis, SRK recommends that additional results be included as tables and/or graphs, showing:
 - a) Predicted pit inflow in time (for mining phase, graphs);
 - b) Pit-lake infilling curves in time (for post-mining, graphs);
 - c) Drawdown propagation (for both mining and post-mining, table); and
 - d) Impact to surface bodies – cumulative change in stream flow (for both mining and post-mining, table).

- 3) Explain the difference seen in Figure 23 between the drawdown contours from transient predictions at 1,000 years post mining, and for the steady-state post-mining conditions. Unless otherwise explained, it is SRK's opinion that steady-state contours of drawdown should not be closer to the pit than the 1,000-year contour generated by the transient predictive runs.
- 4) Add the extent of the steady-state post-closure drawdown to Figure 24 for purposes of comparison. The Figure currently compares drawdown contours at end of mining and after 150 and 1,000 years post closure. Adding the steady-state contour to the figure may shed insight into the differences mentioned in the previous bullet.

4 References

SRK, 2010, Review of Tetra Tech Documents *Groundwater Flow Model Construction and Calibration and Steady-State Sensitivity Analyses*: Technical Memorandum prepared for SWCA, August 17, 2010.

Tetra Tech, 2010a, *Groundwater Flow Model Construction and Calibration*: Technical memorandum submitted to Rosemont Copper Company on July 26, 2010.

Tetra Tech, 2010b, *Predictive Groundwater Modeling Results*: Technical memorandum submitted to Rosemont Copper Company on July 30, 2010.

Tetra Tech, 2010c, *Predictive Groundwater Modeling Results*: Technical memorandum submitted to Rosemont Copper Company on August 17, 2010.

5 Reviewer Qualifications

The Senior Reviewer, 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 hydrogeology of the pit lake predictive model. His resume has been provided to SWCA in prior submissions.