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 *Predictive Groundwater Modeling Results* (TT, 2010a) and *Rosemont Groundwater Flow Model Sensitivity Analyses* (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:
a) Passive groundwater inflows to the pit during 22 years of mining;
b) Groundwater levels and drawdowns;
c) Groundwater discharge into the streams; and the,
d) 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-Porphyry 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-Porphyry Dyke (± order of magnitude),
- Specific storage of all HGUs (± order of magnitude),
- Specific yield of Basin Fill (± 50 percent), and
- Specific yield of Bedrock (± 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-porphyry 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 (± order of magnitude)
- Specific storage of all HGUs (± order of magnitude)
- Specific yield of Basin Fill (± 50 percent)
- Specific yield of Bedrock (± 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.