

Technical Memorandum

To:	Kathy Arnold	From:	David Krizek
Company:	Rosemont Copper Company	Date:	August 31, 2010
Re:	Rosemont Groundwater Flow Model Summary	Doc #:	241/10-320877-5.3
CC:	Grady O'Brien (Engineering Analytics)		

1.0 Introduction

This Technical Memorandum summarizes the results of a groundwater flow modeling effort prepared by Tetra Tech for the proposed Rosemont Copper Project (Project) in Pima County, Arizona. The Tetra Tech groundwater flow model is in addition to the flow model completed by Montgomery & Associates (M&A) and previously transmitted to the Arizona Department of Environmental Quality (ADEQ) in 2009 (M&A, 2009). To date, Tetra Tech has completed a series of technical memoranda illustrating the development of the model. These technical memoranda are provided in Attachments A through E.

- Attachment A – Hydrogeologic Framework Model (Tetra Tech, 2010a)
- Attachment B – Hydraulic-Property Estimates (Tetra Tech, 2010b)
- Attachment C – Groundwater Flow Model Construction and Calibration (Tetra Tech, 2010c)
- Attachment D – Predictive Groundwater Flow Modeling Results (Tetra Tech, 2010d)
- Attachment E – Rosemont Groundwater Flow Model Sensitivity Analysis (Tetra Tech, 2010e)

This information is in response to the April 14, 2010 Comprehensive Request for Additional Information from the ADEQ to Rosemont Copper Company (Rosemont) as part of the aquifer protection permit (APP) application submitted to ADEQ in February 2009 (Tetra Tech, 2009). Specifically, this Technical Memorandum answers the following:

HYDROGEOLOGIC DEFICIENCIES

- *Item no. 1 on pages 1 and 2 of 18 (ADEQ 2010). The application and supporting documents identify a number of reports that are either pending or completed, but do not appear to have been submitted for review. The following documents are necessary to continue the review of the application. They are identified by title, with the location if the reference indicated in parentheses:*

Groundwater Flow Model (Application, Table 7.41 and Analysis of Long-term, Multi-Well Aquifer Test, Errol Montgomery & Associates, May 2009, Page 1)

- *Item no. 8 on pages 3 and 4 of 18. Section 9.2 of the Application indicates that a quantitative groundwater flow model and fate and transport modeling are currently in progress. Section 1.0 of the application indicates that a detailed groundwater flow model, a pit lake geochemical model, and updated facility infiltration and seepage models will be submitted. Section 4.13 of the Application indicates that studies regarding quantities of groundwater withdrawal from the pit are also underway. Please submit the results of these studies and modeling efforts to address the following components of the hydrologic study required in rule.*

R18-9-A202(A)(8)(b)(iv): The rate, volume, and direction of surface water and groundwater flow, including hydrographs, if available, and equipotential maps (Update/revision only).

R18-9-A202(A)(8)(b)(xi): A description of any expected changes in the elevation or flow directions of the groundwater expected to be caused by the facility.

The groundwater model developed by Tetra Tech for the Rosemont Project used the M&A model domain and base data. However, the model was modified based on the comments received by Rosemont during the EIS process. The Tetra Tech groundwater model has been used for the assessment of the discharge impact area (DIA) and a planned update to the February 2010 *Geochemical Pit Lake Predictive Pit Lake Model* (Tetra Tech, 2010f). The ADEQ and EIS processes are therefore using the same groundwater models and the analyses for consistency. The February 2010 *Geochemical Pit Lake Predictive Model* report (Tetra Tech, 2010f) was transmitted to ADEQ in a summary Technical Memorandum titled *Rosemont Geochemical Pit Lake Predictive Model Summary* (Tetra Tech, 2010g). The DIA assessment is provided under a separate Technical Memorandum titled *Rosemont DIA and Area-Wide Fate and Transport Analysis Summary* (Tetra Tech, 2010h).

The sections below provide a summary of the groundwater flow model development and results, including a sensitivity analyses:

- 2.0 Regional Groundwater Flow Model Development
- 3.0 Predictive Model Data Results Summary
- 4.0 Sensitivity Analyses

2.0 Regional Groundwater Flow Model Development

Tetra tech developed three (3) groundwater flow models, pre-mining phase, mining phase, and post-mining/post-closure phase, to simulate potential impacts from open pit mining activities planned for the proposed Project. Dewatering of the Rosemont Open Pit during the mining phase, and pit lake formation during the post-closure phase, will result in groundwater drawdown that will propagate through the groundwater flow system. The objective of the groundwater flow modeling was to provide an estimate of the impact to area water resources due to regional groundwater system drawdown. Of particular interest were potential impacts to Cienega Creek, Davidson Canyon, and regional spring flows.

The Tetra Tech model domain was based on the 2009 groundwater flow model developed by M&A (M&A, 2009). Much of the field data in Montgomery's 2009 report was also used in development of the Tetra Tech model. Montgomery's model and Tetra Tech's model used the



same geologic data. The geologically-based Tetra Tech flow model was built from 3-dimensional Hydrogeologic Framework model. Development of the hydrogeologic framework model, hydraulic-property estimates, and groundwater flow model construction and calibration are provided in Attachments A, B, and C.

A potentiometric-surface map of the current groundwater flow conditions, based on measured water levels, is provided on Figure 11 in the Technical Memorandum titled *Groundwater Flow Model Construction and Calibration* (Tetra Tech, 2010c), which is provided in Attachment C.

3.0 Predictive Model Data Results Summary

Model results predict that a terminal pit lake will form in the Rosemont Open Pit. Steady-state groundwater inflow to the terminal pit lake is estimated to be 230 gallons per minute (gpm) with an anticipated lake-surface elevation of 4,279 feet above mean sea level (amsl). The groundwater divide on the east side of the Open Pit is about 4,600 feet amsl, so the pit lake level would have to rise an additional 321 feet before creating a flow-through condition.

The model also predicts that the base stream flow in the upper reach of Cienega Creek may be reduced by 0.09 cubic feet per second (cfs). This is about 3 percent of the predicted base flow. In Davidson Canyon, the base flow is predicted to decrease about 0.01 cfs.

The predictive model approximates steady-state inflow and lake stage conditions after about 700 years. Attachment D provides details on the predictive groundwater flow model results.

4.0 Sensitivity Analysis Summary

A sensitivity analysis was completed on the three (3) Tetra Tech groundwater flow models: pre-mining phase, mining phase, and post-closure phase. The sensitivity analysis consists of changing model parameter values and evaluating the predictive changes to drawdown, Open Pit groundwater inflows, and surface-water flows. Sensitivity analysis parameters include horizontal and vertical hydraulic conductivity, hydraulic conductivity of the quartz-porphry dike located between the Project site and Davidson Canyon, specific storage, specific yield, and recharge. In addition, parameters specific to the pit-lake development in the post-closure model were evaluated to determine the sensitivity to changes in direct pit-lake precipitation, pit-lake evaporation, and pit-wall runoff.

The most sensitive mining-phase parameters were specific storage (Ss) and specific yield. An order of magnitude decrease in Ss resulted in drawdown propagating nearly one (1) mile in some directions. Conversely, an order of magnitude increase in Ss resulted in drawdown receding over three (3) miles. Similar changes in the extent of drawdown resulted from changes to specific-yield values.

In the post-closure model, the most sensitive parameter changes were the 20-percent pit-lake evaporation decrease and the steady-state recharge distribution. Decreasing the pit-lake evaporation by 20 percent resulted in a higher pit-lake stage and less drawdown in Davidson Canyon and to the southeast toward Cienega Creek. Recharge in the Project area was modeled with and without the influence of the anticipated increase in recharge due to flow-through drains associated with the Project facilities. Without the increased recharge due to the flow-through drains, drawdown contours from the terminal pit lake are anticipated to extend three (3) miles in Davidson Canyon and one (1) to 1.5 miles toward the upper reaches of Cienega Creek after 1,000 years. Relative to the pre-mining model, the total simulated, cumulative decrease in stream flow ranged from 0.04 to 0.20 cfs for individual stream segments.



None of the sensitivity analysis changes resulted in the development of a flow-through pit lake. Details of the sensitivity analysis are provided in Attachment E.



REFERENCES

- Montgomery & Associates (M&A, 2009). *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 (2009). *Aquifer Protection Permit (APP) Application*. Prepared for Rosemont Copper Company. Report Dated February 2009.
- Tetra Tech, O'Brien, G. (2010a). *Hydrologic Framework Model*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 09, 2010.
- Tetra Tech, O'Brien, G. (2010b). *Hydraulic-Property Estimates*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 09, 2010.
- Tetra Tech, O'Brien, G. (2010c). *Groundwater Flow Model Construction and Calibration*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 26, 2010.
- Tetra Tech, O'Brien, G. (2010d). *Predictive Groundwater Flow Modeling Results*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated July 30, 2010.
- Tetra Tech, O'Brien, G. (2010e). *Rosemont Groundwater Flow Model Sensitivity Analysis*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated August 17, 2010.
- Tetra Tech (2010f). *Geochemical Pit Lake Predictive Model – Rosemont Copper Project*. Prepared for Rosemont Copper Company. Report Dated February 2010.
- Tetra Tech, Krizek, D. (2010g). *Rosemont Geochemical Pit Lake Predictive Model*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated August 24, 2010.
- Tetra Tech, Krizek, D. (2010h). *Rosemont DIA and Area-Wide Fate and Transport Analysis Summary*. Technical Memorandum to Kathy Arnold (Rosemont Copper Company). Technical Memorandum Dated August 31, 2010.

ATTACHMENT A
TECHNICAL MEMORANDUM
HYDROGEOLOGIC FRAMEWORK MODEL

**Rosemont Copper Project
Locator Sheet**

Record # 012943

Document Date 2010 07 09

Document Title: Hydrogeologic Framework Model

Author/Recipient Grady O'Brien, Tetra Tech

Description Describes the process for constructing the framework model to support development of regional groundwater flow models.

Other Notes Attachment A of 013312.

This document is located in the following: [CIRCLE THE CATEGORY (from the list below) IN WHICH THIS ITEM IS FILED]

- | | |
|---|--|
| <p>1. Project Management</p> <ul style="list-style-type: none">a. Formal recommendations & Directionsb. Formal meeting minutes & memosc. General Correspondenced. Contracts, Agreements, & MOUs (Rosemont, Udall, SWCA)e. Other <p>2. Public Involvement</p> <ul style="list-style-type: none">a. Announcements & Public Meetingsb. Mailing Listsc. Scoping Period Commentsd. Udall Foundation Working Groupe. Scoping Reportsf. Comments after Scoping Periodg. DEIS Public Comments <p>3. Agency Consultation & Permits</p> <ul style="list-style-type: none">a. Army Corps of Engineers (404 permit)b. US Fish & Wildlife Service (Sec. 7 T&E)c. State Historic Preservation Office (Sec. 106)d. Tribes (Sec. 106)e. Advisory Council on Historic Preservation (Sec. 106)f. Otherg. AZ Dept of Environmental Quality (APP) <p>4. Communication</p> <ul style="list-style-type: none">a. Congressionalb. Cooperating Agenciesc. Organizationsd. Individualse. FOIAf. Internalg. Proponent <p>5. Proposed Action</p> <ul style="list-style-type: none">a. Mine Plan (including compilation)b. Supporting Documentsc. Detailed Designsd. References <p>6. Alternatives</p> | <ul style="list-style-type: none">a. Cumulative Effects Catalogb. Connected Actionsc. Dismissed from Detailed Analysisd. Analyzed in Detail<ul style="list-style-type: none">i. Barrel McClearyii. Barrel Onlyiii. Scholefield McCleary <p>7. Resources</p> <ul style="list-style-type: none">a. Air Quality & Climate Changeb. Biologicalc. Dark Skiesd. Fuels & Fire Managemente. Hazardous Materialsf. Heritageg. Land Useh. Livestock Grazingi. Noise & Vibrationj. Public Health & Safetyk. Recreation & Wildernessl. Riparianm. Socioeconomics & Environmental Justicen. Soils & Geologyo. Transportation & Accessp. Visualq. Water <p>8. Reclamation</p> <ul style="list-style-type: none">a. Plans & Reportsb. Notes & Correspondencec. Referencesd. Other <p>9. DEIS</p> <ul style="list-style-type: none">a. DEISb. References <p>10. FEIS</p> <p>11. Geospatial Analysis (GIS Data)</p> <p>12. FOIA Exempt Documents</p> <p>13. ROD (including BLM & ACOE)</p> |
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ATTACHMENT B
TECHNICAL MEMORANDUM
HYDRAULIC-PROPERTY ESTIMATES

**Rosemont Copper Project
Locator Sheet**

Record # 012944

Document Date 2010 07 09

Document Title: Hydraulic-Property Estimates

Author/Recipient Grady O'Brien, Tetra Tech

Description Describes the analysis + process for obtaining the hydraulic-property estimates.

Other Notes Attachment B of 013312

This document is located in the following: [CIRCLE THE CATEGORY (from the list below) IN WHICH THIS ITEM IS FILED]

1. **Project Management**
 - a. Formal recommendations & Directions
 - b. Formal meeting minutes & memos
 - c. General Correspondence
 - d. Contracts, Agreements, & MOUs (Rosemont, Udall, SWCA)
 - e. Other
2. **Public Involvement**
 - a. Announcements & Public Meetings
 - b. Mailing Lists
 - c. Scoping Period Comments
 - d. Udall Foundation Working Group
 - e. Scoping Reports
 - f. Comments after Scoping Period
 - g. DEIS Public Comments
3. **Agency Consultation & Permits**
 - a. Army Corps of Engineers (404 permit)
 - b. US Fish & Wildlife Service (Sec. 7 T&E)
 - c. State Historic Preservation Office (Sec. 106)
 - d. Tribes (Sec. 106)
 - e. Advisory Council on Historic Preservation (Sec. 106)
 - f. Other
 - g. AZ Dept of Environmental Quality (APP)
4. **Communication**
 - a. Congressional
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 - c. Organizations
 - d. Individuals
 - e. FOIA
 - f. Internal
 - g. Proponent
5. **Proposed Action**
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 - b. Supporting Documents
 - c. Detailed Designs
 - d. References
6. **Alternatives**
7. **Resources**
 - a. Air Quality & Climate Change
 - b. Biological
 - c. Dark Skies
 - d. Fuels & Fire Management
 - e. Hazardous Materials
 - f. Heritage
 - g. Land Use
 - h. Livestock Grazing
 - i. Noise & Vibration
 - j. Public Health & Safety
 - k. Recreation & Wilderness
 - l. Riparian
 - m. Socioeconomics & Environmental Justice
 - n. Soils & Geology
 - o. Transportation & Access
 - p. Visual
 - q. Water i
8. **Reclamation**
 - a. Plans & Reports
 - b. Notes & Correspondence
 - c. References
 - d. Other
9. **DEIS**
 - a. DEIS
 - b. References
10. **FEIS**
11. **Geospatial Analysis (GIS Data)**
12. **FOIA Exempt Documents**
13. **ROD (including BLM & ACOE)**

ATTACHMENT C
TECHNICAL MEMORANDUM
GROUNDWATER FLOW MODEL CONSTRUCTION AND
CALIBRATION

Rosemont Copper Project
Locator Sheet

Record # 013230

Document Date 2010 07 26

Document Title: Groundwater Flow Model Construction & Calibration

Author/Recipient Grady O'Brien, Tetra Tech

Description Info provided supports the groundwater impact analysis & sensitivity analysis tasks being developed by TT.

Other Notes Attachment C of 013312

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| <p>1. Project Management</p> <ul style="list-style-type: none">a. Formal recommendations & Directionsb. Formal meeting minutes & memosc. General Correspondenced. Contracts, Agreements, & MOUs (Rosemont, Udall, SWCA)e. Other <p>2. Public Involvement</p> <ul style="list-style-type: none">a. Announcements & Public Meetingsb. Mailing Listsc. Scoping Period Commentsd. Udall Foundation Working Groupe. Scoping Reportsf. Comments after Scoping Periodg. DEIS Public Comments <p>3. Agency Consultation & Permits</p> <ul style="list-style-type: none">a. Army Corps of Engineers (404 permit)b. US Fish & Wildlife Service (Sec. 7 T&E)c. State Historic Preservation Office (Sec. 106)d. Tribes (Sec. 106)e. Advisory Council on Historic Preservation (Sec. 106)f. Otherg. AZ Dept of Environmental Quality (APP) <p>4. Communication</p> <ul style="list-style-type: none">a. Congressionalb. Cooperating Agenciesc. Organizationsd. Individualse. FOIAf. Internalg. Proponent <p>5. Proposed Action</p> <ul style="list-style-type: none">a. Mine Plan (including compilation)b. Supporting Documentsc. Detailed Designsd. References <p>6. Alternatives</p> | <ul style="list-style-type: none">a. Cumulative Effects Catalogb. Connected Actionsc. Dismissed from Detailed Analysisd. Analyzed in Detail<ul style="list-style-type: none">i. Barrel McClearyii. Barrel Onlyiii. Scholefield McCleary <p>7. Resources</p> <ul style="list-style-type: none">a. Air Quality & Climate Changeb. Biologicalc. Dark Skiesd. Fuels & Fire Managemente. Hazardous Materialsf. Heritageg. Land Useh. Livestock Grazingi. Noise & Vibrationj. Public Health & Safetyk. Recreation & Wildernessl. Riparianm. Socioeconomics & Environmental Justicen. Soils & Geologyo. Transportation & Accessp. Visualq. Water i <p>8. Reclamation</p> <ul style="list-style-type: none">a. Plans & Reportsb. Notes & Correspondencec. Referencesd. Other <p>9. DEIS</p> <ul style="list-style-type: none">a. DEISb. References <p>10. FEIS</p> <p>11. Geospatial Analysis (GIS Data)</p> <p>12. FOIA Exempt Documents</p> <p>13. ROD (including BLM & ACOE)</p> |
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ATTACHMENT D
TECHNICAL MEMORANDUM
PREDICTIVE GROUNDWATER FLOW MODELING RESULTS

**Rosemont Copper Project
Locator Sheet**

Record # 013229

Document Date 2010 07 30

Document Title: Predictive Groundwater Flow Modeling Results

Author/Recipient Grady O'Brien, Tetra Tech

Description Documents the results of the predictive groundwater flow models prepared by Tetra Tech.

Other Notes Attachment D of 013312.

This document is located in the following: [CIRCLE THE CATEGORY (from the list below) IN WHICH THIS ITEM IS FILED]

1. **Project Management**
 - a. Formal recommendations & Directions
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7. **Resources**
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 - ii. Barrel Only
 - iii. Scholefield McCleary
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 - n. Soils & Geology
 - o. Transportation & Access
 - p. Visual
 - q. Water *i*
8. **Reclamation**
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 - b. Notes & Correspondence
 - c. References
 - d. Other
9. **DEIS**
 - a. DEIS
 - b. References
10. **FEIS**
11. **Geospatial Analysis (GIS Data)**
12. **FOIA Exempt Documents**
13. **ROD (including BLM & ACOE)**

ATTACHMENT E
TECHNICAL MEMORANDUM
ROSEMONT GROUNDWATER FLOW MODEL SENSITIVITY
ANALYSIS

Rosemont Copper Project
Locator Sheet

Record # 013231

Document Date 2010 08 17

Document Title: Rosemont Groundwater Flow Model Model Sensitivity Analyses

Author/Recipient Grady O'Brien

Description Presents sensitivity analyses performed on the groundwater flow models.

Other Notes Attachment E of 013312.

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- c. References
- d. Other

9. DEIS

- a. DEIS
- b. References

10. FEIS

11. Geospatial Analysis (GIS Data)

12. FOIA Exempt Documents

13. ROD (including BLM & ACOE)