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**REPORT ON**

**GROUNDWATER MODEL OF WEST PLANT SITE, SUPERIOR, ARIZONA**

*Submitted to:*

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## 1.0 INTRODUCTION

Golder Associates Inc. (Golder) is pleased to submit this report to Resolution Copper Mining, LLC (RCML) describing the development of a numerical groundwater flow model of the West Plant Site (Site) and the modeling results. The Site is located immediately north of the town of Superior, Arizona, as shown on Figure 1. The model was developed in accordance with the Groundwater Assessment and Model Workplan, which was submitted to the Arizona Department of Environmental Quality (ADEQ) on November 21, 2007 (Golder, 2007). The remainder of this report is organized as follows:

- Section 2 – Background – Provides a brief summary of the regulatory drivers and communications.

- Section 3 – Conceptual Model – Provides an overview of the conceptual model presented in the Groundwater Assessment and Model Workplan, which in turn, was used as the basis for developing the numerical groundwater model presented in Section 4.

- Section 4 – Numerical Groundwater Flow Model – Presents a detailed description of model construction, calibration and sensitivity analysis, along with a description and discussion of modeling results.

- Section 5 – Conclusions and Recommendations – Presents key conclusions and recommendations based on the results of the modeling effort.

- Section 6 – References - Lists references cited in the text.

## 2.0 BACKGROUND

The Groundwater Assessment and Model Workplan (Golder, 2007) was required as part of the Area-wide Aquifer Protection Permit (APP) No. P-101703, issued by ADEQ on February 22, 2007, for the West Plant Site under Compliance Schedule Item No. 2 (ADEQ, 2007a), which states:

- Compliance Schedule Item No. 2 – Assess data gaps and adequacy of well locations and/or screened intervals. Select groundwater model(s) and develop workplan for groundwater modeling in accordance with Section 2.7.4.6 of the APP.

The Groundwater Assessment and Model Workplan (Golder, 2007) also fulfilled APP Compliance Schedule Item No. 3, which required:

- Compliance Schedule Item No. 3 – A groundwater model that evaluates transit times to wells and duration of post-closure period.

An updated groundwater assessment and groundwater flow model is due every five years after permit issuance; therefore, the next submittal deadline is March 22, 2013.

As stated previously, The Groundwater Assessment and Model Workplan (Golder, 2007) was submitted to ADEQ on November 21, 2007. ADEQ comments were received in a memorandum dated December 22, 2007 (ADEQ, 2007b). RCML provided ADEQ with a response to the comments in a letter dated February 18, 2008, which included the required updated tables and figures (RCML, 2008). A Completeness Letter was subsequently issued by PBS&J on February 29, 2008 to ADEQ, stating that the Groundwater Assessment and Modeling Workplan had met both the requirements of Compliance Schedule Item No. 2 and the supplemental information that was required by the December 22, 2007 ADEQ memorandum (PBS&J, 2008).

The analysis presented in this report focuses on the APP regulated facilities at the Site. Some of the facilities are exempt, including Tailings Ponds 1 and 2, and Tailings Ponds 3 and 4; therefore, those two facilities are not specifically addressed. However, as noted in Section 4, the hydrogeologic function (e.g., potential recharge) of the exempt facilities must be included in the analysis, in order to model the Site appropriately. Specific APP facilities addressed in this report include:

- Tailings Pond 5
- Tailings Pond 6

- Tailings Pond 7
- Settling Ponds 1 and 2
- Smelter Pond
- Indian Pond

# 3.0 CONCEPTUAL MODEL

## 3.1 Hydrostratigraphy, Hydraulic Properties, and Geometry of the Groundwater Flow System

The geology of the West Plant Site is comprised primarily of Gila Conglomerate. Minor Quaternary Alluvium is present along the washes and along the southern perimeter of the Site. A thick (up to approximately 630 feet) sequence of mudstone occurs within the Gila Conglomerate at the Site, and it is believed to limit the groundwater movement vertically, and also hydraulically separate the Gila Conglomerate lying below the mudstone from the Gila Conglomerate lying above the mudstone. The Gila Conglomerate was initially subdivided into four hydrostratigraphic units as described in the workplan (Golder, 2007), and it was largely around the presence of the mudstone. The hydrostratigraphic units include:

- Unconfined Gila Unit, defined as the Gila Conglomerate in areas not separated by the mudstone;
- Shallow Unconfined Gila Unit, defined as that portion of saturated Gila Conglomerate that overlies the mudstone;
- Confined Gila Unit, defined as that portion of Gila Conglomerate which is overlain by the mudstone; and
- the Mudstone Unit.

The results of hydraulic testing at the Site are summarized in Table 1. The hydraulic conductivity (K) of the alluvium, based on testing of the Smelter Pond monitoring well, is $9.64 \times 10^{-2}$ feet per day (ft/d), ($3.4 \times 10^{-5}$ centimeters per second [cm/s]). The K of the Gila Conglomerate, not including the Mudstone Unit, ranges from $6.5 \times 10^{-2}$ ft/d ($2.3 \times 10^{-5}$ cm/s) to $2.8 \times 10^{-4}$ ft/d ($9.9 \times 10^{-8}$ cm/s) with a geometric mean of $2 \times 10^{-3}$ ft/d ($6.9 \times 10^{-7}$ cm/s), calculated from values located in Table 1. However, there is a division within these data between a few shallow wells with higher K estimates (MCC-9, GAI-02-02, and to a lesser extent, Settling Pond 1 and 2 Alert Well) compared to the K values of all of the other wells located within the Gila Conglomerate (Table 1). Additionally, the K of the Mudstone Unit has been estimated at $3.7 \times 10^{-6}$ ft/d ($1.3\times10^{-9}$ cm/s).

A major characteristic of the Site groundwater flow system is that the Ks of the Site hydrostratigraphic units are low, with the exception of the Alluvial Unit. Figure 2 shows the K estimates at well locations on the Site.

A hydrogeologic cross-section through the Site shown on Figure 3 illustrates the geometry of the hydrostratigraphic units in profile from north to south. The Unconfined Gila Unit, as defined here, is present north of the Mudstone Unit. The Mudstone Unit extends from near the southern edge of Tailings Pond 6 to the southern perimeter of the Site, and, as stated previously, is up to approximately 630-feet thick. As shown on Figure 3, the Mudstone Unit rises to near, or at, land surface along the southern perimeter of the Site, thinning the overlying Gila Conglomerate. In map view (Figure 4), the mudstone underlies the southern half to two-thirds of the Site.

### 3.2 Occurrence of Groundwater and Directions of Flow

Groundwater occurs in all of the units described in subsection 3.1. The depths to groundwater at the Site range from approximately 176 feet below ground surface to 11-feet below ground surface on the north and south sides of the Site, respectively. This translates to groundwater elevations ranging from 2,830 feet to 2,730-feet above mean sea level (amsl) on the north and south sides, respectively. Contours of groundwater elevations in the Shallow Unconfined Gila Unit are shown on Figure 5. Groundwater elevations at selected wells are listed in Table 2 along with measurement dates. Groundwater at the Site flows horizontally from the north through the Unconfined Gila Unit beneath Tailings Ponds 6 and 7 to the south/southwest, where it flows through the Shallow Unconfined Gila Unit and the deep Confined Gila Unit bisected by the Mudstone Unit (Figures 3 through 5). The horizontal hydraulic gradient in the Shallow Unconfined Gila Unit is approximately 0.049 feet per foot.

### 3.3 Groundwater Recharge, Discharge and Estimated Water Balance

Sources and potential sources of groundwater recharge at the Site include infiltration from precipitation and surface water run-on, and from potential seepage from the various mine facilities. Estimates for these water budget components were not available. Calibrated modeled values of these water budget components are provided in Table 3.

Groundwater in the Shallow Unconfined Gila Unit discharges to the surface in the south where it is essentially removed from the groundwater system through evapotranspiration (ET). Some of this groundwater probably discharges southward into the Alluvial Unit, where it continues to flow to the south/southwest, and is at least partially removed via ET. Groundwater that flows beneath the mudstone in the Confined Gila Unit is expected to continue to flow southward to southwestward towards regional discharge areas, including Arnett Creek and Silver King Wash to the southwest.

Estimates of the site water balance based on Darcy Law calculations were presented previously in the workplan (Golder, 2007), to provide perspective on the general characteristics of the groundwater flow system. These estimates indicated that very little groundwater is flowing through the system (less than 5 gallons per minute [gpm]) above and below the mudstone. Also, estimates of groundwater and conservative-constituent velocities through the groundwater system above and below the mudstone were presented in the workplan (Golder, 2007), indicating that velocities are slow - on the order of a few feet or less per year. The model results presented in Section 4 provide updated and more accurate estimates of these quantities.

### 3.4 Groundwater Quality

The groundwater at the Site generally meets Arizona Water Quality Standards (AWQS), as described in the workplan (Golder, 2007). Exceptions primarily include arsenic and fluoride in a few of the wells, which Golder believes to be naturally occurring. There are also occasional exceedances of the AWQS for antimony, cadmium, lead, nickel, selenium, and thallium. None of these exceedances appear to be attributable to mining activities; however, analysis of the major ion chemistry of the groundwater on-site, does indicate that some of the groundwater, primarily in the Shallow Unconfined Gila downgradient of mine facilities and the well installed in the Alluvial Unit, has been impacted by the oxidation of sulfide/gypsum dissolution, a common occurrence in base metal mining operations. Additional discussion of fate and transport of constituents in groundwater is provided in Section 4.7.

# 4.0 NUMERICAL GROUNDWATER FLOW MODEL

## 4.1 Approach

A numerical model was constructed to represent the conceptual groundwater system of the Site. The purpose of the model was to develop a tool that can be used to assess the current groundwater conditions and potential future groundwater conditions following closure. One of the main objectives of the numerical model was to determine the transit times to wells and the duration of the post-closure period in fulfillment of ADEQ Compliance Schedule Item No. 3. The boundary conditions, hydrostratigraphic units, hydrologic inputs, and system stresses were represented using appropriate and widely used software packages, and the model was calibrated using standard modeling methods, as described in the following sections.

## 4.2 Software Selection

MODFLOW-SURFACT, an advanced version of the widely-used and accepted modeling software MODFLOW was used, along with the processing package called Groundwater Vistas, to model the study area (ESI, 2007; HydroGeologic, 2006: McDonald and Harbaugh, 1988). MODFLOW is a fully-saturated, three-dimensional, steady-state or transient-modeling software package. MODFLOW-SURFACT is an enhancement to MODFLOW, which incorporates variably saturated modeling capabilities to allow for more accurate representation of the water table, a more robust recharge package that allows for the reduction of recharge to the subsurface if water levels reach land surface, and the ability to represent seepage face conditions to accurately track groundwater discharge when the water table intersects the land surface.

The enhancements were of particular usefulness in developing the model in this case, because of the specific setting of the Site. The Site consists of generally low K hydrostratigraphic units with a shallow water table, which appears to daylight towards the southern portion of the Site. This type of setting, where the water table is at or near land surface in the lower terrain, increases the importance of accurately representing the water table and associated groundwater recharge and discharge across the land surface. The improved ability to model variably saturated groundwater flow reduces the numerical convergence problems associated with “dry cells.” Also, the location of the water table is more accurately represented, by preventing some cells that are predominantly, but not entirely, above the water table from going dry.

The original MODFLOW recharge package forces the user-specified quantity of recharge into the model domain, regardless of whether the system can physically accept it. This often results in the calculated water table elevations being above land surface, which is a physical impossibility, except in the specific case where lakes are present. MODFLOW-SURFACT's enhanced recharge package (RSF4) represents the physical process of recharge within the Site more appropriately by reducing recharge or eliminating it altogether in the lower elevations where the water table is at or near land surface.

Finally, MODFLOW-SURFACT allows groundwater to discharge at the land surface along the drainages where the water table is intersected. The original MODFLOW code does not easily account for groundwater discharge to land surface when the water table is intersected, again often resulting in modeled water tables being above land surface. The seepage face capability of MODFLOW-SURFACT automatically allows for groundwater to discharge when the water table is intersected.

## 4.3 Model Development

### 4.3.1 Model Domain and Grid

The overall modeled area includes the West Plant Site and extends outward to include Silver King Wash, Arnett Wash, and the Concentrator Fault (Figure 1). The modeled area extends beyond the immediate Site to ensure that the model boundaries do not influence the modeling results. The active model area was reduced to the model boundaries as described below.

The model grid was oriented to the northeast/southwest to be aligned with the principal directions of groundwater flow, as indicated by groundwater elevation contours drawn to correspond to the measured groundwater elevations in the monitoring wells. This grid orientation is also generally aligned with the trend of Silver King Wash to the west, Queen Creek to the south, and with the southern RCML property boundary. The estimation of groundwater flow across this boundary was one objective of this modeling effort, and orienting the grid with this boundary facilitates water-budget estimates and particle tracking.

The model grid size is, at most, 200 by 200 feet (61 x 61 meters) within the bounds of the active model area. The grid reduces to 100 by 100 feet (30.5 x 30.5 meters) in the area of the mine (Figure 6). This grid spacing allows for fine resolution in the area of interest, while maintaining a reasonable number of grid cells across the entire model area.

4.3.2 Model Boundaries

Boundary conditions were assigned to the numerical model such that they do not influence the modeling results. The intent was to reduce the model domain as much as possible to the area of interest, but at the same time ensure that the chosen boundaries did not affect the numerical solution. The potential impacts of the chosen boundary conditions were evaluated as part of the sensitivity analysis.

The active model area was enclosed between the Concentrator Fault to the north and east, Arnett Creek to the south and southwest, and Silver King Wash to the west and northwest (Figures 1 and 6). The Concentrator Fault has been inferred by others (Brown and Caldwell, 1999) to be a barrier to flow, and as such, was assigned as a “no-flow” boundary condition. Arnett Creek and Silver King Wash appear to be natural groundwater discharge areas, based on the regional topography and shallow groundwater conditions throughout the region. Groundwater converges laterally from either side, and/or flows parallel, towards these drainages; therefore, groundwater does not pass beneath the drainages from one side to the other. This hydrogeologic condition can be represented numerically within the model by assigning a “no-flow” boundary along the central axis of the drainages, because groundwater will not cross beneath the drainages to the other side. Land surface topography was imported to assign elevations to the top of model layer 1, so that groundwater flowing towards the drainages can discharge at the surface if the water table daylights using MODFLOW-SURFACT’s RSF4 package. Otherwise, groundwater will flow parallel along the drainages downstream to where the water table eventually does daylight, and discharge at that location. A constant head boundary was assigned at the confluence of Arnett Creek and Silver King Wash, to allow groundwater to flow out of the model domain along the downgradient portion of the drainage at this location.

ET from riparian zones, and from vegetated areas in general, can remove groundwater from significant depths below land surface. Given the low K of the hydrogeologic system in this case, the water table may remain below land surface, however, the hydrogeologic function of the drainages as areas of groundwater discharge remains the same, because the water table is sufficiently shallow to be available for plant uptake and removal from the groundwater system. Incorporation of ET in the numerical model is described further in subsection 4.5.

4.3.3 Model Layering

The numerical model includes seven model layers to represent the vertical flow domain. Model layer 1 represents the alluvium and all of the mine exempt and non-exempt tailings ponds (where present).

In order to model the Site correctly, both exempt and non-exempt facilities need to be included because recharge can be occurring from the exempt facilities as well as from the non-exempt facilities. The present surface topography was imported as the top surface of model layer 1. The same topography with the tailings ponds removed was used to define the bottom of model layer 1 with a minimum thickness between the two surfaces of 1 foot. In addition to model layer 1, model layer 2 represents the alluvium (where present) and was defined with a maximum thickness of 14 feet. The summed thickness of model layers 1 and 2 of 15 feet is assumed representative of the average thickness of the alluvium beneath the washes. Model layer 2 realizes the maximum depth of 15 feet everywhere except where the Mudstone Unit rises close to land surface. Where alluvium is not present, model layers 1 and 2 were assigned a K value, representative of the Gila Conglomerate.

Model layers 3 through 7 represent the Gila Conglomerate to a base elevation of 1,800 feet, which is inferred to be the approximate bottom elevation of the alluvial basin in this area (Oppenheimer and Sumner, 1980). This represents a maximum model thickness of approximately 1,200 feet. The thickness of model layers 3 through 7 is variable and is largely defined by the Mudstone Unit. Model layer 3 was set to a maximum thickness of 40 feet. Except for those areas where the surface topography has been altered by mine features, this equates to a maximum depth below land surface of approximately 55 -feet: 40 feet in Layer 3, plus 14 feet in Layer 2, plus 1 foot in Layer 1. In this way, a higher value of K could be assigned to the shallower Gila Conglomerate (in model layer 3), to accommodate the higher observed K in monitor wells MCC-9, GAI-02-02, and the Smelter Pond Point of Compliance (POC) well (Figure 2), as was indicated as necessary during the preliminary model calibration. These wells are screened up to approximately 53 feet below land surface.

Model layer 4 was initially set to have a maximum depth of 300 feet below land surface. Contours of the top surface of the mudstone were then imported (Figure 4) to replace the elevations of the bottom of model layer 4 within the footprint of the mudstone. Due to the presence of the mudstone, model layers 3 and 4 are less than their maximum thicknesses where the underlying Mudstone Unit approaches land surface. The Mudstone Unit is defined in model layer 5 by the contours of the top elevations of the mudstone and contours of the mudstone thickness, as provided by Brown and Caldwell (1999) (Figure 4). The contours by Brown and Caldwell were filled in to create a completed topographic surface within the “0” foot contour of mudstone thickness, using the contouring software Surfer (Golden Software, 2003). Outside of the footprint area of the mudstone, model layer 5 is assigned a thickness of approximately 1 foot and hydraulic properties of the non-mudstone Gila Conglomerate. Model layers 6 and 7 represent the remaining vertical extent of the

Gila Conglomerate to a depth of 1,800 feet. Representative cross sections of the model layering are shown on Figure 7.

### 4.2 Hydraulic Properties

As explained in Section 3.0, the geology of the study area consists mainly of the Gila Conglomerate and minor amounts of alluvium. K zones were initially assigned homogeneously to the model layers and given initial values based on the geometric mean of the aquifer testing data as described in Section 3.0. The distribution of K zones and the corresponding values were then modified during calibration to best match the observed groundwater elevation data. K zones were defined as follows:

- Zone 1 was assigned to the tailings in model layer 1.
- Zone 2 was assigned to the slag pile.
- Zone 3 was assigned to the alluvium along the washes and in the area of the alluvial fan deposits in the southern area of the Site in model layers 1, 2 and 3.
- Zone 4 was assigned to the shallow Gila Conglomerate in model layers 1, 2, and 3 outside of the alluvial fan deposits.
- Zone 5 was assigned to the Gila Conglomerate in model layers 4 and 5.
- Zone 6 was assigned to the Mudstone Unit in model layer 5.
- Zone 7 was assigned to the Gila Conglomerate in model layers 6 and 7 including the deep Gila Conglomerate underlying the Mudstone Unit.

These zones were assigned horizontal and vertical K, as described in subsection 4.6.3. The final, calibrated values of horizontal K represented in the model area are shown on Figure 8 and in Table 3.

### 4.5 Hydraulic Stresses

The hydraulic stresses (inflows and outflows) represented in the model included recharge, ET, and discharge to land surface along drainages. Water budget inflows simulated in the model included:

regional infiltration (recharge) of direct precipitation and surface water run-on,

- regional infiltration (recharge) of direct precipitation and surface water run-on,

- seepage of water from Settling Ponds 1 and 2 and Tailings Pond 1 and 2,
- seepage of water from the Indian Ponds,
- seepage of water from the Smelter Pond, and
- seepage of water from Tailings Pond 6.

Where not specifically noted above, recharge was assigned to mine facilities at the rate assumed for regional infiltration of precipitation and surface water run-on; therefore, some recharge is assumed to occur due to seepage from all exempt and non-exempt facilities.

- Water budget outflows simulated in the model included:
- ET,
- downgradient groundwater flow, and
- discharge of groundwater to land surface along drainages or topographic low areas.

The infiltration of precipitation, leakage of water from Settling Ponds 1 and 2, Tailings Pond 1 and 2, Indian Pond, and Smelter Pond was simulated with MODFLOW-SURFACT's RSF4 recharge package. An initial estimate of infiltration of precipitation was taken from previous modeling at the Site (Brown and Caldwell, 1999). With MODFLOW-SURFACT's RSF4 package, assigned values of recharge are in effect, at a maximum, as the advanced recharge package reduces or eliminates recharge in certain areas (e.g., discharge areas) to prevent the water table from rising above land surface. Infiltration through the ponded portion of Tailings Pond 6 was simulated with the General Head Boundary package, using an estimated steady state elevation in the pond of 2,945 feet.

Consumptive use of groundwater by vegetation was simulated with the ET package. Preliminary model calibration to wells along the washes indicated the need to represent the removal of shallow groundwater in the riparian areas. Initial estimates of the ET rate were taken from the pan evaporation rate of 83-inches per year (in/yr) (Golder, 2007) and multiplying by the standard correction factor of 70 percent, to arrive at the open water evaporation rate of 58-in/yr. The open water evaporation rate is typically considered the maximum possible ET rate. Discharge of groundwater to land surface along topographic low areas was simulated with MODFLOW-SURFACT's RSF4 recharge package. Lastly, in the southwest corner of the model where Arnett

Creek and Silver King Wash meet, a constant head cell was assigned at the base of model layer 3 (the base of the shallow Gila Conglomerate material) to allow any shallow groundwater that had converged toward the washes but was flowing downgradient parallel to, or along the washes, to discharge.

These components of the water budget were varied during the model calibration and were tested during the sensitivity analysis. The final, calibrated values for each water budget component along with the initial estimates, where available, are presented in Table 3.

### 4.6 Model Calibration

The numerical model described above was calibrated to observed groundwater elevations in monitor wells, as described in this section.

#### 4.6.1 Method

Calibration is the process of finding a set of parameters, boundary conditions, and stresses that best reproduce the observed water levels, flow rates, and/or velocities (Anderson and Woessner, 1992). The calibration procedure first followed a standard trial-and-error approach and was followed by using UCODE_2005 an automated parameter estimation routine (Poeter et al., 2005). K values and hydraulic stresses were modified within ranges deemed appropriate for the parameters until the best possible match was made to the observed water level conditions. Most of the groundwater elevation data was collected in 2007: however, other data were used as necessary to provide better coverage over the modeled area. Table 2 summarizes the groundwater elevation data. Initially, each model layer was defined with a uniform, homogenous value of K, and infiltration from tailings ponds was not simulated. Gradually, a small amount of increased complexity was added, in the form of heterogeneity of K and infiltration from the tailings ponds, as indicated by the difference between the model calculated hydraulic heads and the observed hydraulic heads. The heterogeneity, or the number of hydrostratigraphic units represented in the numerical model was intentionally limited, given the large size of the model domain relative to the small number of measurement points (observed hydraulic heads and estimates of K). This approach limits the ability to match hydraulic heads everywhere in the model area. However, this approach is preferred over introducing heterogeneity to match hydraulic heads without having additional information to support the added complexity. Heterogeneity of K was incorporated through the definition of the model layers (i.e. inclusion of a relatively thin model layer 3 to represent the higher K estimated in some shallow Gila

Conglomerate wells), and separate K zones for the alluvium versus the shallow Gila Conglomerate and the Mudstone Unit.

After the trial-and-error method of calibration resulted in a combination of K zones and recharge rates that provided the best match to observed hydraulic heads, UCODE_2005 was used on the defined K zones to provide a comparison between the "hand-calibrated" model and an automated calibrated model. The resulting K values from UCODE_2005 were comparable to the hand-chosen values.

#### 4.6.2 Numerical Parameters

The numerical model was solved using MODFLOW-SURFACT's stable and robust Pre-Conjugate Gradient 5 (PCG5) solver (HydroGeoLogic, 2006). This solver was used in conjunction with a Newton-Raphson Linearization for stability, using a backtracking factor of 0.2 and a residual reduction factor of 1.2. The head change criteria for convergence was set to 0.001 feet.

#### 4.6.3 Calibration Results

The K values and groundwater inflows that produced the best match to observed hydraulic heads are presented on Figure 8 and Table 3. The calibrated, modeled values of each water budget component are also presented in Table 3. Contours of the model calculated shallow groundwater elevations are shown on Figure 9. Target residuals, the difference between observed and model calculated hydraulic heads in each monitor well (target), are also presented on Figure 9 and in Table 4. As shown on Figure 9, the modeled groundwater elevation contours are more variable than the hand-contoured groundwater elevations measured at the monitoring wells (Figure 5). This is due to the influence of surface topography and the associated discharge that occurs in the lower topographic areas where either the water table daylights, or where ET removes groundwater. In response, groundwater flows towards these areas of groundwater discharge, resulting in groundwater contours mimicking surface topography.

The calibrated K values for the various zones are as follows:

- Zone 1-0.015 ft/d (5.2 x 10-6 cm/s) for the tailings (Zone 1). This value was calculated from the geometric mean of K measurements of fine and coarse tailings from Volume 3 of the APP Application (Golder, 2005c).

- Zone 2 - 9.64 ft/d (3.4 x 10-3 cm/s) for the slag pile (Zone 2). This value was set to be 100 times higher than the alluvium to represent very coarse material.

- Zone 3 - 0.096 ft/d (3.4 x 10-5 cm/s) for the alluvium (Zone 3), taken from the estimate of K in the Smelter Pond monitor well.

- Zone 4 - 0.066 ft/d (2.3 x 10-5 cm/s) for the shallow Gila Conglomerate. This compares well with the higher K values ($10^{-2}$ ft/d [$10^{-5}$ cm/s]) estimated from shallow monitor wells, MCC-9 and GAI-02-02.

- Zone 5 - 0.0011 ft/d (3.7 x $10^{-7}$ cm/s) for the deeper Gila Conglomerate that overlies the Mudstone Unit.

- Zone 6 - 3.7 x 10-6 ft/d (1.3 x 10-9 cm/s) for the Mudstone Unit taken from the estimate of K in monitor well MCC-3B.

- Zone 7 - 0.0011 ft/d (3.7 x 10-7 cm/s) for the remaining Gila Conglomerate beneath the Mudstone Unit, and at depth elsewhere in the model area.

The Gila Conglomerate was divided into multiple K zones (Zones 4 through 7), to allow the value to vary between model layers 4 through 7. The K value of 0.0011-ft/d (3.7 x $10^{-7}$ cm/s) assigned to Zones 5 and 7 was found to provide the best calibration to observed groundwater elevations. This value of K is equivalent to the geometric mean of estimates for the Gila Conglomerate, not including the Mudstone Unit (Zone 6) or shallow monitor wells MCC-9 and GAI-02-02 (Zone 4). The alluvium and Gila Conglomerate K zones were simulated with a ratio of horizontal to vertical anisotropy of 100:1, and the Mudstone Unit was simulated with a ratio of 1,000:1, as is common in modeling applications (Anderson and Woessner, 1992).

The final, calibrated amount of recharge due to direct precipitation and surface water run-on is 0.09 inches per year (in/yr). This is less than the initial value assumed, based on the work by Brown and Caldwell (1999); however, the value is believed reasonable for this climatic and hydrogeologic setting based on previous experience. Over the modeled area, the calibrated recharge rate of 0.09 in/yr equates to a volumetric flux of 32-gpm (Table 3).

Initial model calibration also indicated the need to include seepage from the ponds at the Site. In particular, the Tailings Pond 5 POC well and Settling Ponds 1 and 2 Alert well did not calibrate well without modeling seepage from Settling Ponds 1 and 2, and Tailings Ponds 1 and 2. Recharge zones were added to the model to represent Settling Ponds 1 and 2, Tailings Pond 1 and 2, the Smelter Pond, and the Indian Ponds, and a general head boundary was added to the model to represent the contained Stormwater on Tailings Pond 6. The head at the general head boundary was set equal to an estimate of the steady state water level in the pond of 2,945-feet amsl, and the conductance of the boundary was adjusted during calibration. Recharge rates, representing seepage from the remaining ponds, were determined during calibration and are presented in Table 3.

Initial model calibration was undertaken with no assumed ET; however, the final calibration was refined by simulating ET. ET was modeled with a maximum rate of 58-in/yr and an extinction depth of 30 feet over the entire model domain excluding mine features, and 50 feet along the washes and riparian areas (Table 3).

The model achieved an acceptable match to the observed hydraulic heads, particularly in the shallower portions of the Gila Conglomerate. A scatter plot of observed versus model simulated hydraulic heads is shown on Figure 10. Ideally, all targets would fall directly on a 45 degree line, indicating a perfect match between observed and model simulated hydraulic heads. The targets in the shallower portions of the Gila Conglomerate (model layers 2 through 4) show a very good calibration, lying on or very close to the 45-degree line. The targets below the Mudstone Unit (model layer 6) show that the model overpredicts the groundwater elevations at depths, including at well MCC-3C. Attempts to better calibrate the model to the groundwater levels in the deeper zone were unsuccessful; regardless, the deeper portion of the Gila Conglomerate was not a main focus of this modeling effort. Effort was concentrated on achieving the best possible calibration in the shallower portions of the Gila Conglomerate to best represent the flow paths and velocities at the Site near the APP facilities.

The residuals (difference between observed and model simulated hydraulic heads) for each target are shown in Table 4. The average residual was -19.5 feet (-5.9 meters), with a standard deviation of 42 feet (12.8 meters). The average residual indicates that there is a bias in the model to overpredict water levels; however this is mainly limited to the wells in the lower Gila Conglomerate (model layer 6). The average residual for targets in model layers 2 through 4 is -1.36 feet (-0.4 meters).

The quality of the calibration can also be expressed as the statistical measures of the residual sum of squares, which is the sum of the squared residual in each target, and the root mean squared (RMS) error which is defined as follows:

$$RMS = [\frac{1}{n}\sum_{i=1}^{n}\{h_o - h_s\}_i{}^2]^{0.5}$$

where n is the number of targets, $h_o$ is the observed hydraulic head, and $h_s$ is the model simulated hydraulic head. The residual sum of squares provides a measure of the calibration that removes the bias of over or underpredicted hydraulic heads and allows for direct comparison between different models of the same site. This measure was used to evaluate the model response during the sensitivity analysis. The RMS error provides a means of relating the calibration error to the variation in hydraulic heads across the model area. If the RMS error is a small percentage of the total head change, then the calibration errors are only a small part of the overall model response (Anderson and Woessner, 1992). The residual sum of squares for the calibrated model is 43,361 square feet ($ft^2$) (4,028 square meters [$m^2$]), and the RMS error is approximately 10 percent of the range in observed hydraulic heads at the Site (Table 4).

These statistical parameters were also evaluated for only the shallower targets in model layers 2 through 4. Only these targets were considered because the deeper targets did not calibrate well, and calibration to these deep targets was not a primary goal of the model. The residual sum of squares for the calibrated model, in layers 2 through 4, is 7,479 $ft^2$ (2,279 $m^2$) and the RMS error is approximately 5 percent of the range in observed hydraulic heads at the Site (Table 4). These statistics, contours of the model calculated hydraulic head, and the scatter plot of observed versus model-simulated hydraulic heads show that the model realized a level of calibration acceptable for use as a tool to evaluate groundwater flow paths and velocities.

#### 4.6.4 Sensitivity Analysis

A sensitivity analysis was conducted to test the appropriateness of the modeled parameters and hydraulic stresses. Sources of recharge to the model and K were varied independently and in combinations to test the model response. Where model response is small, it can give insight as to the parameters that do not necessarily play a dominant role in the groundwater flow system and are not necessarily as important to accurately quantify or estimate. Where model response is high, this gives an indication of the parameters that are most important to controlling groundwater flow, and can give insight to areas of future data collection that may prove most valuable. The sensitivity analysis described below was performed on the initial calibrated model before ET was included, for reasons explained in the final portion of this section.

##### *4.6.4.1 Recharge and Evapotranspiration*

Several sensitivity analysis runs were conducted to test the sensitivity of the model response to the modeled recharge rates. Sensitivity runs that illustrate the model response were chosen and are presented in graphical form in Appendix A. When infiltration from precipitation and stormwater run-on was increased to 0.38 in/yr (calibrated value of 0.09 in/yr, Table 3), the response of the model was large, resulting in increases in groundwater levels of typically 20 to 30 feet over the calibrated model. The calibration fit was generally poorer. The residual sum of squares was increased from 43,361 $ft^2$ to 87,108 $ft^2$ (Appendix A). Decreasing the infiltration from precipitation and stormwater run-on to 0.05-in/yr, caused little change over the calibrated model, as did removing the seepage from the ponds at the Site, with the exception that the groundwater levels in the Tailings Pond 5 and Settling Pond 1 and 2 Alert wells were notably lower (Appendix A).

#### *4.6.4.2 Hydraulic Conductivity*

Several sensitivity analysis runs were conducted to test the sensitivity of the model response to the modeled K values. Sensitivity runs that illustrate the model response were chosen, and are presented in graphical form in Appendix A. The first set of sensitivity runs addressed the K values assigned to the Gila Conglomerate (not including the Mudstone Unit). The K value was set equal to the geometric mean of hydraulic testing results for the Gila Conglomerate (0.002 ft/d [6.9 x 10-7 cm/s]) in all model layers, calculated from values in Table 1. The response from this run was significant, with groundwater levels rising by approximately 20 to 30 feet compared to the calibrated model. A second set of runs tested the sensitivity of the model to just the K value for the shallow Gila Conglomerate. The K value was decreased to 0.0046 ft/d (1.6 x 10-6 cm/s) from 0.066 ft/d (2.3 x 10-5 cm/s), the geometric mean of K estimates in wells that are in model layers 3 and 4. Groundwater levels were approximately 20 to 25 feet higher than the calibrated model.

An additional sensitivity run was conducted, in which the K of the shallow Gila Conglomerate was lowered to 0.0046 ft/d (1.6 x 10-6 cm/s) and recharge from precipitation and surface water run-on was not simulated. This resulted in lower groundwater levels in many of the targets, by a maximum of approximately 100 feet. Most of the targets in the shallow Gila Conglomerate were not as severely affected, because the decrease in recharge was compensated by the decrease in K. The targets in model layer 4 and some of the targets in model layer 3 became poorly calibrated, with groundwater levels that were too low. The targets in model layer 6 were improved (Appendix A, Figure 2), given that the groundwater levels in model layer 6 were overpredicted in the calibrated model.

A sensitivity run was conducted to test raising the K of the alluvium and the Gila Conglomerate (both the shallow and deep) and raising the recharge rate from infiltration of precipitation and surface water run-on. Although higher K values (above the calibrated values) are not supported by the hydraulic testing data, this analysis was intended to create a model with higher groundwater flow velocities, in which more water was cycled through the hydrogeologic system and the hydrogeologic system itself was more transmissive. In this manner, the slow velocities, indicated by particle tracking analysis (subsection 4.7), and the resulting conclusions regarding mass transport velocities and the likelihood of containment transport off mine property, could be compared to a more conservative scenario in which groundwater flow velocities within the Gila Conglomerate were higher. In this scenario, K of the alluvium and the Gila Conglomerate were raised by one order of magnitude (ten times) above the values used in the calibrated model. Infiltration of precipitation and surface water run-on was also increased by one order of magnitude. From a calibration viewpoint, the hydraulic heads in many targets were raised too high, by as much as 60 feet above the calibration results. The sensitivity of the particle tracking analysis and resulting conclusions of groundwater flow velocities and mass transport velocities to this scenario are presented below in subsection 4.7.

#### *4.6.4.3 Boundary Conditions*

A sensitivity run was also conducted to test whether the closeness of the Silver King Wash (simulated with MODFLOW-SURFACT’S RSF4 package, the ET package, and no-flow boundaries) affected model results within the area of the mine facilities and monitor wells. The western model boundary was moved further to the west and the results were compared to the calibrated model. The calibration in the target wells was not affected by this change. Particle tracking between the calibrated model and this sensitivity run yielded very similar results, and indicated that this boundary does not affect the estimation of groundwater flow paths or velocities near the mine.

The appropriateness of the no-flow boundary assigned to the Concentrator Fault was also reviewed from the perspective of whether recharge applied within the model boundaries was sufficient from the water balance perspective. The calibrated model results with recharge from precipitation and storm run-on of 0.09 in/yr indicates that there is likely insignificant inflows into the model area across the Concentrator Fault. Depths to water in the mine shafts located east of the fault are on the order of 1,000 feet deeper than the groundwater levels west of the fault, indicating that flow across the fault into the Site area is unlikely.

#### *4.6.4.4 Summary and Discussion of Sensitivity Analysis*

The results of the sensitivity analysis suggest that the model is sensitive to the modeled values of recharge and K. The range of values tested as part of the sensitivity analysis generally resulted in poorer fits to the observed groundwater elevation data, suggesting that the chosen parameters of the calibrated model provide the best fit to the observed data. Typically, lower values of K resulted in higher estimates of hydraulic head, usually higher than the observed hydraulic heads, causing greater amounts of groundwater to discharge to land surface where intersected by the water table. The results of the sensitivity analysis indicate that the calibrated K values and recharge values are reasonable.

The analysis described above was performed prior to including ET in the final calibration. Including ET resulted in slightly lower groundwater levels, particularly in the wells with the lowest groundwater elevations located to the south along Silver King Wash, which were lowered approximately 40 feet (Appendix A). Repeating some of the sensitivity analysis described above by varying recharge rates and K values with ET included, showed that the model calculated hydraulic heads were significantly less sensitive to these model parameters. The reason for this reduced sensitivity may be attributable to groundwater levels across the model area being fairly shallow, typically less than 50 feet, and therefore subject to removal by ET. Furthermore, because the groundwater volumetric flux through the groundwater system is low as a result of low K, ET has the potential to remove most of the water, dropping the water table to near the inferred bottom of the root zone. Reducing K further in comparison to the calibrated case, would have minimal effect on groundwater levels. This is because ET would remove groundwater to its extinction depth, and not allow the water table to rise as would typically occur when K is reduced. Increasing or decreasing recharge further has little effect, because in both cases the volumetric flux of groundwater remains limited due to the low site K, and ET can still remove the groundwater to the extinction depth. The model calculated hydraulic heads are only sensitive to significant increases in K when ET is included. This is because increasing K values allows the model calculated groundwater levels to drop below the ET extinction depth.

### 4.7 Simulation Results

As stated previously, the primary objective of the groundwater model was to evaluate the adequacy of existing monitoring well locations relative to APP facilities, transit times to wells and the required duration of post-closure monitoring. Infiltration rates from mine facilities, travel paths of potential seepage from the tailings ponds, and the site water balance were also evaluated to provide an overall perspective of the site groundwater flow system.

Based on analysis of groundwater constituents and AWQS, an obvious constituent of concern has not been identified (Golder, 2007). As such, the numerical modeling work focused on evaluating the rates of conservative constituent movement through the flow system. This was done through the process of particle tracking, using the routine MODPATH (Pollock, 1989).

Subsection 4.7.1 presents an evaluation of the POC and Alert monitoring well locations relative to upgradient APP facilities and velocities (travel times) from these APP facilities to the POC and Alert wells. Subsection 4.7.2 presents an evaluation of the site water balance including estimates of the total amount of groundwater that leaves the site property. This subsection also discusses the possible seepage rates from the APP facilities, as well as groundwater flow paths and velocities across the Site. Subsection 4.7.3 presents a fate and transport analysis of non-conservative constituents. This analysis incorporates the potential source water chemistry (tailings porewater), the buffering capacity of the geologic media, and the estimated groundwater volumetric fluxes derived from the numerical groundwater flow model, to estimate the potential rate and extent of plume migration away from the tailings ponds.

### 4.7.1 Monitoring Well Locations and Groundwater Velocities

This subsection describes an analysis of the locations of monitoring wells relative to the respective APP facilities. The APP facilities and associated monitoring wells are listed in Table 5. The analysis was performed by tracking particles representing groundwater flow paths between the APP facilities and the wells using MODPATH. The particles were "released" near the wells and tracked backwards from the wells to where the groundwater is recharged. The particles were placed around the subject monitoring wells within the model layer screened by the well, to evaluate whether the wells are screened at the appropriate depth. Particles were released both at the top and bottom of the layers near the wells to evaluate how the travel paths of shallow and deep water in the vicinity of the well screens may differ. A porosity value of 0.39 was used for the Gila Conglomerate, while the tailings and slag pile were assigned porosity values of 0.4 and 0.5, respectively. The tailings and slag pile porosity estimates are based on previous experience with similar mine sites. Appendix B presents maps with the modeled groundwater travel paths.

The results indicate that the POC wells in general were placed in appropriate locations and screened at reasonable depths for monitoring the upgradient source areas. A discussion of the travel paths and velocities for each APP facilities is presented below.

#### *4.7.1.1 Smelter Pond*

MCC-9 – This well is located south of the Smelter Pond and is screened at a depth of between 28 and 48 feet (8.5 and 14.6 meters) in Gila Conglomerate. Figure B-1 shows the groundwater flow paths from the well upgradient towards the Smelter Pond to the north. The northernmost extent of the travel paths show where the groundwater is recharged at the water table from infiltration at land surface or from the tailings ponds or other facilities. As shown on Figure B-1a, the groundwater passing near the well in the upper portion of the screened model layer is primarily recharged from beneath the Smelter Pond. Figure B-1b shows that the groundwater passing near the well in the lower portion of the screened model layer is recharged to the north near Pond 5. The results indicate that the well is in a reasonable location for monitoring the Smelter Pond and that the well is screened at an appropriate depth.

The amount of time for groundwater to flow from the southern edge of Smelter Pond to Well MCC-9 is estimated from the model at 3.6 years. The groundwater quality at Well MCC-9 meets AWQS for all constituents, with the exception of a one-time nickel exceedence. Sulfate (SO4) and total dissolved solids (TDS) concentrations are higher than that postulated for background groundwater quality, as inferred from the chemistries of Wells MCC-1, MCC-6A and MCC-6B (TDS 230 to 260-milligrams per liter [mg/L]), SO4 concentrations of less than 10 mg/L). As such, the groundwater quality at Well MCC-9 is consistent with what would be expected associated with seepage from the Smelter Pond.

Smelter Pond Well – This well is located south of the Smelter Pond and south of Well MCC-9 and is screened at a depth of between 7 and 17 feet (2 and 5 meters) in alluvium. Figure B-2 shows the groundwater flow paths from the well upgradient towards the Smelter Pond to the north. As shown on Figure B-2a, the groundwater passing near the well in the upper portion of the screened model layer is primarily recharged from beneath the northern portion of the Smelter Pond. Figure B-2b shows that the groundwater passing near the well in the lower portion of the screened model layer is recharged north near Pond 5, similar to the situation with Well MCC-9. The results indicate that the well is in a reasonable location for monitoring the Smelter Pond and is screened at an appropriate depth.

The amount of time for groundwater to flow from the southern edge of the Smelter Pond to the Smelter Pond POC well is estimated from the model at 140 years. The quality of groundwater monitored at this well is similar to that of Well MCC-9, indicating some impact from mining activity, potentially stormwater or other local non-APP source(s). However, according to available data, the water quality remains within AWQS.

*4.7.1.2 Tailings Pond 6 and 7*

GAI-02-01 – This well is located south of Pond 6 and east of Well MCC-6C and is screened at a depth of between 152 and 206 feet (46.3 and 62.8 meters) in Gila Conglomerate. Figure B-3 shows the groundwater flow paths from the well upgradient towards Pond 6 to the north. As shown on Figure B-3a, the groundwater passing near the well in the upper portion of the screened model layer is recharged locally near the well. Figure B-3b shows that the groundwater passing near the well in the lower portion of the screened model layer travels from where it is recharged, north of the tailings ponds, and underneath Pond 6 to the well. The results indicate that groundwater flowing through the central portion of the layer screened by the well is recharged from beneath the tailings, and as such, the well is in a reasonable location for monitoring Pond 6 and is screened at an appropriate depth.

The amount of time for groundwater to flow from the southern edge of Pond 6 to Well GAI-02-01 is estimated from the model at 8,000 years. This greater travel time, compared to previous estimates, stems in part from the deeper groundwater flow path to the well. The groundwater sampled at this well is relatively low in TDS and sulfate, and meets all AWQS. This groundwater may not be impacted from mining activities.

MCC-6C – Well MCC-6C is located southwest of Pond 6 and is screened at a depth of between 75 and 116 feet (23 and 35.4 meters) in Gila Conglomerate. Figure B-4 shows the groundwater flow paths from the well upgradient towards Pond 6. As shown on Figure B-4a, the groundwater passing near the well in the upper portion of the screened model layer travels from the northeast where it is recharged from underneath Pond 5 and Pond 6 and from surrounding areas. Figure B-4b shows that the groundwater passing near the well in the upper portion of the screened model layer travels from recharge areas farther upgradient and north of Pond 6. The results show that in general, the well is in a reasonable location for monitoring Pond 6, but the screened interval may be somewhat deep. Additional simulations of discharge from Pond 6 discussed in subsection 4.7.2 indicate that a more optimal location of the well would be to the northeast, closer to Pond 6.

The amount of time for groundwater to flow from the southwestern edge of Pond 6 to Well MCC-6C is estimated from the model at 6,100 years. This greater travel time can be, in part, attributed to both the deeper groundwater flow path to the well, and its greater distance from the tailings pond. The groundwater sampled at this well is relatively low in TDS and sulfate, and meets all AWQS, with the exception of a one-time exceedence of the standard for arsenic. This groundwater may not be impacted from mining activities.

#### *4.7.1.3 Tailings Pond 5*

Tailings Pond 5 Well – This well is located southeast of Pond 5 and is screened at a depth of between 80 and 120 feet (24.4 and 36.6 meters) in Gila Conglomerate. Figure B-5 shows the travel paths of groundwater between the well upgradient towards Pond 5 to the north As shown on Figure B-5a, the groundwater passing near the well in the upper portion of the screened model layer travels from the northwest and is primarily recharged just south of Pond 5. Figure B-2b shows that the groundwater passing near the well in the lower portion of the screened model layer travels beneath Pond 5 from its recharge area to the north. The results indicate that the central portions of the screened model layer is receiving recharge from beneath Pond 5, and as such, the well is in a reasonable location for monitoring Pond 5 and is screened at an appropriate depth.

The amount of time for groundwater to flow from beneath the Tailings Pond 5 to the Tailings Pond 5 POC well is estimated from the model on the order of 21,000 years. This greater travel time stems, in part, from the deeper groundwater flow path to the well and its greater distance from the tailings pond. The groundwater sampled at this well is relatively low in TDS and sulfate, and meets all AWQS. This groundwater may not be impacted from mining activities.

#### *4.7.1.4 Settling Ponds 1 and 2*

Settling Ponds 1 and 2– This well is located on the southeast side of the settling pond and is screened at a depth of between 140 and 180 feet (42.7 and 55 meters) in Gila Conglomerate. Figure B-6 shows the travel paths of groundwater between the well upgradient towards the settling pond to the northwest. As shown on Figure B-6a, the groundwater passing near the well in the upper portion of the screened model layer travels northwestward and is recharged primarily from beneath the settling pond. Figure B-6b shows that the groundwater passing near the well in the lower portion of the screened model layer travels beneath the Settling Pond from where it is recharged farther upgradient to the northwest. The results indicate that the well is in a reasonable location for monitoring Settling Ponds 1 and 2 and is screened at an appropriate depth.

The amount of time for groundwater to flow from beneath the Settling Pond to the alert well is estimated from the model to range from less than one year to several thousand years. The groundwater sampled at this well, however, is relatively low in TDS and sulfate, and meets all AWQS. This groundwater does not appear to be impacted from mining activities despite the estimated short travel times from the facility.

#### *4.7.1.5 Tailings Pond 5 and Settling Ponds 1 and 2*

MCC-3C– Well MCC-3C is located west of Indian Ponds and is screened at a depth below the Mudstone Unit, of between 499 and 579 feet (152 to 176 meters) in the Confined Gila Conglomerate. Figure B-7 shows the groundwater flow paths of groundwater reaching these wells. The groundwater sampled by this well is shown to travel a substantial distance from where it is recharged north of

Tailings Pond 5, beneath the Mudstone Unit, to the well. As such, the well does not appear to be within the flow path of groundwater that may be impacted by any of the mine facilities. Further analysis of the flow paths of potential recharge associated with the APP facilities presented in subsection 4.7.2, indicates that all of the potentially impacted groundwater is confined to the shallow Gila Conglomerate and/or alluvium overlying the Mudstone Unit; none of the potentially impacted groundwater travels through or beneath the Mudstone Unit.

*4.7.1.6 Tailings Pond 5, 6, and 7*

MCC-4 – Well MCC-4 is located immediately south of Pond 1, and is screened at a depth below the Mudstone Unit, of between 200 and 250 feet (61 to 76 meters) in the Confined Gila Conglomerate. Figure B-8 shows the groundwater flow paths of groundwater reaching the well. The groundwater sampled by this well is shown to travel a substantial distance from where it is recharged north of tailings Pond 5. As such, this well also does not appear to be within the flow path of groundwater that may be impacted by any of the mine facilities. Further, similar to Well MCC-3C, none of the potentially impacted groundwater appears to travel through or beneath the Mudstone Unit (subsection 4.7.2).

*4.7.1.7 Indian Pond*

Indian Ponds Well – This well is located south of the Indian Ponds and is screened at a depth of between 7 and 47 feet (2 and 14.3 meters) in alluvium. The alluvium was dry when the well was first installed. The purpose of installing this well was to sample any groundwater that might flow within the alluvium during wetter periods; however, to date, the well has been dry, and as such, no analysis was conducted for this well.

*4.7.1.8 Discussion and Summary of Monitoring Well Location Analysis*

To provide further confidence in the analysis, additional simulations were conducted to determine how sensitive the above described travel paths were to the assumed model parameters. As described in subsection 4.6.4.2, one simulation was conducted assuming that the K of the alluvium and the Gila Conglomerate was 1 order of magnitude (10 times) greater than the values used in the calibrated model. Infiltration of precipitation and surface water run-on was also increased by 1 order of magnitude, and ET was not simulated. This simulation resulted in a poor fit to the observed groundwater elevations, as further described in subsection 4.6.4.2; however, particle tracking using this simulation indicated that the travel paths upgradient of the monitoring wells are not very sensitive to the assumed model parameters. This in turn provides further confidence that the POC wells are in appropriate locations and are generally screened at the proper depths to monitor any seepage from the upgradient mine facilities.

Specific conclusions drawn from the analysis are as follows:

- The results of the monitoring well location analysis indicate that most of the wells are located appropriately and screened at reasonable depths to monitor their respective APP facility.

- Well MCC-6C (Tailings Ponds 6 and 7) - Based on the analysis, Well MCC-6C appears to be screened deeper than what would be ideal. As further discussed in the following subsection and shown in Appendix C, a more ideal location for the well would be closer to Tailings Pond 6, to the northeast. The results further indicate that the well should ideally be screened across the water table.

- Wells MCC-3C and MCC-4 (Tailings Pond 5 and Settling Ponds 1 and 2; Tailings Ponds 5, 6, and 7) – Based on the analysis, neither well MCC-3C or MCC-4 are located within a flow path downgradient of any of the APP facilities. Both are screened below the Mudstone Unit, and as described in the following subsection and shown in Appendix C, all of the potentially affected groundwater is confined to the Gila Conglomerate and/or alluvium overlying the Mudstone Unit.

- 4.7.2 Site Water Balance and Flow Conditions

A preliminary estimate of the site water balance was presented in Golder (2007a) to provide a general sense of the quantities of groundwater flowing across the Site in the shallow Gila Conglomerate above the Mudstone Unit as well as beneath the Mudstone Unit. Using the calibrated model, approximately 4-gpm of groundwater is estimated to flow across the Site and the property boundary to the south and southwest in the shallow Gila Conglomerate. Groundwater flowing beneath the mudstone across the Site to the south is likewise estimated using the model at a rate of 0.25-gpm. These updated estimates supersede the estimates presented in Golder (2007a); however, as before, the estimated quantities of groundwater leaving the site are notably small.

Additional particle tracking was undertaken to evaluate the flow paths of any potential seepage released from the APP facilities. The results indicate that all of the potentially impacted groundwater stays above the Mudstone Unit in the shallow Gila Conglomerate and/or alluvium. Appendix C shows the results of particle tracking from the APP facilities. Evaluation of the velocities of the inferred seepage supports the long travel times to the monitoring wells described in the preceding section. The analysis suggests that groundwater velocities associated with any potential seepage from the APP facilities is on the order of 1.8 x 10-4 ft/d, or 6.6 feet in 100 years.

Estimates of the current quantities of seepage from the APP facilities were not available for this study; however, estimates were derived through the model calibration process. From the calibrated modeling results, the groundwater seepage estimates from beneath Tailings Ponds 5 and 6 is approximately 2.2-gpm and from Tailings Pond 7 is approximately 0.03-gpm. The groundwater seepage from beneath Settling Ponds 1 and 2 is estimated at 1.8-gpm. The estimated seepage from Indian Ponds is at 0.4- gpm, and the seepage from Smelter Pond is estimated at 0.4-gpm. These values differ from the inflows reported in Table 3 in that the values listed here, in subsection 4.7.2, represent groundwater that leaves the footprint area of the facilities. The values in the Table 3 represent the quantities of groundwater that infiltrates through the surface of the tailings only.

The results of the sensitivity analysis indicates that groundwater elevations are not highly sensitive to assumed infiltration rates; however, as noted previously, additional recharge was required in Settling Ponds 1 and 2, and Tailings Pond 1 and 2, to better match the observed groundwater elevations in this area. The lack of sensitivity to the assumed infiltration rates illustrates that the actual infiltration rates are uncertain; however, the sensitivity analysis also indicates that the low K of the underlying Gila Conglomerate constrains the amount of infiltration through the tailings materials that can enter the Gila Conglomerate and reach the water table. Additional recharge applied to the model is either rejected because the water table is at or near land surface, or is removed by ET before traveling a significant distance into the underlying Gila Conglomerate.

### 4.7.3 Fate and Transport of Constituents of Concern

The discussion in subsection 4.7.2 illustrates that velocities of constituents of concern (COCs) are slow, and contaminant mass transport is minimal under the assumption that COCs travel at the same rate as groundwater; i.e. conservative. However, most potential COCs, do not travel at the same rate as groundwater, but instead are attenuated by chemical and physical processes such as precipitation, dissolution, and sorption. These processes are generally pH dependent. This subsection presents an assessment of how far COCs may travel downgradient of the APP facilities, based on a geochemical analysis performed by Golder (2005), combined with the groundwater volumetric fluxes calculated using the numerical groundwater flow model.

The geochemical analysis was undertaken to determine the potential attenuation of seepage from Tailings Ponds 5 and 6 at the Site. The goals of the analysis were to examine the interaction between seepage from Tailings Ponds 5 and 6 and the underlying Gila Conglomerate, and determine the potential for buffering and natural attenuation of seepage constituents. As described in Golder (2005) , the Gila Conglomerate contains significant neutralization potential that will neutralize acidic solutions generated by the tailings ponds. Neutralization of acidic solutions will subsequently result in attenuation of certain metals through precipitation and/or sorption.

The Golder (2005) analysis included:

- review and analysis of Gila Conglomerate physical and acid-base accounting (ABA) properties;
- examination of tailings porewater chemistry, monitoring well chemistry, column test data, and kinetic testing data for Tailings Ponds 5 and 6;
- geochemical modeling to examine the interaction of expected seepage chemistry with reactive minerals in the Gila Conglomerate; and
- the analysis of data and modeling results.

Detailed results of the analysis, along with a description of the data utilized, assumptions, and geochemical modeling are provided in of Golder (2005). Geochemical modeling was performed using the computer program PHREEQC (Parkhurst and Appelo 1999), a widely accepted thermodynamic model published by the U.S. Geological Survey. The approach to modeling was intended to mimic the outflow of seepage from the tailings facilities into the Gila Conglomerate and to provide an estimate of the number of pore volumes required to consume the neutralizing and attenuation capacity of the Gila Conglomerate. Geochemical samples collected from the Gila Conglomerate indicate that it has an average neutralization potential of 80 kilograms calcium carbonate per metric ton (kg $CaCO_3$/ton) as calculated from the ABA data. This compares with more recent sampling results (five samples) for which the neutralization potential of the Gila Conglomerate averages 150 kg $CaCO_3$/ton (Golder, 2007b), or nearly double that used in the analysis. The 80 kg $CaCO_3$/ton used in the analysis equates to 8 percent calcite. Based on available data for the Gila Conglomerate, calcite is assumed to be the predominant neutralizing mineral in the Gila Conglomerate.

Geochemical model simulations were performed using the average tailings porewater chemistry and monitoring well water chemistry to evaluate the fate and transport of constituents under current conditions. Model simulations were also performed using the average column effluent chemistry and Week 20 humidity cell effluent chemistry to evaluate the fate and transport of constituents under the assumption that acidic conditions within the tailings will occur at some time in the future.

Under the current conditions scenario, the geochemical modeling results indicate that no depletion of the neutralization and attenuation capacity of the Gila Conglomerate would occur. This is largely because the tailings porewater is currently non-acidic and close to, or at equilibrium with, calcite. Also, the tailings porewater does not contain high concentrations of metals (with the exception of manganese (Mn) in the Tailings Pond 6 column leachate) and as such is not expected to significantly impact water quality within the Gila Conglomerate. Table 6 summarizes the tailings porewater chemistry.

Assuming acidic tailings solutions for the potential future conditions scenario, the modeling results show that the neutralization of the Gila Conglomerate beneath the tailings will occur, resulting in attenuation and eventual depletion of the neutralizing capacity. The modeling results indicate that the number of pore volumes required to deplete calcite ranges from 13 to 310, depending on the chemistry assumed for the future tailings porewater, and given the differences in the column testing and humidity cell testing results. The more acidic the solution, the more quickly the calcite and attenuation capacity will be consumed. Following calcite depletion, the modeling results indicate that pH will remain buffered for some time by secondary minerals that precipitate during the process as described in Golder (2005).

The acidic tailings porewater for this scenario generally has higher concentrations of sulfate ($SO_4$), copper (Cu), and arsenic (As). Sulfate is initially attenuated through gypsum precipitation and then by precipitation of aluminum-hydroxysulfates as the pH begins to decrease. However, when the neutralization capacity is consumed and the pH drops, the secondary $SO_4$ minerals will be re-dissolved, remobilizing $SO_4$. Ultimately, $SO_4$ concentrations will be controlled by equilibrium with gypsum solubility limits. The modeling results indicate attenuation trends for metals such as As and Cu, which are attenuated through precipitation of mineral phases and sorption to ferrihydrite. As the pH drops, these mineral phases re-dissolve, and ferrihydrite releases the previously sorbed minerals and dissolves as well. Under this scenario, these solutions will be neutralized and the particular metals attenuated by the Gila Conglomerate for an even greater number of pore volumes, because the precipitation/dissolution and sorption/desorption processes continue to attenuate these metals until the pH begins to drop. The pH values are not expected to drop until after the calcite has been depleted, which as noted above, may occur after 13 to 310 pore volumes. The large number of pore volumes required to exhaust the attenuation capacity of the Gila Conglomerate indicates that its ability to buffer acidic solutions would persist for a considerable period of time.

Further insight into the rate of advancement of tailings porewater constituents through the underlying Gila Conglomerate is provided here by combining the geochemical modeling results summarized above with the groundwater flow modeling results. The number of pore volumes required to deplete the neutralizing capacity of the Gila Conglomerate calculated from the geochemical modeling was combined with the volumetric flux through the Gila Conglomerate immediately downgradient of the tailings ponds calculated from the numerical groundwater flow model. From the groundwater flow model, a total of 1.2 gpm of groundwater flows downgradient from Ponds 5 and 6 through a cross-sectional area of the Gila Conglomerate above the Mudstone Unit of 170,400 $ft^2$. This equates to an average $6.86 \times 10^{-6}$ gpm per square foot of cross sectional area of the Gila Conglomerate, or $1.32 \times 10^{-3}$ cubic feet of water per day per square foot ($ft^3$/day/$ft^2$). At this rate, one pore volume within one cubic foot of Gila Conglomerate (porosity is assumed at 0.39) would be replaced in an average of 266 days. Assuming that it takes between 13 and 310 pore volumes of an assumed acidic tailings porewater to deplete the calcite within the Gila Conglomerate, the acidic front would travel through one cubic foot of Gila Conglomerate on average between 9.5 and 226 years. This would equate to a calculated plume travel distance of between 0.2 and 105 feet in a period of 1,000 years. This calculation clearly indicates that for practical purposes, the buffering and attenuation capacity of the Gila Conglomerate, together with its low K, act to arrest contaminant transport within a short distance of the tailings ponds.

## 5.0 CONCLUSIONS

The primary objective of the groundwater model was to evaluate the adequacy of existing monitoring well locations relative to APP facilities, the transit times to wells and the required duration of post-closure monitoring. Infiltration rates from mine facilities, the travel paths of potential seepage from the tailings ponds, and the site water balance were also evaluated to provide an overall perspective of the site groundwater flow system.

Major conclusions of this report include:

- The low K of the Site geologic units limits the quantity of groundwater flowing across the Site and the groundwater velocity. From the calibrated numerical model, approximately 4-gpm of groundwater flows across the Site in the Gila Conglomerate and/or alluvium above the Mudstone Unit. The average groundwater flow velocity above the Mudstone Unit is estimated at 1.8 x 10-4 ft/d, or 6.6 feet per 100 years.

- The modeling results indicate that any potential discharge from APP facilities will be confined to the shallow Unconfined Gila Unit and/or alluvium that overlies the Mudstone Unit. None of the potential discharge from these facilities appears to flow through or beneath the Mudstone Unit.

- APP facility monitoring wells are generally located appropriately and are screened at reasonable depths. Exceptions include Well MCC-6C, which is intended to monitor Tailings Ponds 6 and 7. This well is screened deeper than it should be ideally, and is located farther away from the facility than it should be. Also, Well MCC-3C is intended to monitor Tailings Pond 5 and Settling Ponds 1 and 2, and Well MCC-4 is intended to monitor Tailings Ponds 5, 6, and 7. Both of these wells are screened in the Confined Gila Unit located beneath the Mudstone Unit, and as stated above, none of the potential discharge from the APP facilities flows through or beneath the Mudstone Unit.

- The groundwater at the Site generally meets AWQS. The few exceedances that have occurred do not appear to be attributable to mining activities, and as such no obvious COCs have been identified. An analysis was undertaken to estimate the potential rate and extent of plume migration away from the tailings ponds. The analysis incorporated the potential source water chemistry (tailings porewater), the buffering capacity of the geologic media, and the estimated groundwater volumetric flux derived from the numerical groundwater flow model. The tailings porewater was assumed to be acidic, based on column and humidity cell testing results, which indicate that the tailings porewater could potentially become acidic in the future. The analysis indicated that even if the tailings porewater does become acidic in the future, the volumetric fluxes within the Gila Conglomerate and its high buffering capacity will effectively arrest expansion of the acidic water within a few to several feet from the APP facilities. Specifically, the analysis indicates that the postulated acidic water could travel between 0.2 and 105 feet after 1,000 years. The results further suggest that post closure monitoring may not be required, because the theoretical duration of post-closure monitoring would extend to in perpetuity, given the exceedingly slow rate of plume movement.

Additional conclusions based on the modeling effort include the following:

**Model Calibration**

- The numerical model was successfully calibrated using K values, and recharge and ET rates that are consistent with the available hydrogeologic, topographic, and climatic data. The average recharge across the site is relatively low at 0.09 in/yr; however, this low rate is reasonable given the low K of the geologic units. Actual ET rates and extinction depths are not well known, and could be lower than assumed in the model; however, significant ET was required to obtain a reasonable match to the observed groundwater levels.

- The calibrated model matches the observed groundwater levels in the shallower Gila Conglomerate and alluvium above the Mudstone Unit reasonably well. The model is less successful at matching the observed groundwater levels from wells installed below the mudstone. Given that any discharge from the APP facilities will be confined to the shallow groundwater system, the model was deemed appropriately calibrated for its intended purpose.

- A higher recharge rate compared to the average rate for the Site was required for Settling Ponds 1 and 2, and Tailings Ponds 1 and 2, to match the hydraulic heads observed in this area. This is consistent with continued draindown from their use as stormwater ponds, until a few years ago.

**Model Sensitivity**

- The sensitivity analysis indicates that the selected values of recharge and K are reasonable. The model results are sensitive to these two parameters when ET is not included in the model. When ET is included, the modeling results become less sensitive to assumed recharge and K values. This situation is believed to be associated with the relatively shallow depths to water across the Site, and the low volumetric groundwater flux that occurs in response to the low K of the system. In this case, ET effectively removes water to the assumed extinction depth, regardless of the K or recharge rates.

- Sensitivity analysis results indicate that the boundary conditions have been chosen such that they do not negatively affect the modeling results. The sensitivity results further indicate that there are sufficient sources of recharge within the model area to account for the observed hydraulic heads. Inflows across the Concentrator Fault are unlikely, given that the depth to water in the workings east of the fault is approximately 1,000 feet below groundwater elevations west of the fault.

- Additional confidence in the analysis of the well locations relative to the APP facilities is provided by a demonstration of the insensitivity of flow paths upgradient of the wells, and relative to assumed model parameters. Simulations were conducted where the assigned hydraulic conductivities and recharge rates were ten times higher than that of the calibrated case, and where no ET was assumed. The resulting groundwater flow paths were similar to those of the calibrated model, even though the resulting hydraulic heads were significantly higher than the observed heads.

**Contaminant Fate and Transport**

- The current chemistry of tailings porewater is near-neutral pH and generally contains low constituent concentrations; however, column and humidity cell testing of tailings suggests the possibility that the tailings porewater could become acid generating at some time in the future.

- The buffering capacity of the Gila Conglomerate of 80 kg $CaCO_3$/ton was used in the geochemical modeling analysis undertaken in 2005 (Golder, 2005). This analysis indicated that it would take between 13 and 310 pore volumes of assumed acidic water to deplete the Gila Conglomerate's buffering capacity. This translates to depleting the buffering capacity in a cubic foot of Gila Conglomerate between 9.5 and 226 years at the average volumetric groundwater flow rate immediately downgradient of Tailings Ponds 5 and 6. As noted in the fourth paragraph of the major conclusions of this report subsection, this further translates to a travel distance of between 0.2 and 105 feet in 1,000 years. Additional sampling results available subsequent to the geochemical modeling effort indicate that the buffering capacity of the Gila Conglomerate may be even higher. The average buffering capacity of five Gila Conglomerate recently collected samples is 150 kg $CaCO_3$/ton (Golder, 2007b), or nearly double that assumed for the geochemical modeling, lending additional confidence that any acidic plume stemming from the APP facilities will affectively be arrested a short distance from the facility.

## 6.0 REFERENCES

Anderson and Woessner, 1992. *Applied Groundwater Modeling, Simulation of Flow and Advective Transport.* Academic Press, Inc., San Diego, California.

Arizona Department of Environmental Quality (ADEQ), 2007a. *State of Arizona, Area-Wide Aquifer Protection Permit No. P-101703, Place ID # 7820, LTF# 36954*. Signed February 22, 2007

ADEQ, 2007b. *Memorandum from Eric Wilson and Kevin Herbert, PBS&J, through Jon D. Risinger, Project Manager, PBS&J, to Jeff Emde, Senior Hydrologist/Advisor, ADEQ, Subject: Resolution Copper Mining LLC Compliance Conformance Services, Master Contract EV06-0060, Task Assignment No. EV06-0157, Amendment No. 5 Inventory No. 101703, Site Code (USAS) No. 502878-03, LTF No. 44027 Task 12-FY 2008 Significant Amendment, Compliance Item No. 2, Groundwater Assessment and Model Workplan.* December, 22, 2007

Arizona Geological Survey (AGS), 1998. DI-13 – Geologic Map of Portions of the Globe 30' X 60' Quadrangle, Arizona

Brown and Caldwell, 1999. *Site Characterization Report*. Prepared for BHP Copper, Superior Operations. June, 1999.

Environmental Simulations, Inc. (ESI), 2007, *Groundwater Vistas* version 5

HydroGeoLogic, Inc., 2006. *MODFLOW-SURFACT* version 3.0.

Golden Software, 2003. *Surfer*, version 8, October, 2003.

Golder, 2005. *Volume 3 – Technical Information, Aquifer Protection Permit Application, West Plant Site, Superior Mine, Superior, Arizona.* Submitted to: Resolution Copper Mining Company. June 25, 2005.

Golder, 2007. *Groundwater Assessment and Model Workplan, West Plant Site, Superior, Arizona*. Submitted to Resolution Copper Mining LLC. November, 21, 2007.

Golder, 2007b. Well Installation Report For New Point of Compliance and Alert Wells, West Plant Site, Superior, Arizona. Submitted to Resolution Copper Mining LLC. November, 21, 2007.

McDonald, M.G. and A.W. Harbaugh, 1988. *A Modular Three-dimensional Finite-difference Groundwater Flow Model*. U.S. Geological Survey Open-File Report 83-875.

Parkhurst, D.L., and Appelo, C.A.J., 1999. User's guide to PHREEQC (version 2), a computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 312 pp.

PBS&J Corporation, 2008. Completeness Letter, to ADEQ, February 29, 2008

Oppenheimer, J.M. and Sumner, J.S. 1980. *Depth-to-Bedrock Map, Basin and Range Province, Arizona.* University of Arizona, Department of Geosciences, Laboragory of Geophysics, 1 sheet, scale 1:1,000,000.

Poeter, E.P., Hill, M.C., Banta, E.R., Mehl, Steffen, and Christensen, Steen, 2005. UCODE_2005 and Six Other Computer Codes for Universal Sensitivity Analysis, Calibration, and Uncertainty Evaluation: U.S. Geological Survey Techniques and Methods 6-A11, 283 pp.

Pollock, D.W., 1989. *Documentation of computer programs to complete and display pathlines using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water model,* USGS, Open File Report 89-381, 81pp.

Resolution Copper Mining LLC (RCML), 2008. Response to Comments

**TABLES**

**TABLE 1**
**HYDRAULIC TESTING SUMMARY**

| Monitoring Well Identification | Screened Geologic Unit | Analysis Type | Estimated Hydraulic Conductivity (cm/sec) | Estimated Hydraulic Conductivity (ft/day) | Geometric Mean of Estimated Hydraulic Conductivity (cm/sec) | Geometric Mean of Estimated Hydraulic Conductivity (ft/day) |
|---|---|---|---|---|---|---|
| **Mudstone Unit** | | | | | | |
| **MCC-3B** | Gila Mudstone | Theis* | 1.3E-09 | 3.69E-06 | 1.30E-09 | 3.69E-06 |
| **Unconfined Gila Unit** | | | | | | |
| **MCC-1** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 1.10E-06 | 3.12E-03 | 3.42E-07 | 9.69E-04 |
| | | Bower and Rice Falling Head Slug Test | 1.40E-07 | 3.97E-04 | | |
| | | Bower and Rice Falling Head Slug Test | 3.50E-07 | 9.92E-04 | | |
| **MCC-6A** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 1.10E-07 | 3.12E-04 | | |
| | | Bower and Rice Falling Head Slug Test | 2.50E-07 | 7.09E-04 | | |
| **MCC-6B** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 2.80E-07 | 7.94E-04 | | |
| | | Bower and Rice Falling Head Slug Test | 3.50E-08 | 9.92E-05 | | |
| **MCC-6C** | Gila Conglomerate | Bower and Rice Falling Head Slug Test | 7.10E-07 | 2.01E-03 | | |
| **Settling Ponds 1 & 2 Alert Well** | Gila Conglomerate | Cooper-Jacob Drawdown | 1.76E-06 | 4.99E-03 | | |
| | | Theis Recovery | 7.06E-07 | 2.00E-03 | | |
| **Tailings Pond 5 POC** | Gila Conglomerate | Cooper-Jacob Drawdown | 7.06E-07 | 2.00E-03 | | |
| | | Theis Recovery | 2.82E-07 | 7.99E-04 | | |
| **Confined Gila Unit** | | | | | | |
| **MCC-3C** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 1.10E-06 | 3.12E-03 | 3.73E-07 | 1.06E-03 |
| | | Bower and Rice Falling Head Slug Test | 3.50E-07 | 9.92E-04 | | |
| **MCC-4** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 2.80E-07 | 7.94E-04 | | |
| | | Bower and Rice Falling Head Slug Test | 1.80E-07 | 5.10E-04 | | |
| **Shallow Unconfined Gila Unit** | | | | | | |
| **GAI-02-01** | Gila Conglomerate | Cooper-Jacob Drawdown | 1.76E-06 | 4.99E-03 | 2.01E-06 | 5.69E-03 |
| | | Theis Recovery | 1.06E-06 | 3.00E-03 | | |
| **GAI-02-02** | Gila Conglomerate | Cooper-Jacob Drawdown | 2.47E-05 | 7.00E-02 | | |
| | | Theis Recovery | 2.12E-05 | 6.01E-02 | | |
| **MCC-2** | Gila Conglomerate | Bower and Rice Rising Head Slug Test | 3.50E-08 | 9.92E-05 | | |
| | | Bower and Rice Falling Head Slug Test | 3.50E-07 | 9.92E-04 | | |
| **MCC-9** | Gila Conglomerate | Theis Recovery | 1.10E-05 | 3.12E-02 | | |
| **Alluvial Unit** | | | | | | |
| **Smelter Pond POC** | Alluvium | Cooper-Jacob Drawdown | 3.33E-05 | 9.44E-02 | 3.40E-05 | 9.64E-02 |
| | | Theis Recovery | 3.47E-05 | 9.84E-02 | | |

Notes:
* = Approximation based on long term recovery data
cm/sec = centimeter per second
ft/day = feet per day

# TABLE 2
## SUMMARY OF TARGET WATER LEVEL MEASUREMENTS

| Name | Arizona State Plane, Central Zone, NAD 83 | | Water Level (ft amsl) | Sample Date |
|---|---|---|---|---|
| | Easting | Northing | | |
| **Resolution On-Site Wells** | | | | |
| Settling Ponds 1 & 2 POC | 948295.6 | 837766.8 | 2898.8 | Sep-07 |
| Tailings Pond 5 POC | 947439.1 | 837337.5 | 2896.5 | Sep-07 |
| GAI-02-01 | 945370.1 | 837325.0 | 2832.2 | Sep-07 |
| MCC-1 | 944976.4 | 838613.7 | 2804.1 | Sep-07 |
| MCC-6B | 944142.1 | 837242.3 | 2788.7 | Sep-07 |
| MCC-2 | 946075.4 | 835794.5 | 2787.0 | Sep-07 |
| MCC-6A | 944162.0 | 837257.1 | 2783.8 | Sep-07 |
| MCC-3A | 947907.5 | 835644.9 | 2769.7 | Sep-07 |
| MCC-6C | 944158.1 | 837240.0 | 2762.5 | Sep-07 |
| MCC-9 | 947318.2 | 834907.6 | 2753.1 | Sep-07 |
| Smelter Pond POC | 947378.4 | 834588.6 | 2735.1 | Sep-07 |
| MCC-3C | 947898.4 | 835636.7 | 2700.8 | Sep-07 |
| Indian Ponds POC | 945032.8 | 832934.3 | 2628.5 | Sep-07 |
| MCC-4 | 944405.8 | 832965.1 | 2593.9 | Sep-07 |
| **Superior Domestic Irrigation Wells** | | | | |
| ADWR# 634259 | 947993.5 | 833531.9 | 2724.0 | Jan-37 |
| ADWR# 639388 | 948232.3 | 834261.5 | 2725.0 | Jan-08 |
| ADWR# 590392 | 947996.9 | 833095.3 | 2722.8 | Jan-08 |
| ADWR# 635958 | 950284.0 | 833731.7 | 2786.9 | Jan-08 |
| ADWR# 638029 | 946514.1 | 831191.6 | 2652.0 | May-67 |
| ADWR# 558551 | 942618.7 | 829014.9 | 2585.0 | Aug-96 |
| ADWR# 635628 | 934288.9 | 830592.2 | 2449.0 | Oct-40 |
| ADWR# 635629 | 934171.4 | 830589.2 | 2451.0 | Apr-73 |

# TABLE 3
## CALIBRATED MODEL PARAMETERS AND WATER BUDGET

| **Hydraulic Conductivity Values:** | **Initial Estimate** | | **Calibrated Model Value** | |
|---|---|---|---|---|
| | **ft/d[1]** | **cm/s[1]** | **ft/d** | **cm/s** |
| Alluvial Unit | 0.096 | $3.4 \times 10^{-5}$ | 0.096 | $3.4 \times 10^{-5}$ |
| Shallow Unconfined Gila Unit | 0.0057 | $2.0 \times 10^{-6}$ | 0.066 | $2.33 \times 10^{-5}$ |
| Unconfined Gila Unit | 0.00096 | $3.4 \times 10^{-7}$ | 0.00105 | $3.7 \times 10^{-5}$ |
| Confined Gila Unit | 0.00105 | $3.7 \times 10^{-7}$ | 0.00105 | $3.7 \times 10^{-5}$ |
| Mudstone Unit | $3.69 \times 10^{-6}$ | $1.3 \times 10^{-9}$ | $3.69 \times 10^{-6}$ | $1.3 \times 10^{-9}$ |
| | | | | |
| **Water Budget:** | **rate** | | **rate** | **volume** |
| Inflows: | | | | |
| Infiltration from precipitation and surface water run-on | 0.38 in/yr[2] | | 0.09 in/yr | 32 gpm |
| Inflows from Ponds | N/A | | | 38.3 gpm |
| *Pond 6 (GHB)* | | | | *31.4 gpm* |
| *Settling Ponds 1 and 2/Tailings Pond 1 and 2* | | | 4.8 in/yr | *6.1 gpm* |
| *Indian Ponds* | | | 1 in/yr | *0.4 gpm* |
| *Smelter Pond* | | | 1 in/yr | *0.45 gpm* |
| Total Inflows | | | | 70.3 gpm |
| | | | | |
| Outflows: | | | | |
| Evapotranspiration | 58 in/yr[1,3] | | 58 in/yr | 40.0 gpm |
| Seepage to drainages[4] | N/A | | | 30.2 gpm |
| Downgradient Flow | N/A | | | 0.008 gpm |
| Total Outflows | | | | 70.2 gpm |
| | | | | |
| Mass Balance Error | | | | 0.05% |

Notes:
ft/d = feet per day
cm/s = centimeter per second
in/yr = inches per year
gpm = gallons per minute
GHB = general head boundary
[1]Source: Groundwater Assessment and Model Workplan, West Plant Site, Superior, Arizona.
Golder Associates, Inc., November 21, 2007
[2]Source: Site Characterization Report, Brown and Caldwell, June 1999.
[3]Source: Report on North Mine Area Groundwater Flow Model: Chino Mine, New Mexico.
Golder Associates, Inc., January 13, 2005.
[4]MODFLOW-SURFACT's RSF4 package

# CALIBRATED MODEL RESIDUAL

| Well (Target) Name | Model Layer | Observed Water Level (ft) | Model Simulated Water Level (ft) | Residual (ft) |
|---|---|---|---|---|
| 590392 | 2 | 2722.79 | 2703.78 | 19.01 |
| MCC-3A | 3 | 2769.68 | 2781.25 | -11.57 |
| MCC-9 | 3 | 2753.06 | 2743.28 | 9.78 |
| Smelter Pond POC | 3 | 2735.07 | 2726.52 | 8.55 |
| 634259 | 3 | 2724 | 2701.73 | 22.27 |
| 639388 | 3 | 2724.95 | 2709.41 | 15.54 |
| 635628 | 3 | 2449 | 2444.32 | 4.68 |
| 635629 | 3 | 2451 | 2439.70 | 11.30 |
| Settling Ponds 1&2 | 4 | 2898.8 | 2882.78 | 16.02 |
| Tailings Pond 5 POC | 4 | 2896.45 | 2870.58 | 25.87 |
| GAI-02-01 | 4 | 2832.15 | 2852.88 | -20.73 |
| MCC-2 | 4 | 2787.03 | 2805.69 | -18.66 |
| MCC-6A | 4 | 2783.75 | 2816.77 | -33.02 |
| MCC-6C | 4 | 2762.47 | 2816.23 | -53.76 |
| 635958 | 4 | 2786.92 | 2802.53 | -15.61 |
| MCC-1 | 6 | 2804.1 | 2825.48 | -21.38 |
| MCC-6B | 6 | 2788.69 | 2787.75 | 0.94 |
| MCC-3C | 6 | 2700.75 | 2782.39 | -81.64 |
| MCC-4 | 6 | 2593.94 | 2718.97 | -125.03 |
| 638029 | 6 | 2652 | 2726.34 | -74.34 |
| 558551 | 6 | 2585 | 2672.17 | -87.17 |
| | | | | |
| | | | **All Layers** | **Model Layers 2 through 4** |
| Residual Mean (ft) | | | -19.47 | -1.36 |
| Residual Standard Deviation | | | 42.07 | 23.07 |
| Residual Sum of Squares ($ft^2$) | | | 43,361 | 7,479 |
| Absolute Residual Mean (ft) | | | 32.23 | |
| Root Mean Squared Error (ft) | | | 45.44 | 22.33 |
| Minimum Residual (ft) | | | -125.03 | |
| Maximum Residual (ft) | | | 25.87 | |
| Range in Target Values (ft) | | | 449.80 | 449.8 |
| RMS/Range | | | 0.101 | 0.050 |

# TABLE 5
## APP FACILITIES AND ASSOCIATED MONITORING WELLS

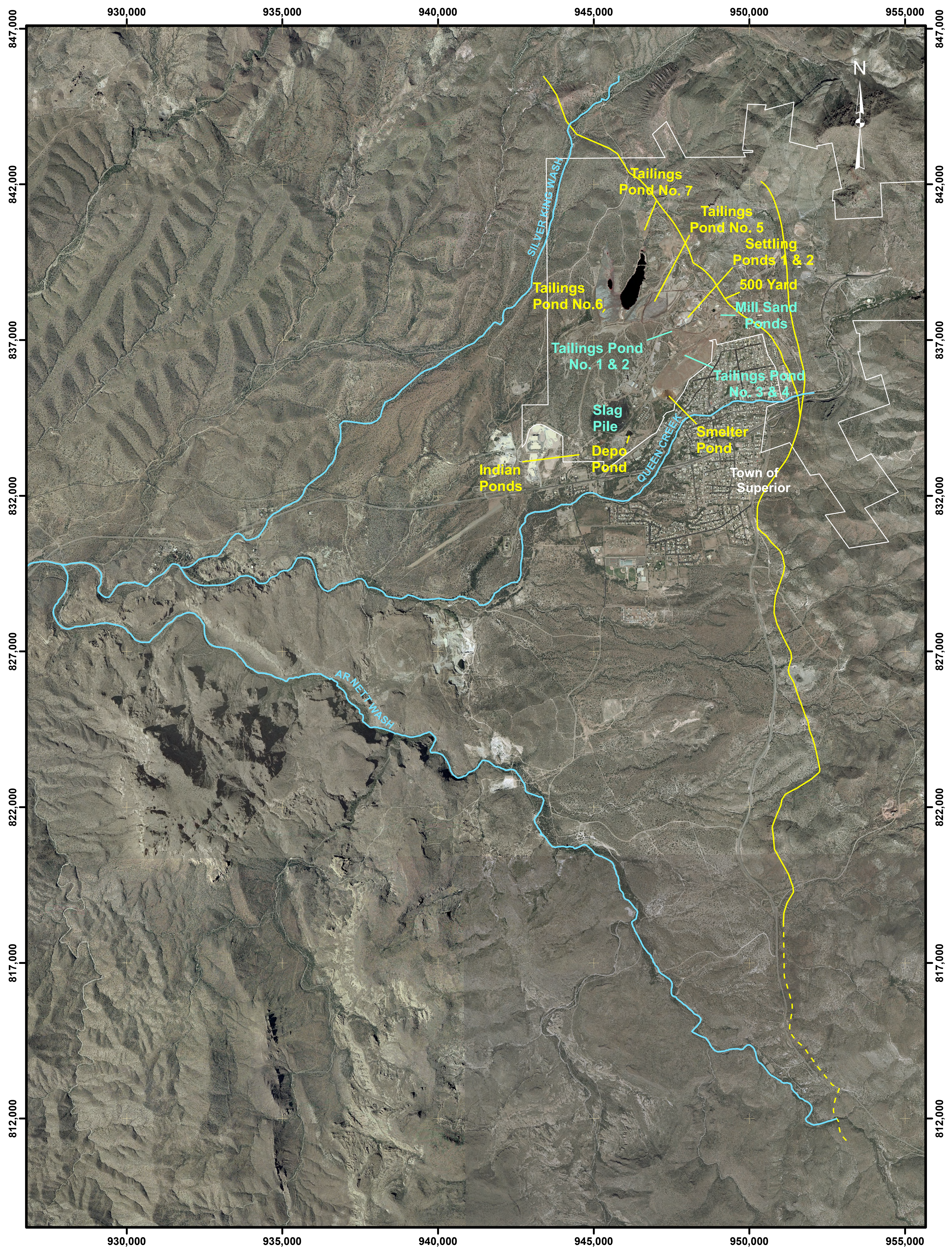
| APP Facility | Well Name | Potential Flow Path | Well Depth (ft) | Sandpack Interval (ft) | Screen Length (ft) |
|---|---|---|---|---|---|
| Smelter Pond | MCC-9 | Shallow Unconfined Gila Conglomerate | 60 | 20 to 60 | 20 |
| Smelter Pond | Smelter Pond | Alluvium | 17.5 | 7 to 17 | 10 |
| Tailings Ponds 6 and 7 | GAI-02-01 | Shallow Unconfined Gila Conglomerate | 440 | 152 to 206 | 50 |
| Tailings Ponds 6 and 7 | MCC-6C | Unconfined Gila Conglomerate | 122 | 75 to 116 | 40 |
| Tailings Pond 5 | Tailings Pond 5 | Shallow Unconfined Gila Conglomerate | 125 | 80 to 120 | 40 |
| Settling Ponds 1 and 2 | Settling Ponds 1 and 2 | Shallow Unconfined Gila Conglomerate | 185 | 140 to 180 | 40 |
| Tailings Pond 5, Settling Ponds 1 and 2 | MCC-3C | Confined Gila Conglomerate | 582 | 499 to 579 | 80 |
| Tailings Ponds 5, 6, and 7 | MCC-4 | Confined Gila Conglomerate | 255 | 200 to 250 | 50 |
| Indian Pond | Indian Pond | Alluvium | 52 | 7 to 47 | 40 |

# TABLE 6
## SOLUTION CHEMISTRIES USED IN GEOCHEMICAL ANALYSIS

| Sample ID | Unit | MCC-6C | Tailings Pond 5 Porewater | Tailings Pond 5 Column Test Effluent | Tailings Pond 5 Humidity Cell Effluent | Tailings Pond 6 Porewater | Tailings Pond 6 Column Test Effluent | Tailings Pond 6 Humidity Cell Effluent |
|---|---|---|---|---|---|---|---|---|
| pH | s.u. | 8.28 | 7.86 | 2.6 | 4.14 | 7.63 | 7.44 | 2.95 |
| Alkalinity | mg/L | 167 | 77 | 0.001 | 1 | 208 | 114 | 1 |
| Ca | mg/L | 25.7 | 548.3 | 600 | 87.0 | 593.2 | 546 | 39.0 |
| Mg | mg/L | 4.4 | 185.0 | 2730 | 207.0 | 367.0 | 979 | 64.0 |
| Na | mg/L | 131 | 200 | 5 | 1 | 200 | 83 | 1 |
| K | mg/L | 1.6 | 80.7 | 15 | 1.0 | 126.8 | 140 | 1.0 |
| $SO_4$ | mg/L | 160 | 2237 | 45700 | 1360 | 3016 | 6,100 | 982 |
| Cl | mg/L | 23 | 57.7 | 0.25 | 1.0 | 80.0 | 80.7 | 1.0 |
| F | mg/L | 0.730 | 7.300 | 0.1 | 2.300 | 3.828 | 2.8 | 1.400 |
| Sb | mg/L | 0.001 | 0.017 | 0.0025 | 0.001 | 0.012 | 0.0025 | 0.001 |
| As | mg/L | 0.014 | 0.003 | 0.4 | 0.002 | 0.021 | 0.05 | 0.001 |
| Ba | mg/L | 0.038 | 0.027 | 0.05 | 0.010 | 0.042 | 0.0005 | 0.010 |
| Cu | mg/L | 0.003 | 0.076 | 1670 | 15.700 | 0.026 | 0.8 | 32.100 |
| Fe | mg/L | 0.033 | 0.015 | 18800 | 0.960 | 0.964 | 0.015 | 42.800 |
| Pb | mg/L | 0.001 | 0.001 | 0.015 | 0.002 | 0.001 | 0.0015 | 0.001 |
| Mn | mg/L | 0.010 | 4.807 | 1090 | 142.000 | 7.516 | 115 | 34.800 |
| Hg | mg/L | 0.0001 | 0.0005 | 0.0002 | 0.0010 | 0.0010 | 0.0001 | 0.0010 |
| Ni | mg/L | 0.008 | 0.020 | 3 | 0.282 | 0.017 | 0.2 | 0.164 |
| Se | mg/L | 0.001 | 0.006 | 0.01 | 0.022 | 0.006 | 0.01 | 0.002 |
| U | mg/L | 0.000 | 0.032 | -- | -- | 0.045 | 0 | -- |
| Zn | mg/L | 0.039 | 0.038 | 386 | 22.000 | 0.050 | 1.61 | 3.810 |
| Al | mg/L | 0.035 | 0.050 | 1,040 | 9.100 | 0.044 | 0.015 | 77.900 |

Notes:
Red values indicate one-half detection limit used
MCC-6C: average chemistry Sept 1996 to April 2004
Tailings Pond 5 Porewater: average of three porewater samples
Tailings Ponds 5 and 6 Humidity cell effluent from Week 20
Tailings Pond 6 Porewater: average of three porewater samples and two monitoring well samples
s.u. = standard unit
mg/L = milligrams per liter

**FIGURES**




## LEGEND

Property Boundary

Washes

Fault (dashed where approximate)

Facilities in yellow are APP facilities
Facilities in light blue are non-APP facilities

## REFERENCE

1) Projection:NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery

3,000 0 3,000
SCALE 1:36,000 FEET

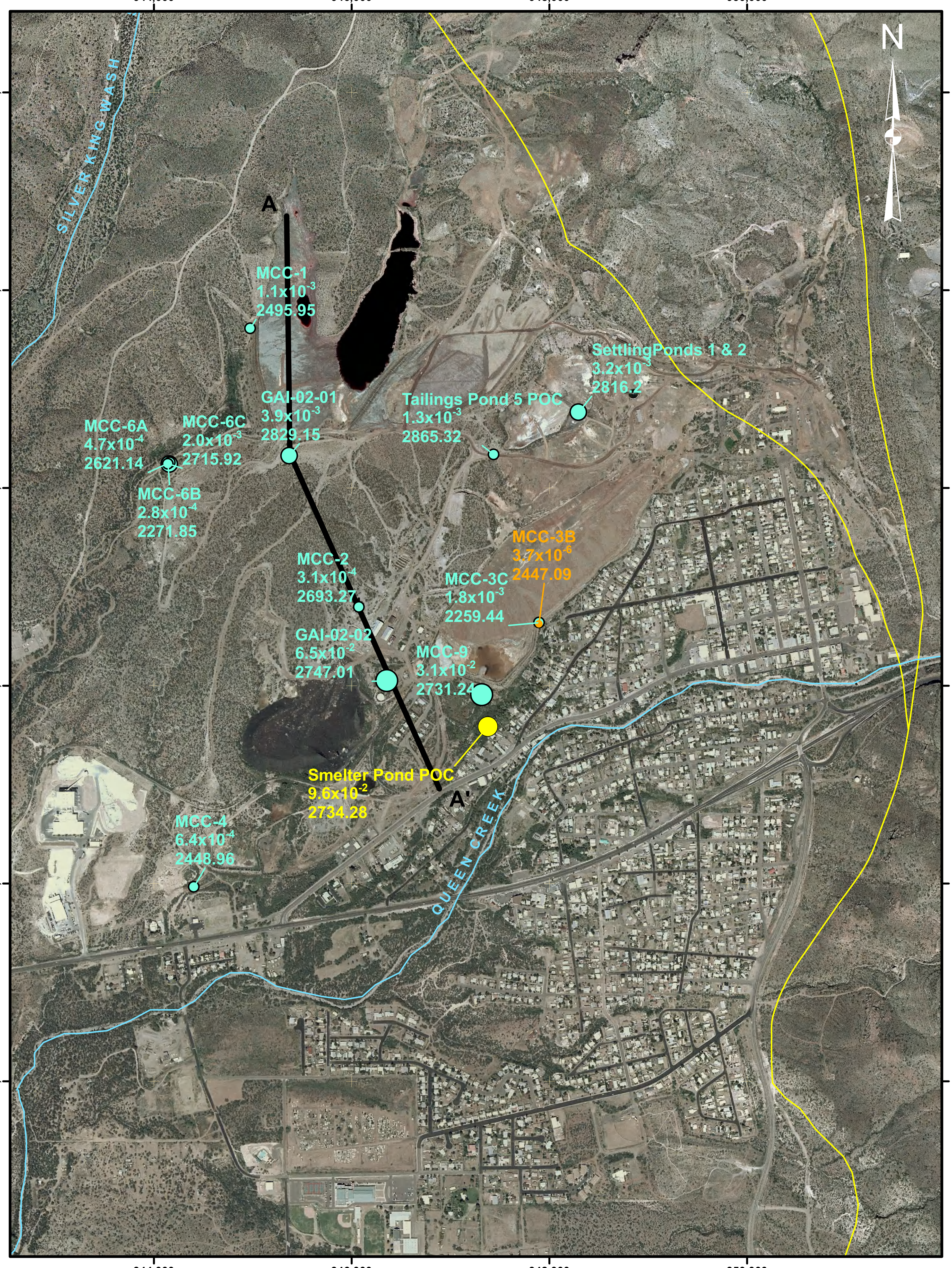
PROJECT
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE
# Study Area

Golder Associates
Tucson, Arizona

| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | -- | | FIGURE: 1 | |
| GIS | TA | 03/17/2008 | | |
| CHECK | MM | 03/17/2008 | | |
| REVIEW | BS | 03/17/2008 | | |

Project:L:\2007\07392565\x01_05\MXDs\07392565x01_05F07.mxd- Plot: L:\2007\07392565\x01_05\Export\Figures\20080317\07392565x01_05F07.pdf




## LEGEND

MCC-4 Well Name
$6.3 \times 10^{-4}$ Hydraulic Conductivity (K) Value (ft/d)
2448.96 Screen Midpoint Elevation (ft)

Gila K Values (ft/d)
- $2.8 \times 10^{-4}$ - $2.0 \times 10^{-3}$
- $2.1 \times 10^{-3}$ - $3.9 \times 10^{-3}$
- $4.0 \times 10^{-3}$ - $6.5 \times 10^{-2}$

Alluvium K Value (ft/d)
- $9.6 \times 10^{-2}$

Mudstone K Value (ft/d)
- $3.7 \times 10^{-6}$

A A' Cross Section (shown on Figure 3)

Washes

Fault

1,000 0 1,000
SCALE 1:12,000 FEET

## REFERENCE

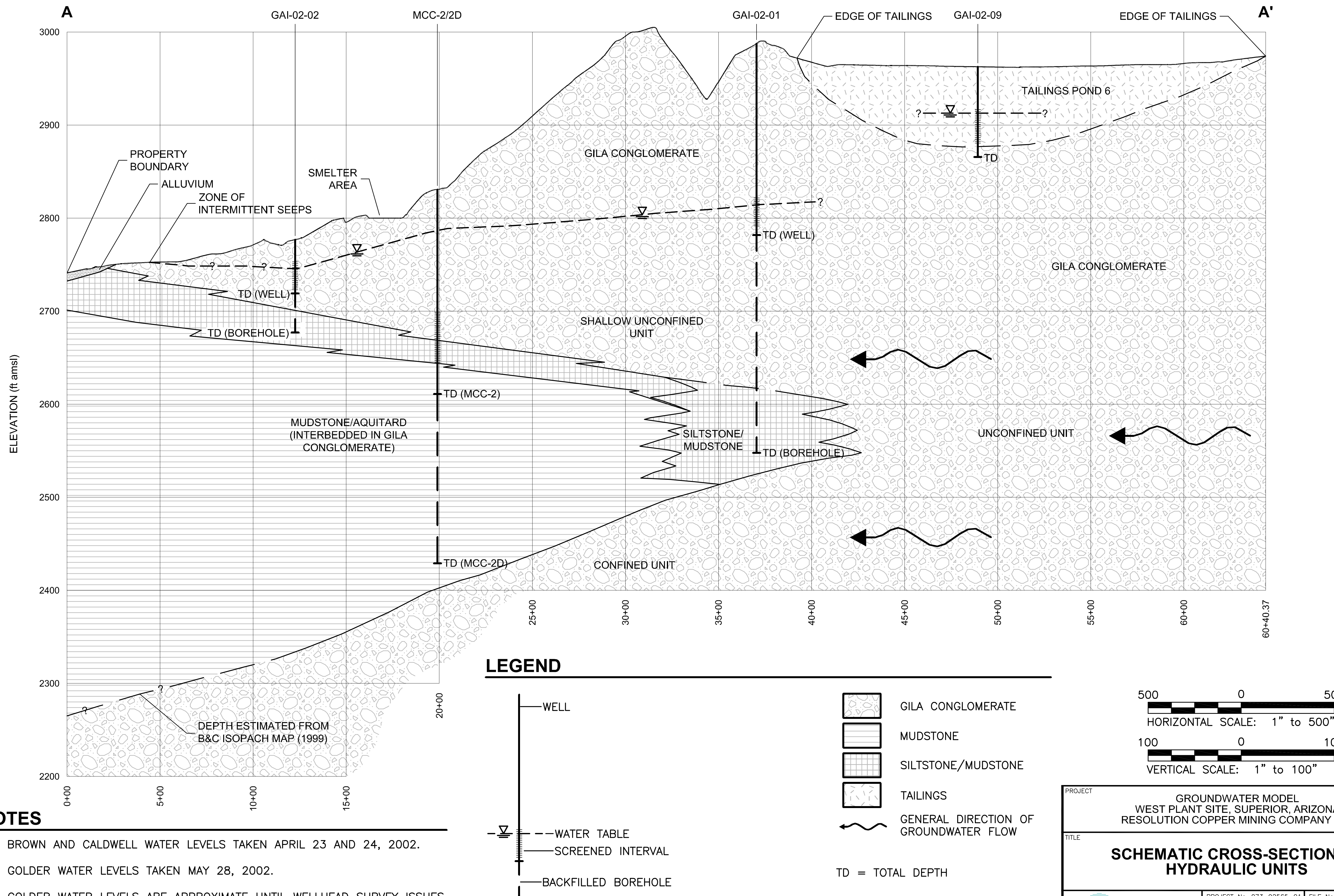
1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery

PROJECT
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE
# Results of Hydraulic Testing

Golder Associates
Tucson, Arizona

| PROJECT No. 073-9256-501 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| GIS | TA | 03/17/2008 | FIGURE: 2 | |
| CHECK | MM | 03/17/2008 | | |
| REVIEW | BS | 03/17/2008 | | |




## NOTES

1.) BROWN AND CALDWELL WATER LEVELS TAKEN APRIL 23 AND 24, 2002.

2.) GOLDER WATER LEVELS TAKEN MAY 28, 2002.

3.) GOLDER WATER LEVELS ARE APPROXIMATE UNTIL WELLHEAD SURVEY ISSUES ARE RESOLVED.

FT AMSL = FEET ABOVE MEAN SEA LEVEL

PROJECT

GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE

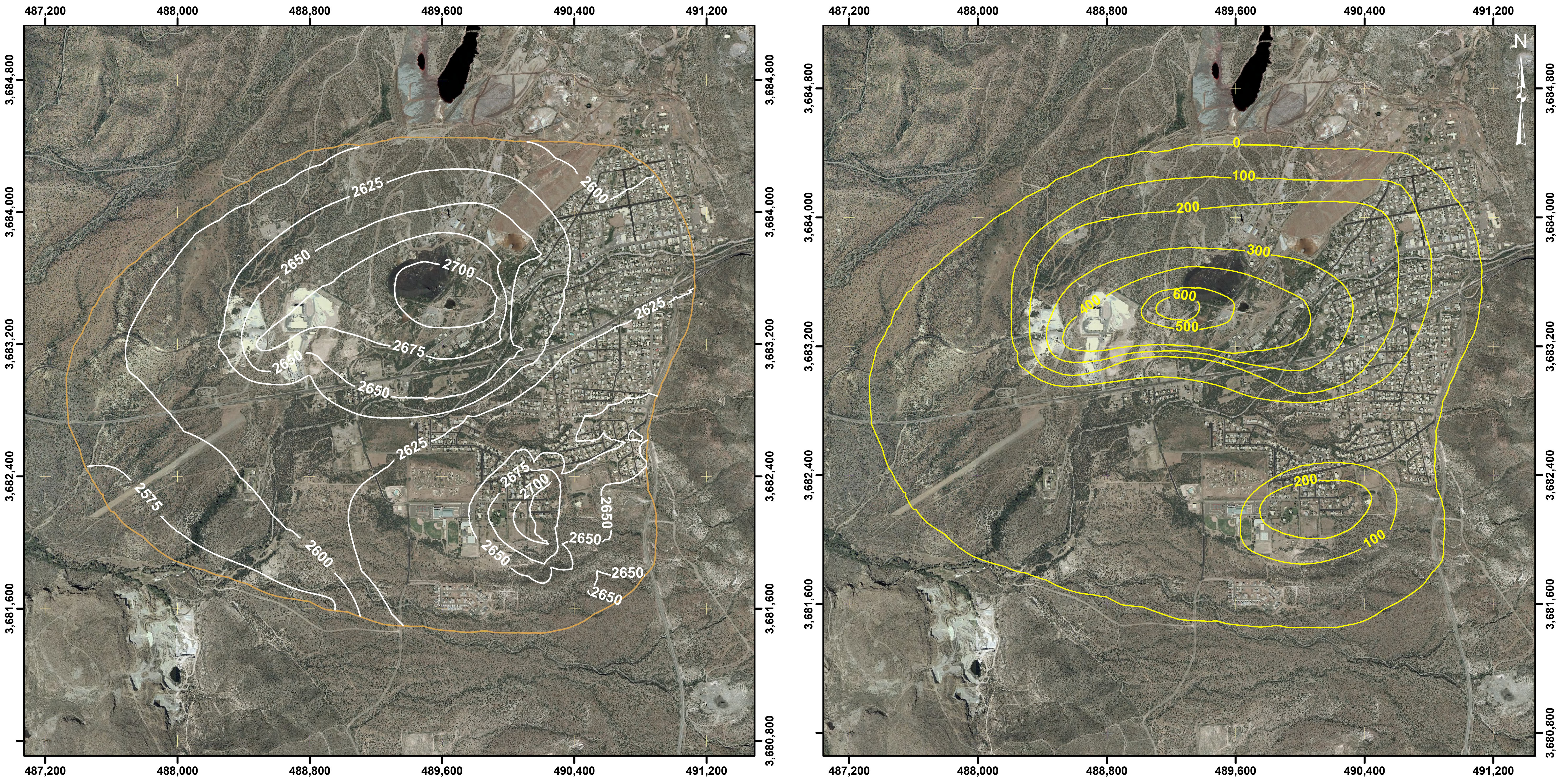
# SCHEMATIC CROSS-SECTION OF HYDRAULIC UNITS

Golder Associates
Tucson, Arizona

| | | | | |
|---|---|---|---|---|
| PROJECT No. 073-92565-01 | | | FILE No. | 0739256501A001 |
| DESIGN | MB | 03/12/08 | SCALE AS SHOWN | REV. A |
| CADD | NIL | 03/12/08 | | |
| CHECK | --- | ---- | FIGURE 3 | |
| REVIEW | MB | 03/12/08 | | |

Drawing file: 0739256501A001.dwg Mar 19, 2008 - 2:24pm

Project:L:\2007\07392565\x01_05\MXDs\07392565x01_05F05.mxd- Plot: L:\2007\07392565\x01_05\Export\Figures\20080317\07392565x01_05F05.pdf




**LEGEND**

Contour of Mudstone Top Surface (25 foot interval)

Contour of Mudstone Thickness (100 foot interval)

Approximate Mudstone Extent

**REFERENCE**

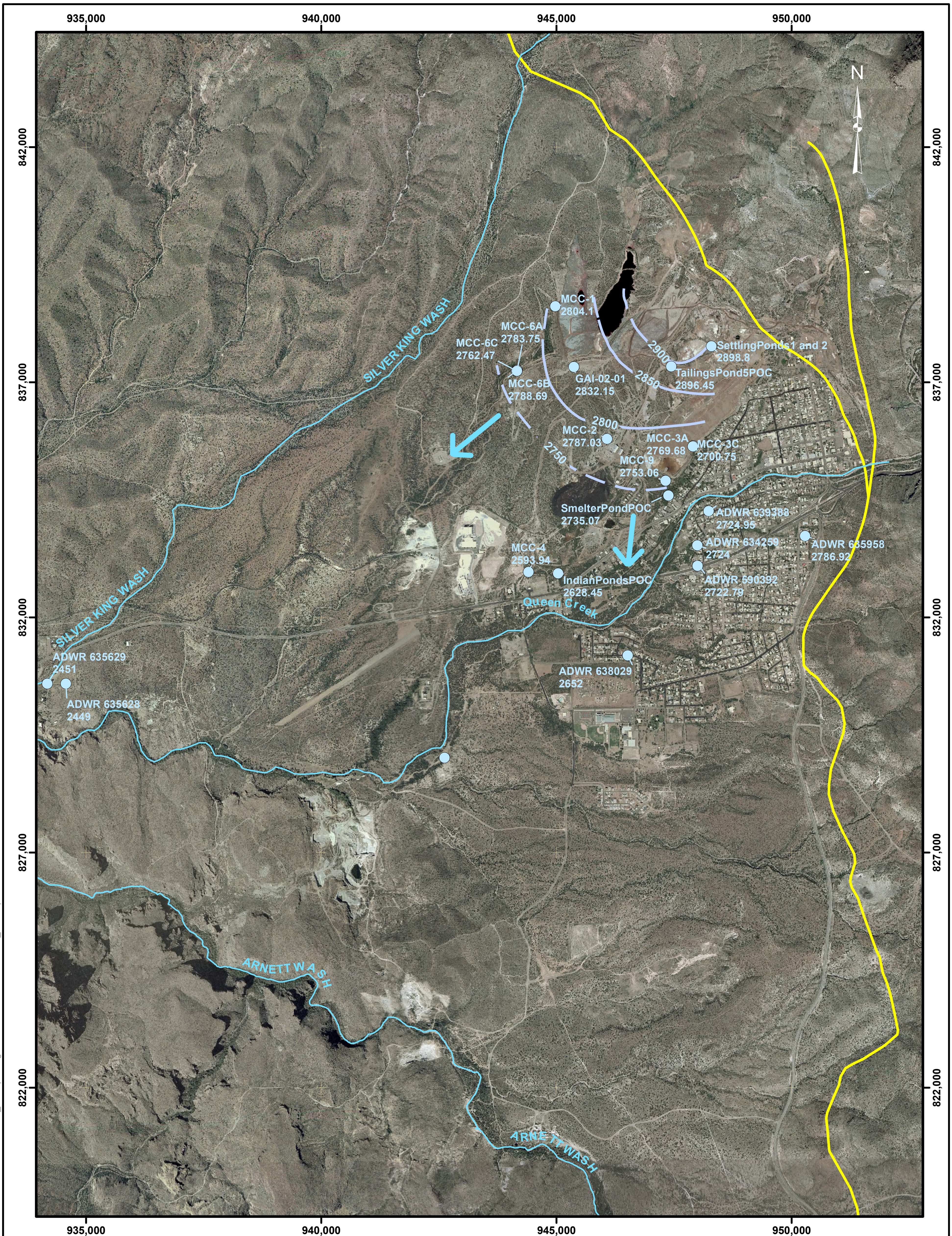
1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery
3) Mudstone contours extrapolated from Brown and Caldwell, 1999. Site Characterization Report, June 1999.

PROJECT
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE
# Definition of the Mudstone Unit

Golder Associates
Tucson, Arizona

| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| | | | | |
| GIS | TA | 03/17/08 | **FIGURE: 4** | |
| CHECK | MM | 03/17/08 | | |
| REVIEW | BS | 03/17/08 | | |




## LEGEND

- Regional Groundwater Flow Direction
- Well with Groundwater Elevation (ft) - Measurement dates provided in Table 2
- Fault
- Groundwater Elevation Contour (50 ft) (dashed where inferred)

2,000 0 2,000

SCALE 1:24,000 FEET

## REFERENCE

1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery

PROJECT

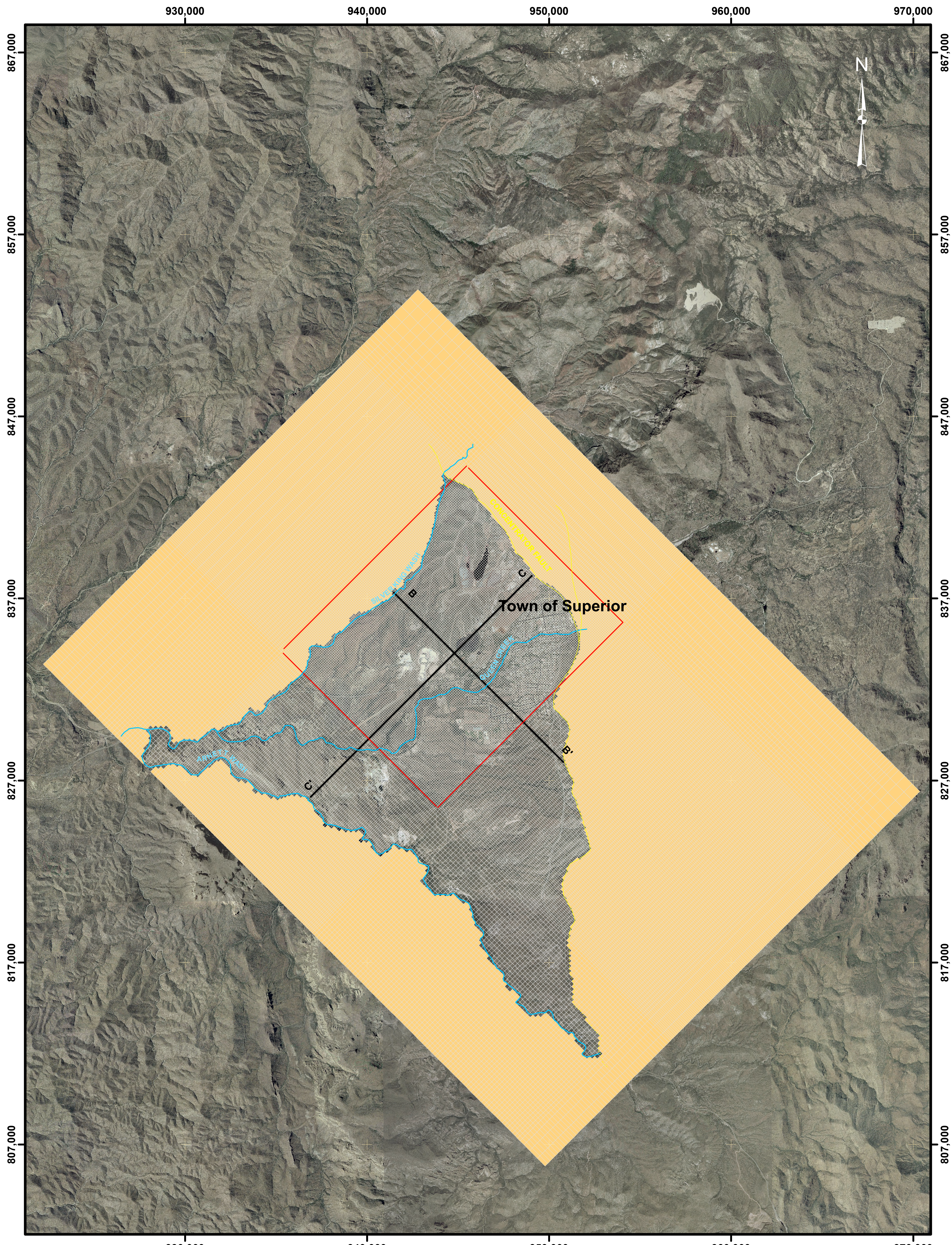
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE

# Contours of Shallow Groundwater Elevations

Golder Associates
Tucson, Arizona

| | | | | |
|---|---|---|---|---|
| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
| GIS | TA | 03/17/2008 | FIGURE: 5 | |
| CHECK | MM | 03/17/2008 | | |
| REVIEW | BS | 03/17/2008 | | |




## LEGEND

Fault (dashed where approximate)
(Concentrator Fault used as Boundary to Numerical Model)

Wash (Silver King Wash and Arnett Wash used as Boundaries to Numerical Model)

Area of 100 ft by 100 ft Grid

Numerical Model Grid

Inactive (no-flow) Model Cells

B B' Cross Sections (shown on Figure 7)

6,000 0 6,000

SCALE 1:62,000 FEET

### REFERENCE

1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery

PROJECT

GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

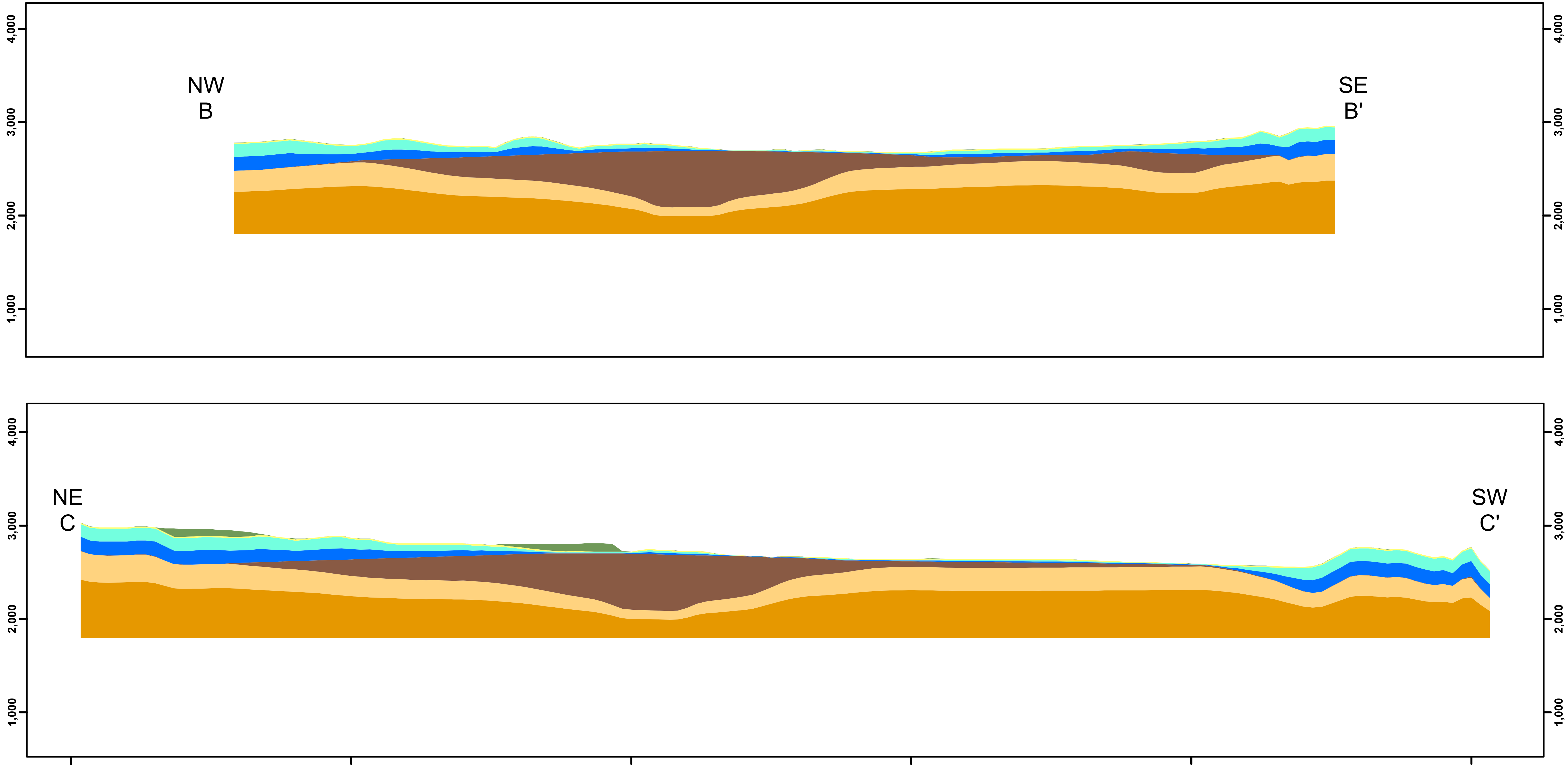
TITLE

# Numerical Model Grid

Golder Associates
Tucson, Arizona

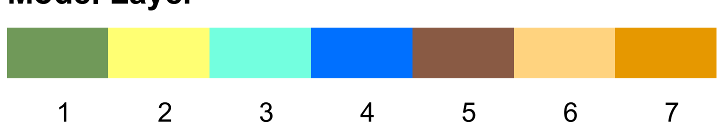
| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| GIS | TA | 03/12/2008 | FIGURE: 6 | |
| CHECK | MM | 03/17/2008 | | |
| REVIEW | BS | 03/17/2008 | | |

Project:L:\2007\07392565\x01_05\MXDs\07392565x01_05F03bs.mxd - Plot: L:\2007\07392565\x01_05\Export\Figures\20080317\Figure 7.pdf




**LEGEND**

**Model Layer**




**NOTE**

1) Schematic cross section (not to scale) plotted as elevation versus row or column number. Row and column values are multiplied by 100.

PROJECT

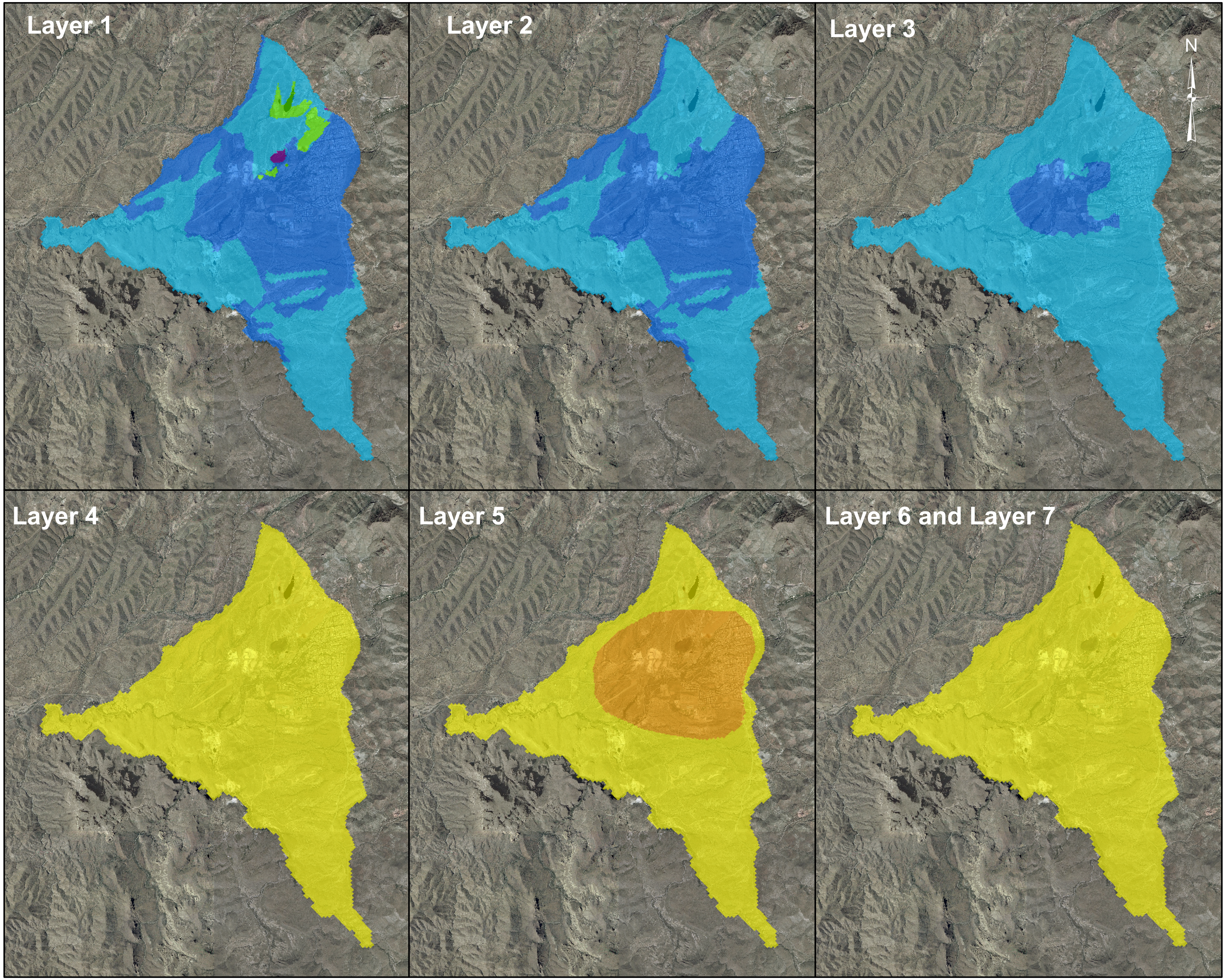
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

TITLE

**Cross Sections of Model Layering**

Golder Associates
Tucson, Arizona

| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | --- | --- | **FIGURE: 7** | |
| GIS | MM | 3/17/2008 | | |
| CHECK | BS | 3/17/2008 | | |
| REVIEW | MB | 3/17/2008 | | |




**LEGEND**

K Values for Model

- Zone 1 = 0.15 ft/d
- Zone 2 = 9.64 ft/d
- Zone 3 = 0.096 ft/d
- Zone 4 = 0.066 ft/d
- Zone 5 and 7 = 0.0011 ft/d
- Zone 6 = $3.7 \times 10^{-6}$ ft/d

**REFERENCE**

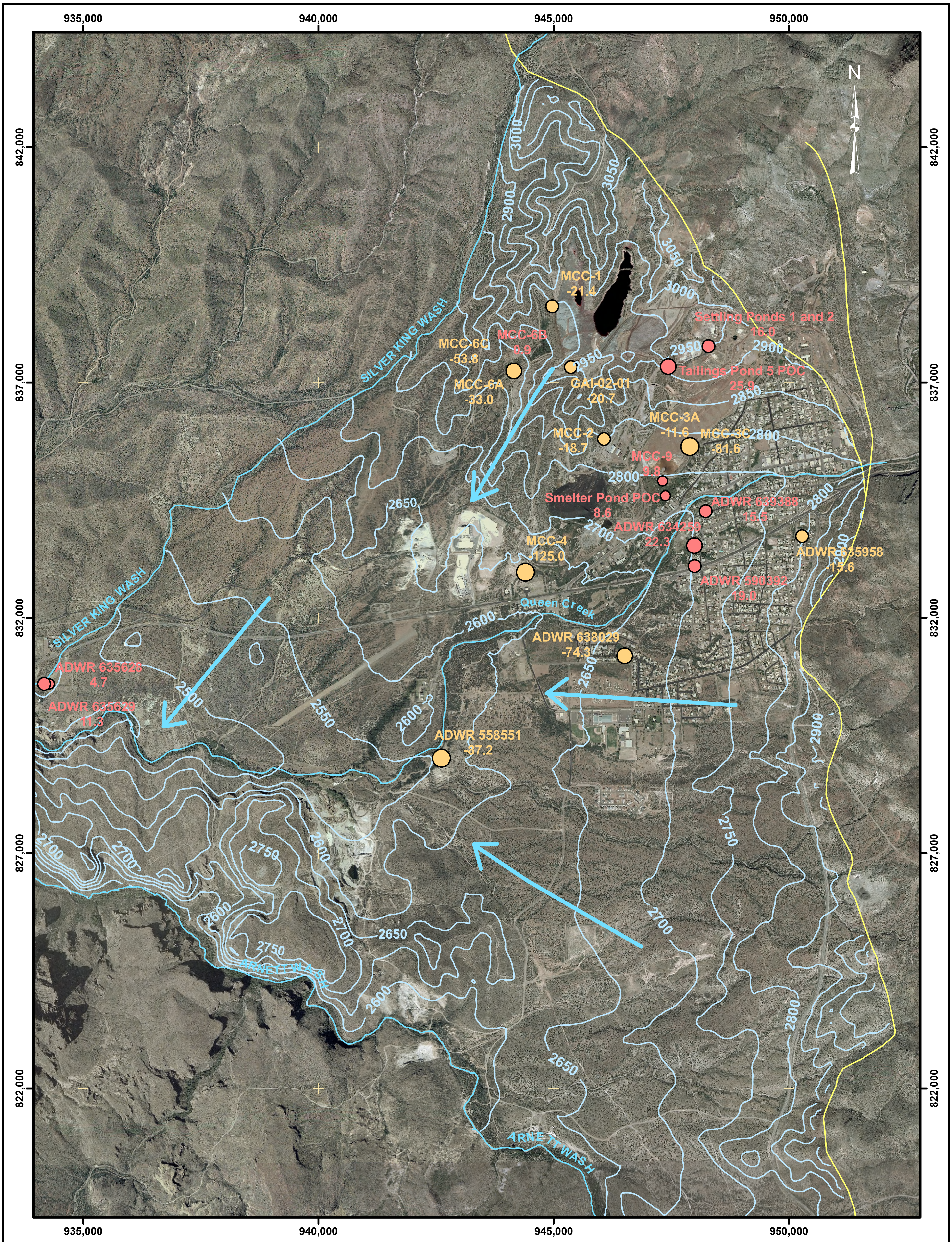
1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery.

6,000 0 6,000

SCALE 1:90,000 FEET

| PROJECT | GROUNDWATER MODEL<br>WEST PLANT SITE, SUPERIOR, ARIZONA<br>RESOLUTION COPPER MINING COMPANY LLC |
|---|---|
| TITLE | **Calibrated Model Hydraulic Conductivity Zones** |

| Golder Associates<br>Tucson, Arizona | PROJECT No. 07-3925-65 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|---|
| | GIS | TA | 3/19/2008 | **FIGURE 8** | |
| | CHECK | MM | 3/19/2008 | | |
| | REVIEW | BS | 3/19/2008 | | |




## LEGEND

**Residual (feet)**

- -125.0 - -75.1 (over estimated)
- -75.0- -40.1
- -40.0 - -12.1
- -12.0 - 0.0
- 0.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0 (under estimated)

- Modeled Groundwater Contours in Model Layer 3 (50 ft interval)
- Modeled Regional Flow Direction
- Fault

2,000 0 2,000
SCALE 1:24,000 FEET

## REFERENCE

1) Projection: NAD 1983 State Plane Arizona Central FIPS 0202 Feet
2) 2005 Arizona Digital Orthophotograph Provided Arizona State Land Department, Arizona Land Resource Information System 1-meter resolution orthoimagery

PROJECT
GROUNDWATER MODEL
WEST PLANT SITE, SUPERIOR, ARIZONA
RESOLUTION COPPER MINING COMPANY LLC

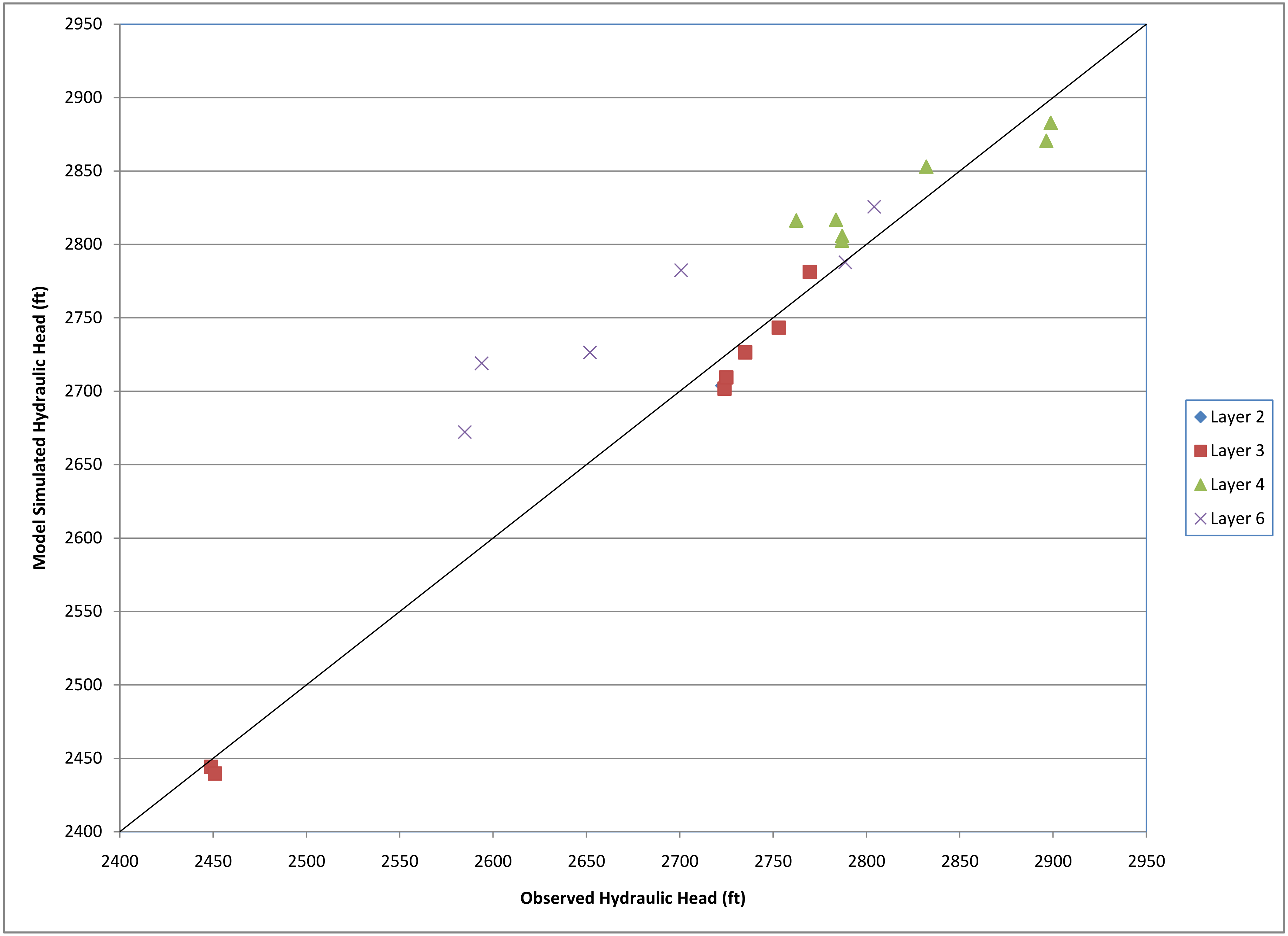
TITLE
# Residuals and Water Level Contours Calibrated Model

Golder Associates
Tucson, Arizona

| PROJECT No. 073-92565-01 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| GIS | TA | 03/17/2008 | **FIGURE: 9** | |
| CHECK | MM | 03/17/2008 | | |
| REVIEW | BS | 03/17/2008 | | |

# FIGURE 10
## SCATTER PLOT OF MODEL CALIBRATION

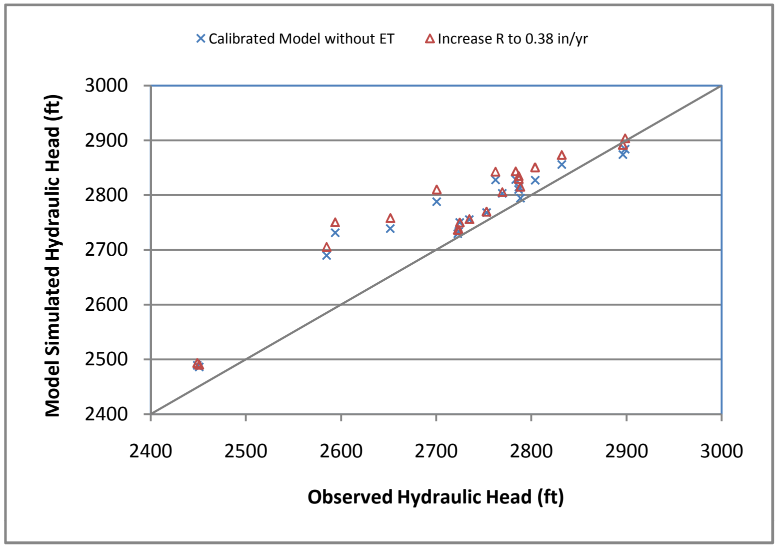


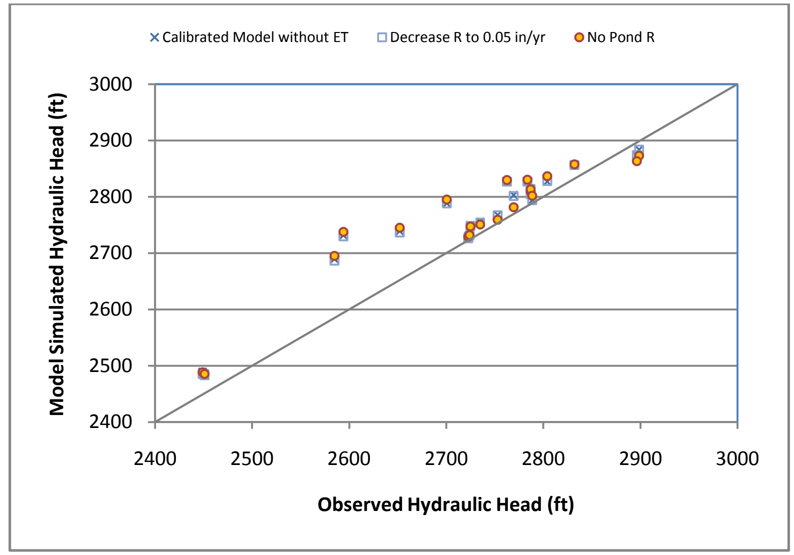


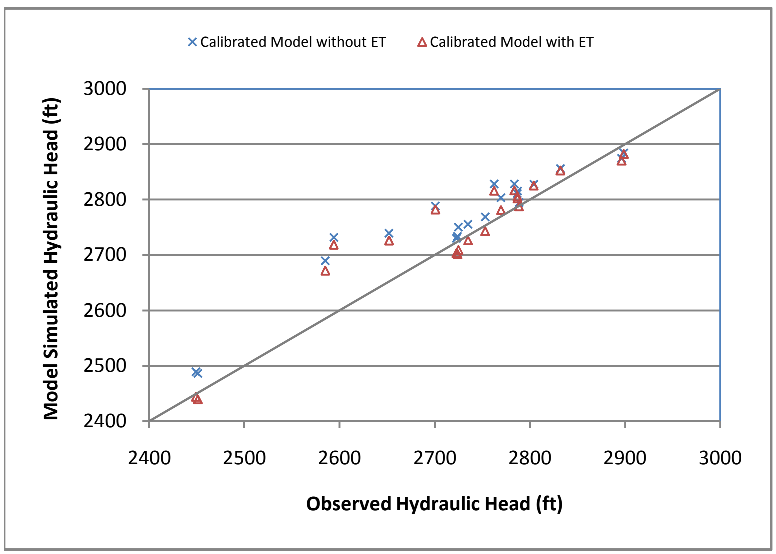
# APPENDIX A

# SENSITIVITY ANALYSIS

# APPENDIX A, FIGURE 1
# RESULTS OF SENSITIVITY ANALYSIS OF RECHARGE AND EVAPOTRANSPIRATION



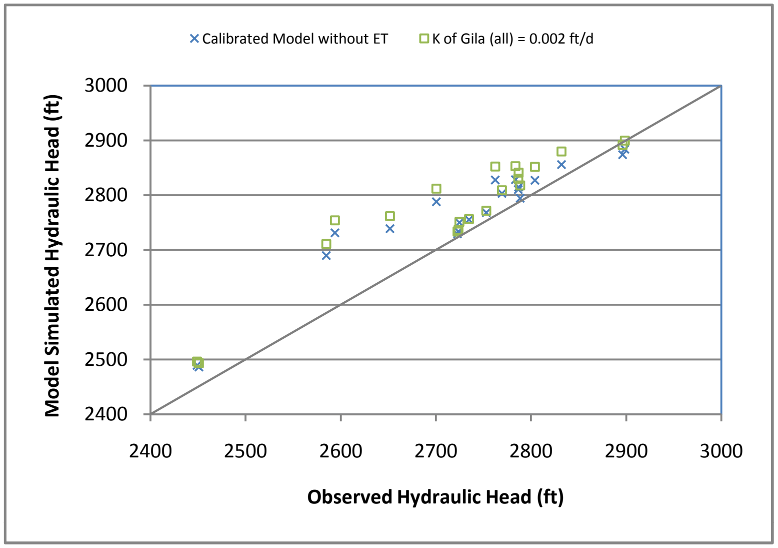



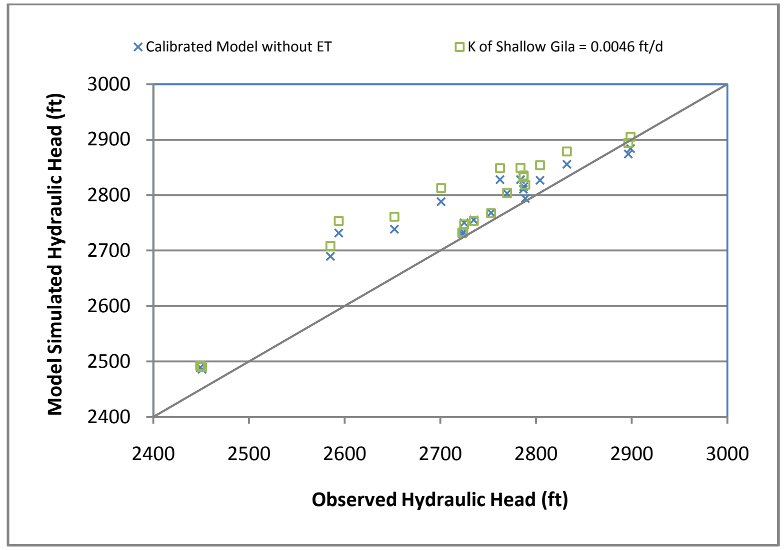

| | Residual Sum of Squares ($ft^2$) | % RMS |
|---|---|---|
| Calibrated Model without ET | 59,990 | 11.9% |
| Increase recharge[1] to 0.38 in/yr | 87,108 | 14.3% |
| Decrease recharge[1] to 0.05 in/yr | 57,181 | 11.6% |
| Remove Pond recharge | 65,766 | 12.4% |
| Calibrated Model with ET | 43,361 | 10.0% |

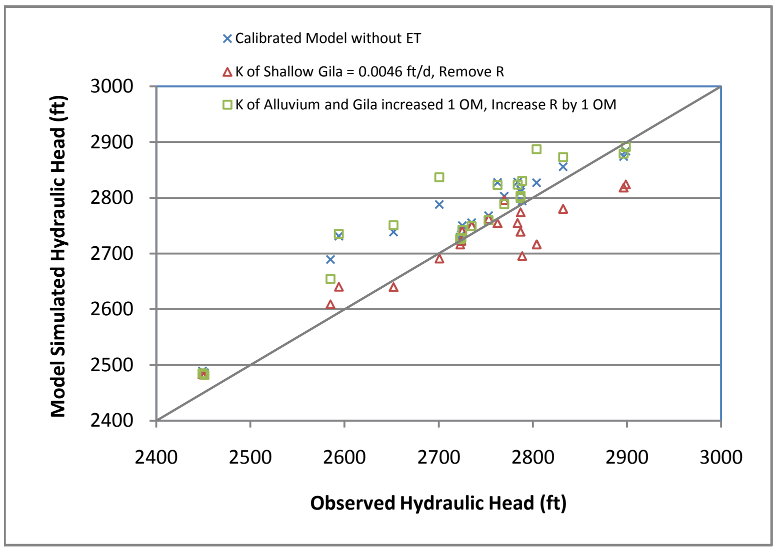
[1]infiltration of precipitation and stormwater runon

%RMS = ratio of the root mean squared error to the range in observed hydraulic heads

# APPENDIX A, FIGURE 2
## RESULTS OF SENSITIVITY ANALYSIS OF HYDRAULIC CONDUCTIVITY




| | Residual Sum of Squares ($ft^2$) | % RMS |
|---|---|---|
| Calibrated Model without ET | 59,990 | 11.9% |
| All Gila Ks = 0.002 ft/d | 95,615 | 15.0% |
| Shallow Gila K = 0.0046 ft/d | 40,251 | 9.7% |
| Alluvium and all Gila Ks increased 1 OM, R increased 1OM | 72,914 | 13.1% |

OM = order of magnitude

%RMS = ratio of the root mean squared error to the range in observed hydraulic heads

# APPENDIX B

# MONITORING WELL PARTICLE TRACKING

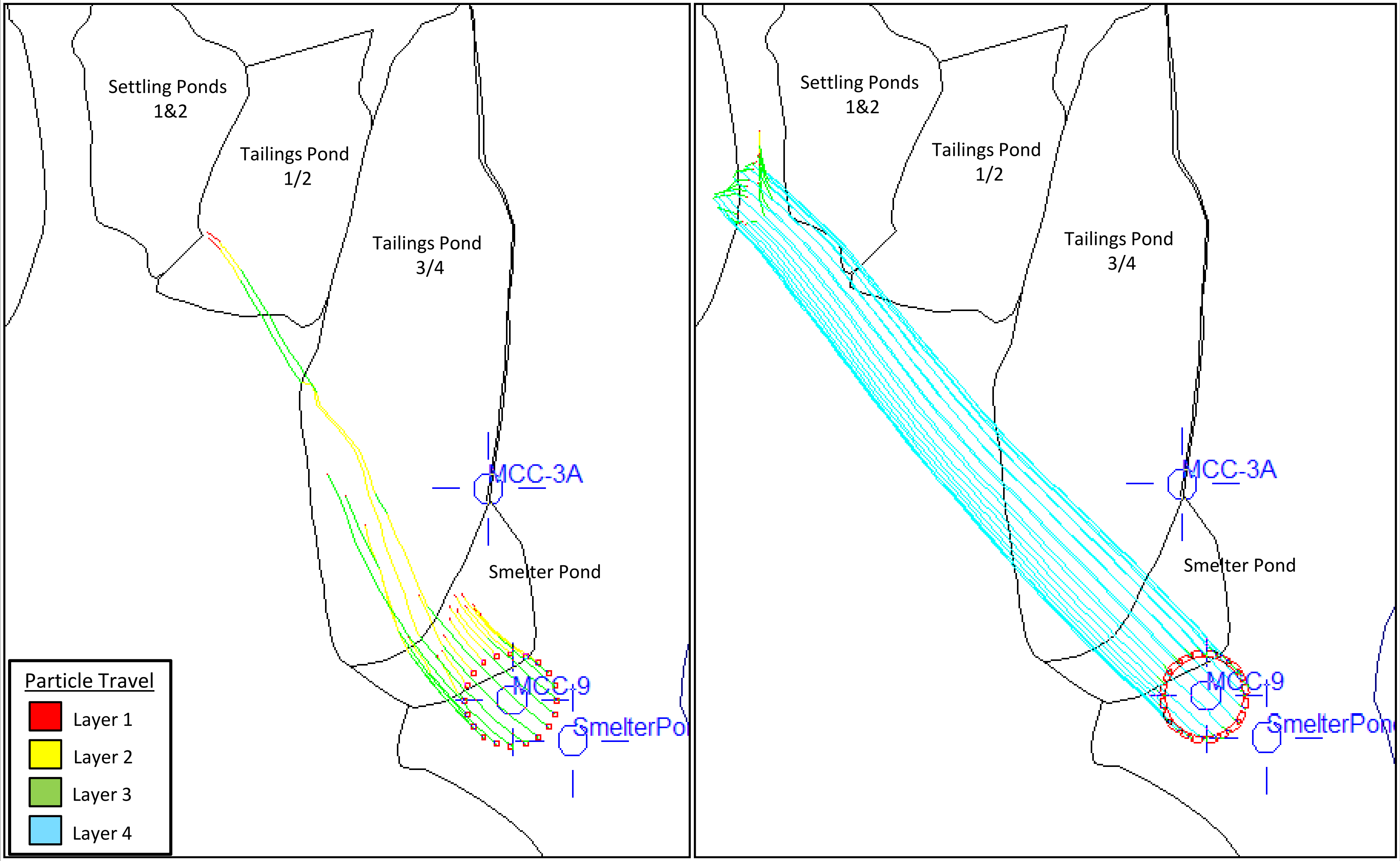



**Figure B-1a**
Flow lines captured by MCC-9 from the top of model layer 3.

**Figure B-1b**
Flow lines captured by MCC-9 from the bottom of model layer 3.

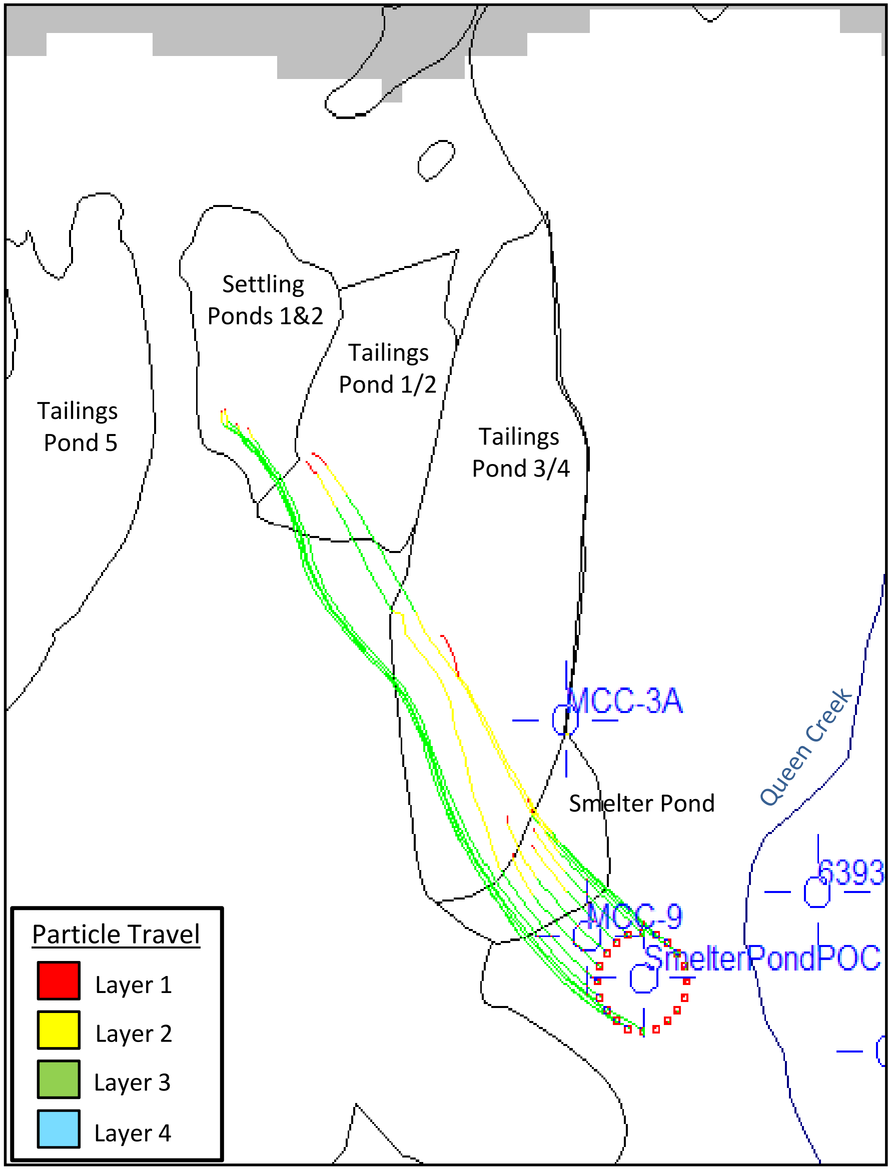



**Figure B-2a**
Flow lines captured by Smelter Pond POC from the top of model layer 3.

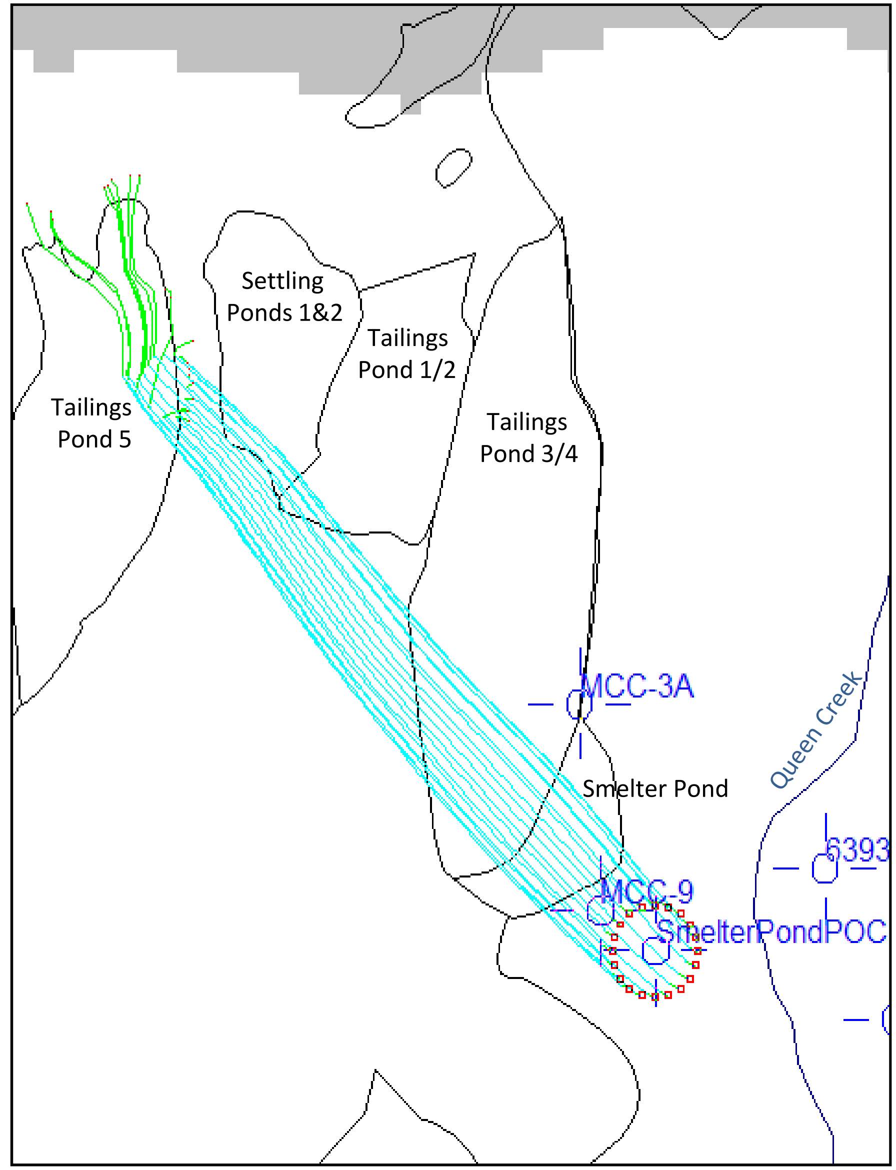



**Figure B-2b**
Flow lines captured by Smelter Pond POC from the bottom of model layer 3.

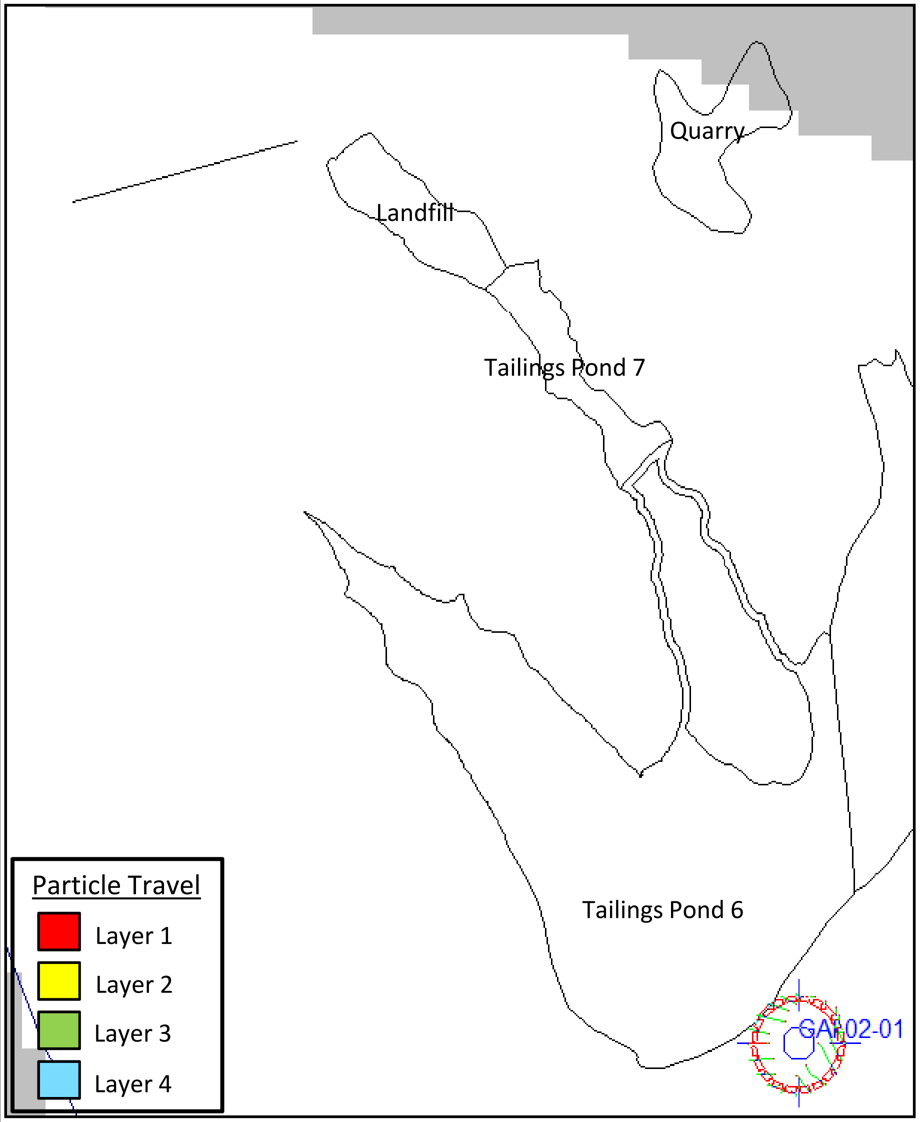



**Figure B-3a**
Flow lines captured by GAI-02-01 from the top of model layer 4.

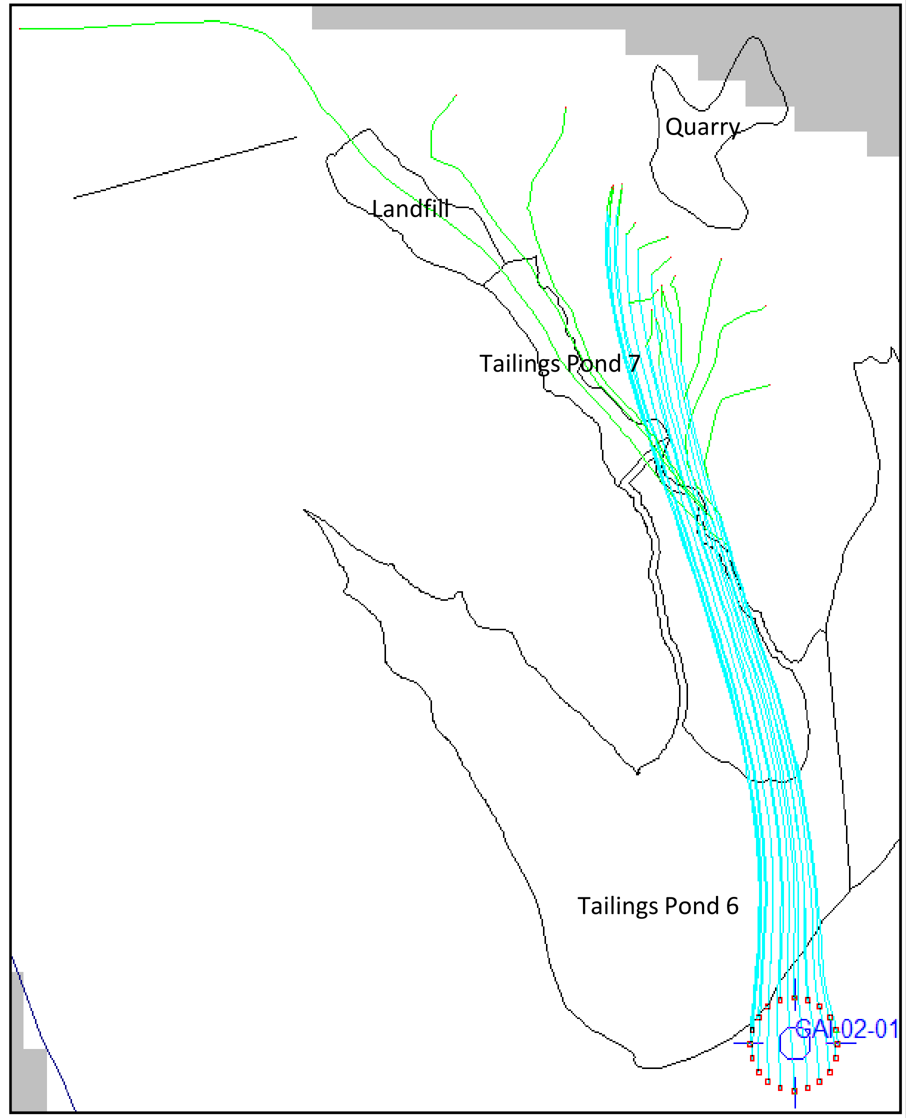



**Figure B-3b**
Flow lines captured by GAI-02-01 from the bottom of model layer 4.

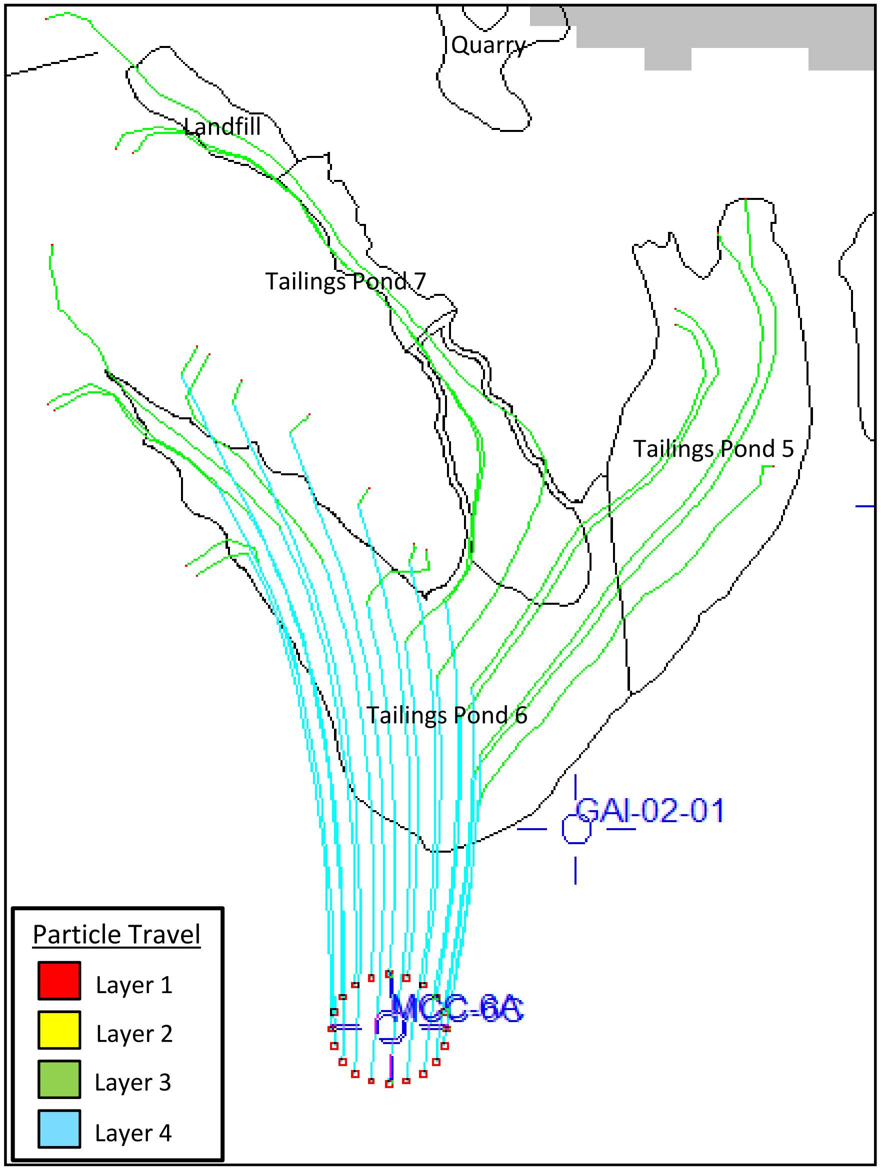



**Figure B-4a**
Flow lines captured by MCC-6C from the top of model layer 4.

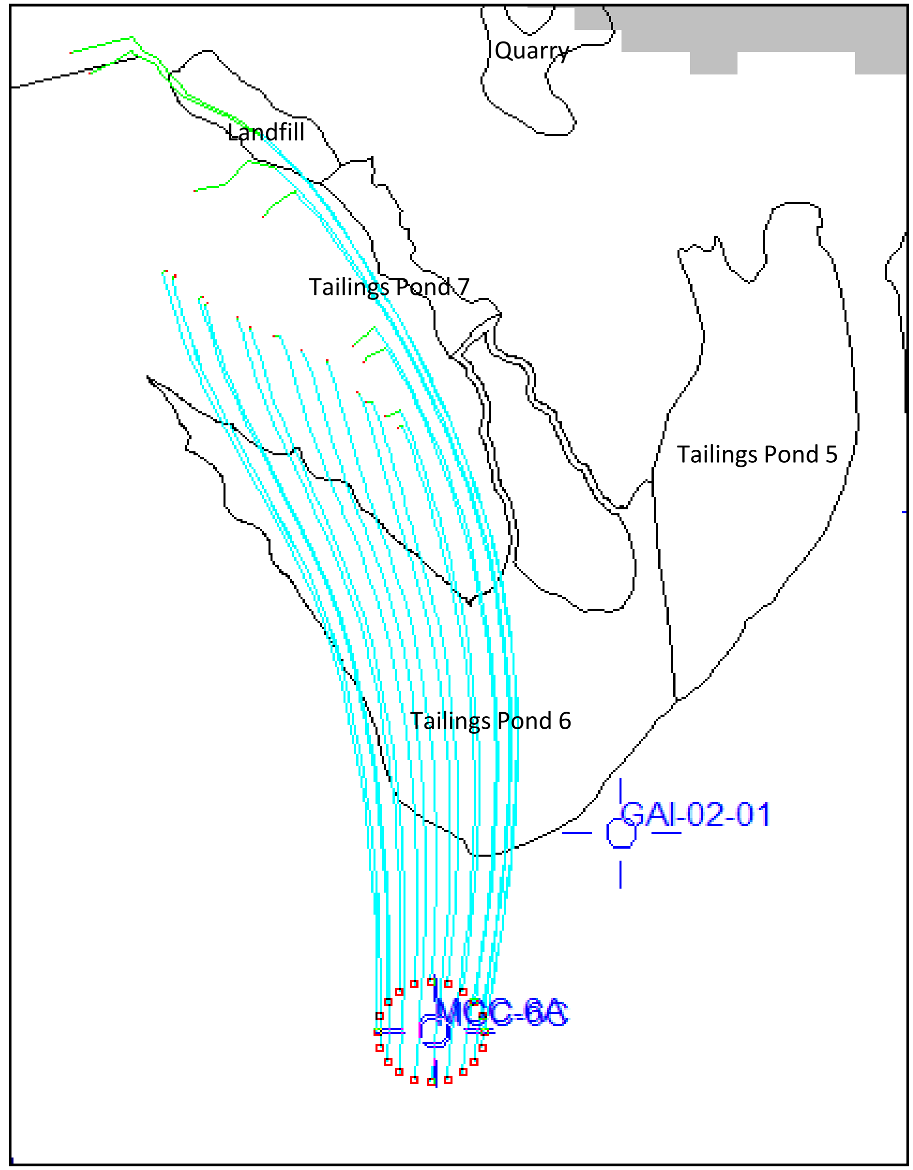
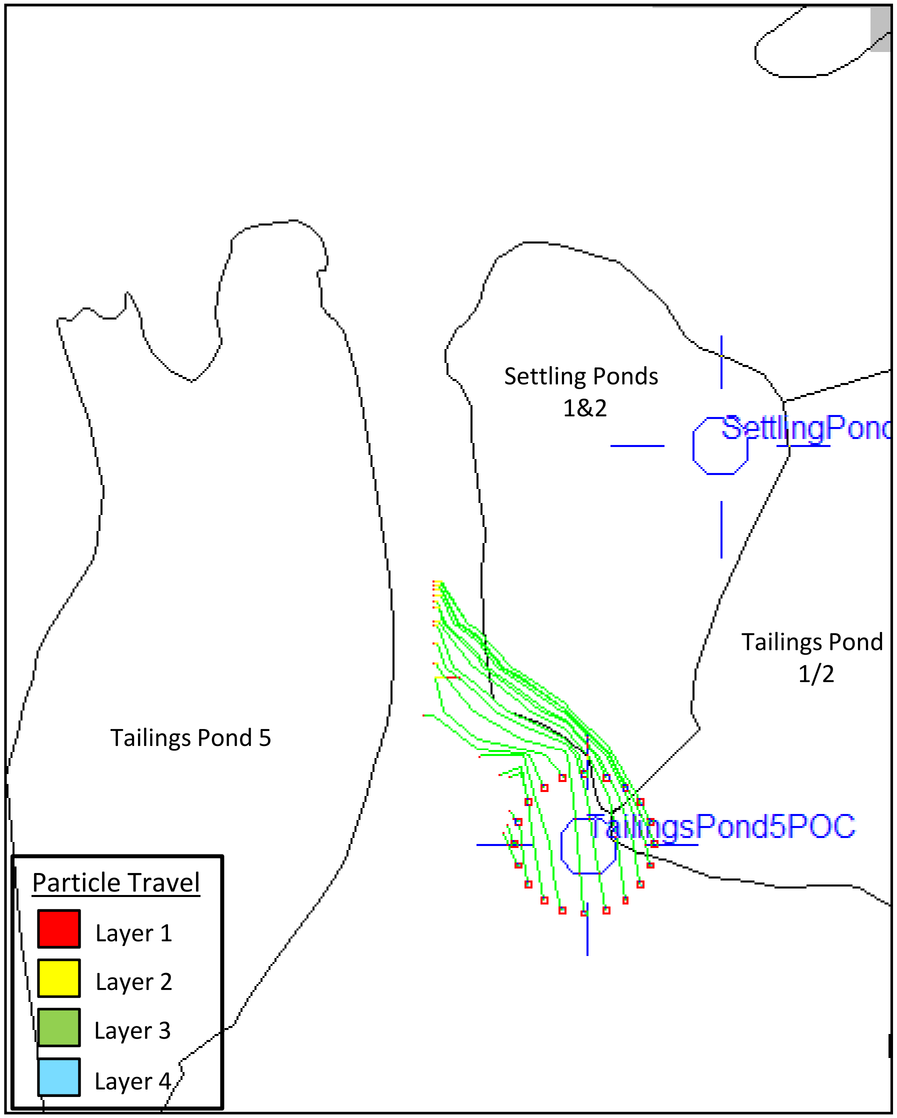



**Figure B-4b**
Flow lines captured by MCC-6C from the bottom of model layer 4.



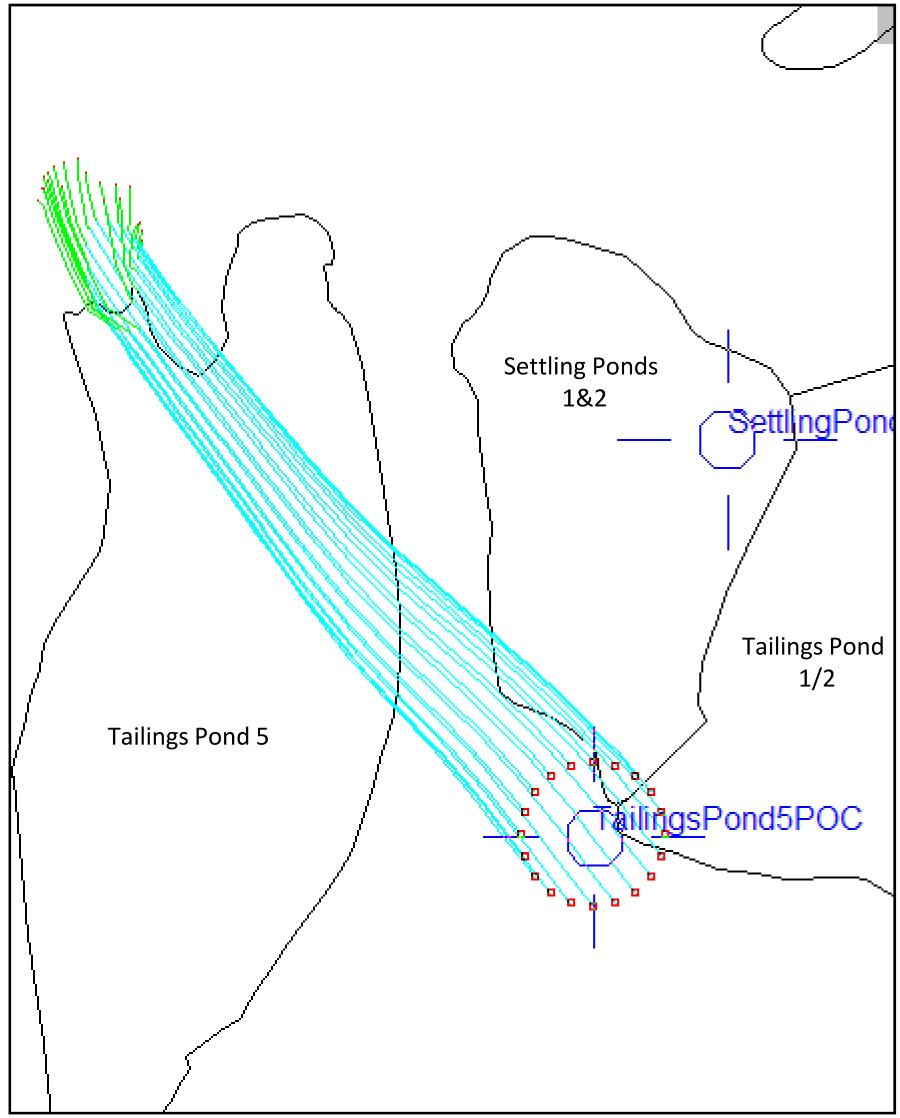
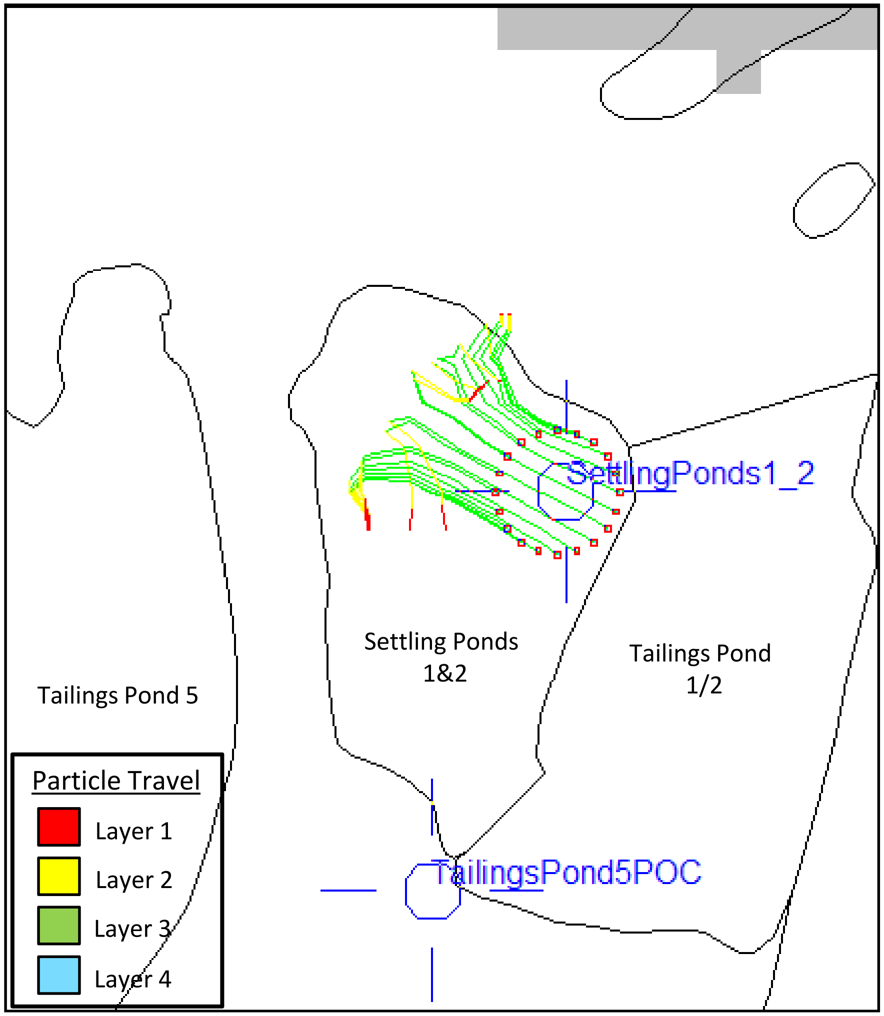




**Figure B-5a**
Flow lines captured by Tailings Pond 5 POC from the top of model layer 4.

**Figure B-5b**
Flow lines captured by Tailings Pond 5 POC from the bottom of model layer 4.



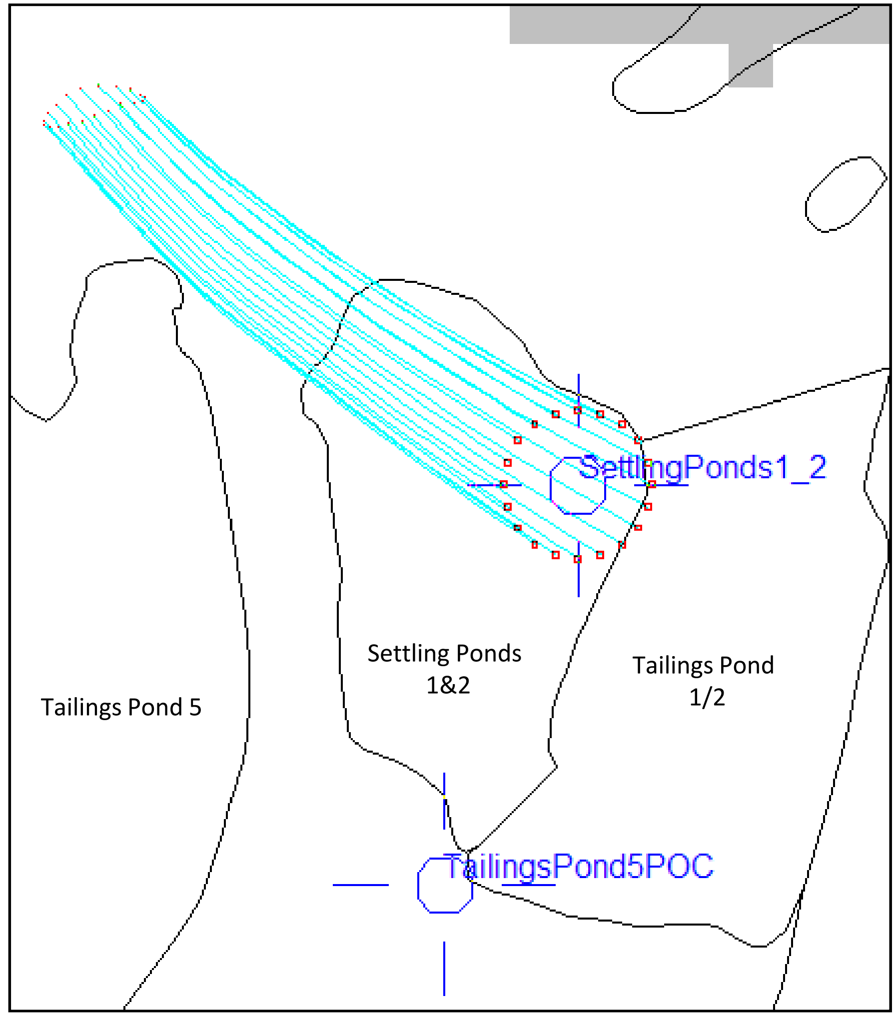




**Figure B-6a**
Flow lines captured by Settling Ponds 1 & 2 Alert Well from the top of model layer 4.

**Figure B-6b**
Flow lines captured by Settling Ponds 1 & 2 Alert Well from the bottom of model layer 4.

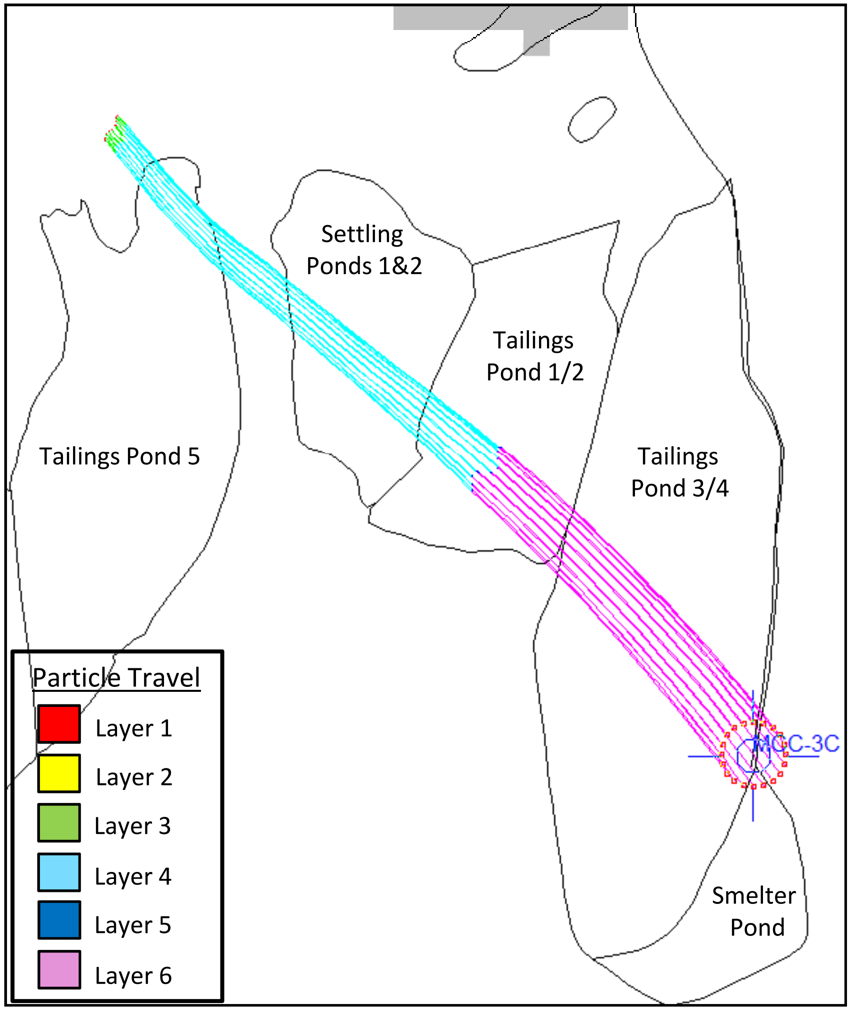



**Figure B-7a**

Flow lines captured by MCC-3C from the top of model layer 6.

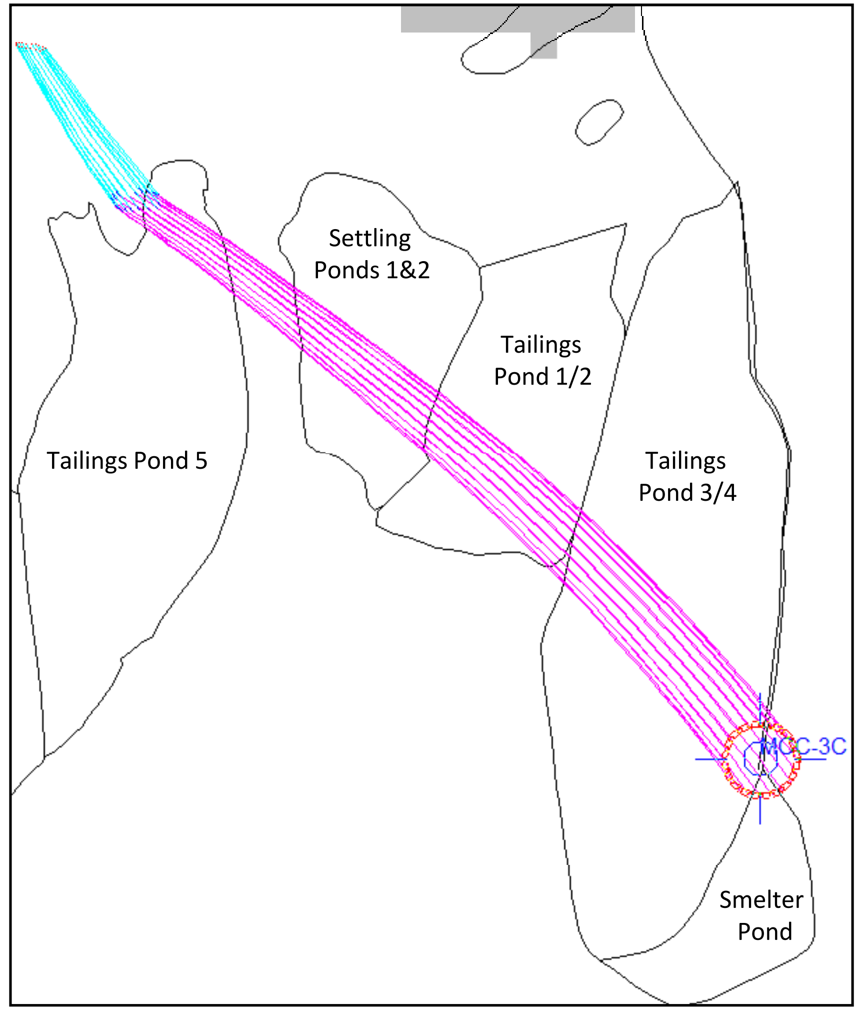



**Figure B-7b**

Flow lines captured by MCC-3C from the bottom of model layer 6.

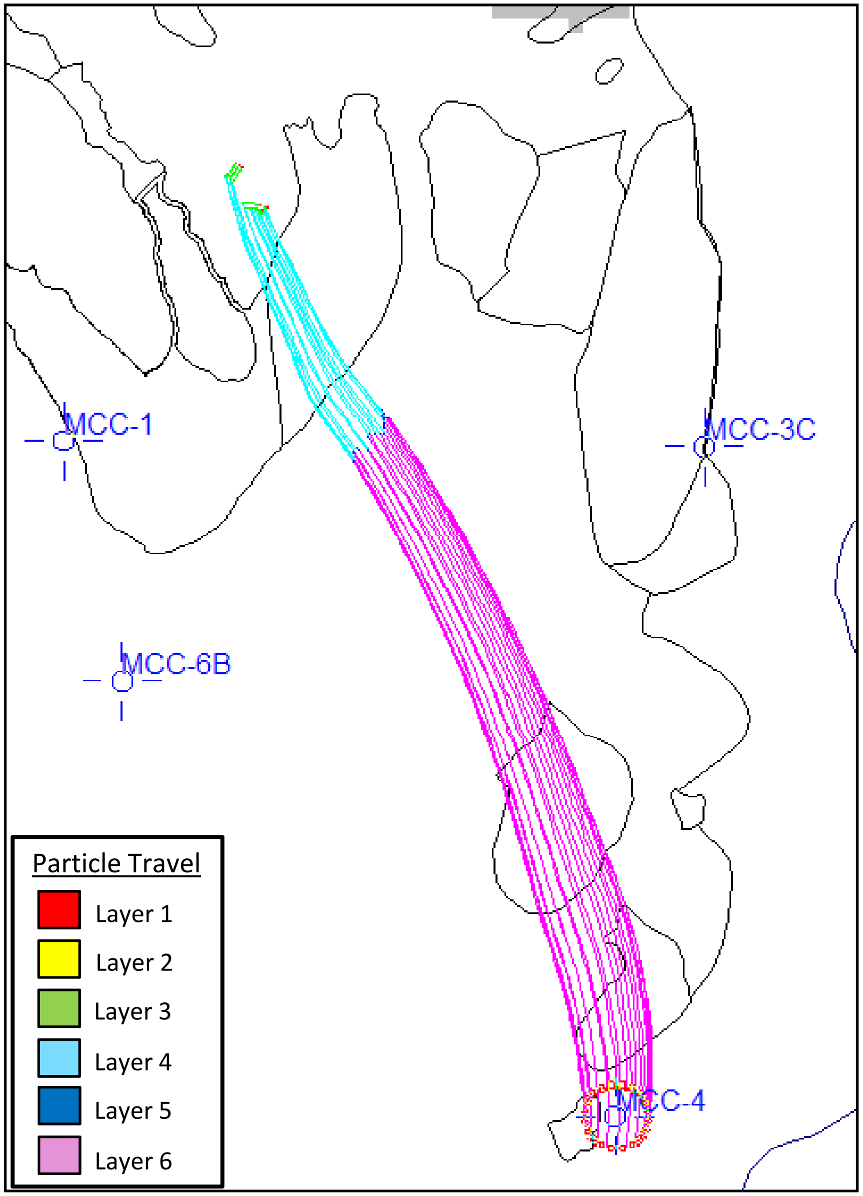



**Figure B-8a**

Flow lines captured by MCC-4 from the top of model layer 6.

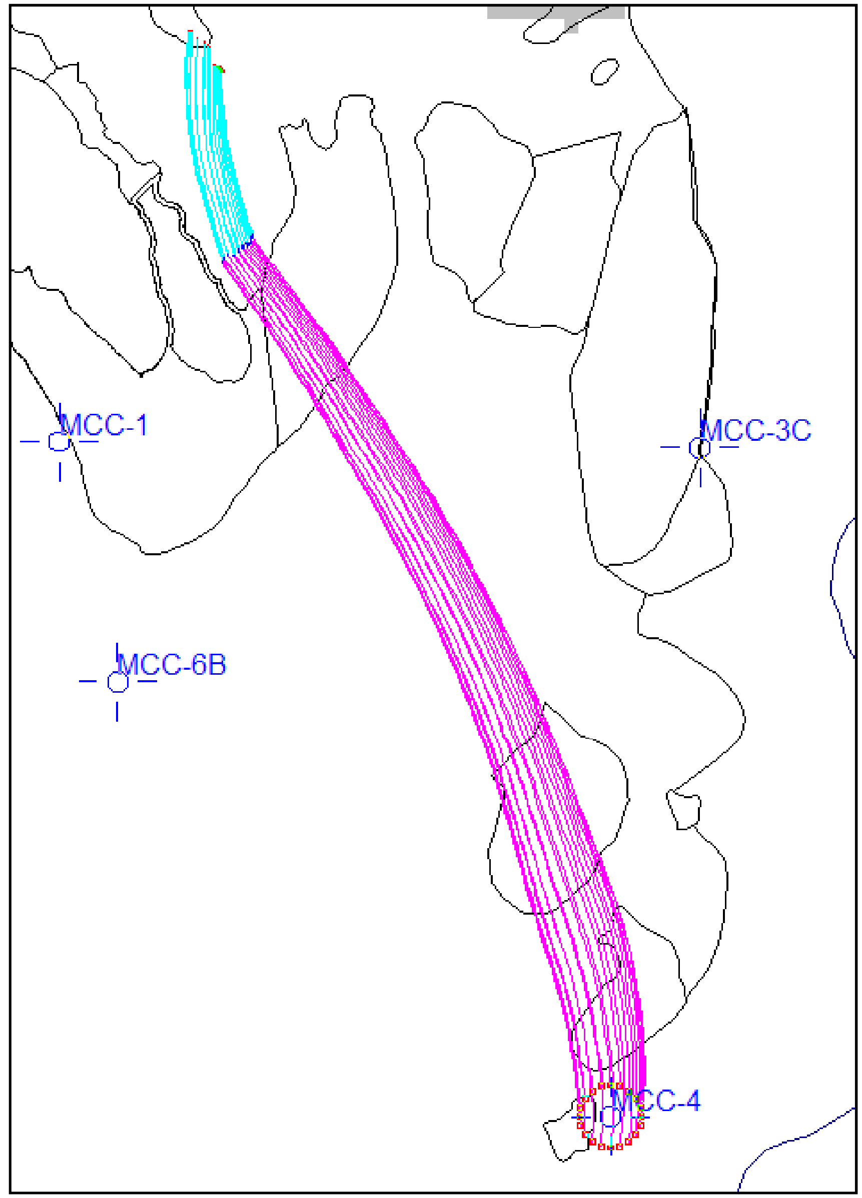



**Figure B-8b**

Flow lines captured by MCC-4 from the bottom of model layer 6.

# APPENDIX C

# MINE FACILITY PARTICLE TRACKING

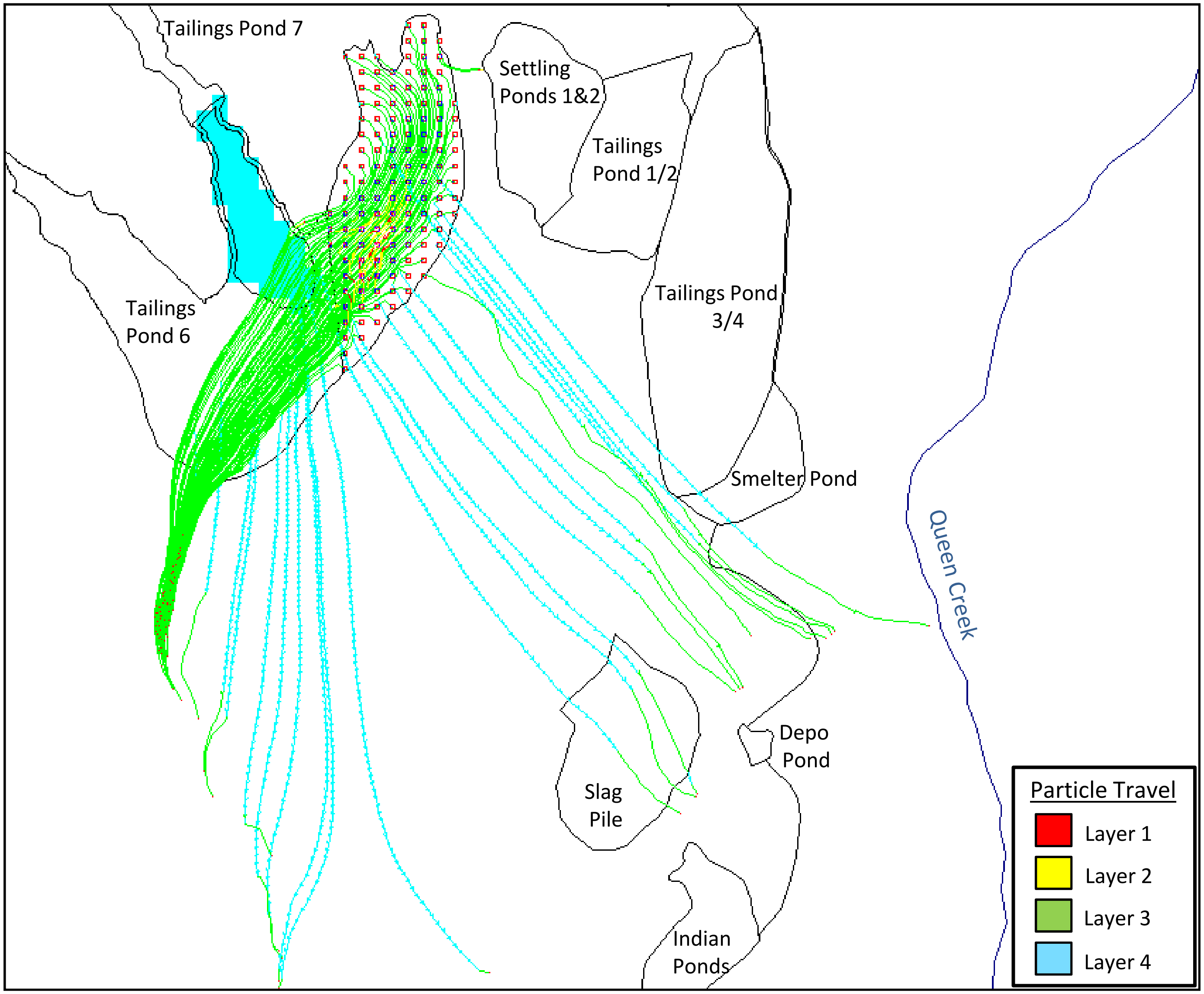



**Figure C-1**

Flow lines from Tailings Pond 5.

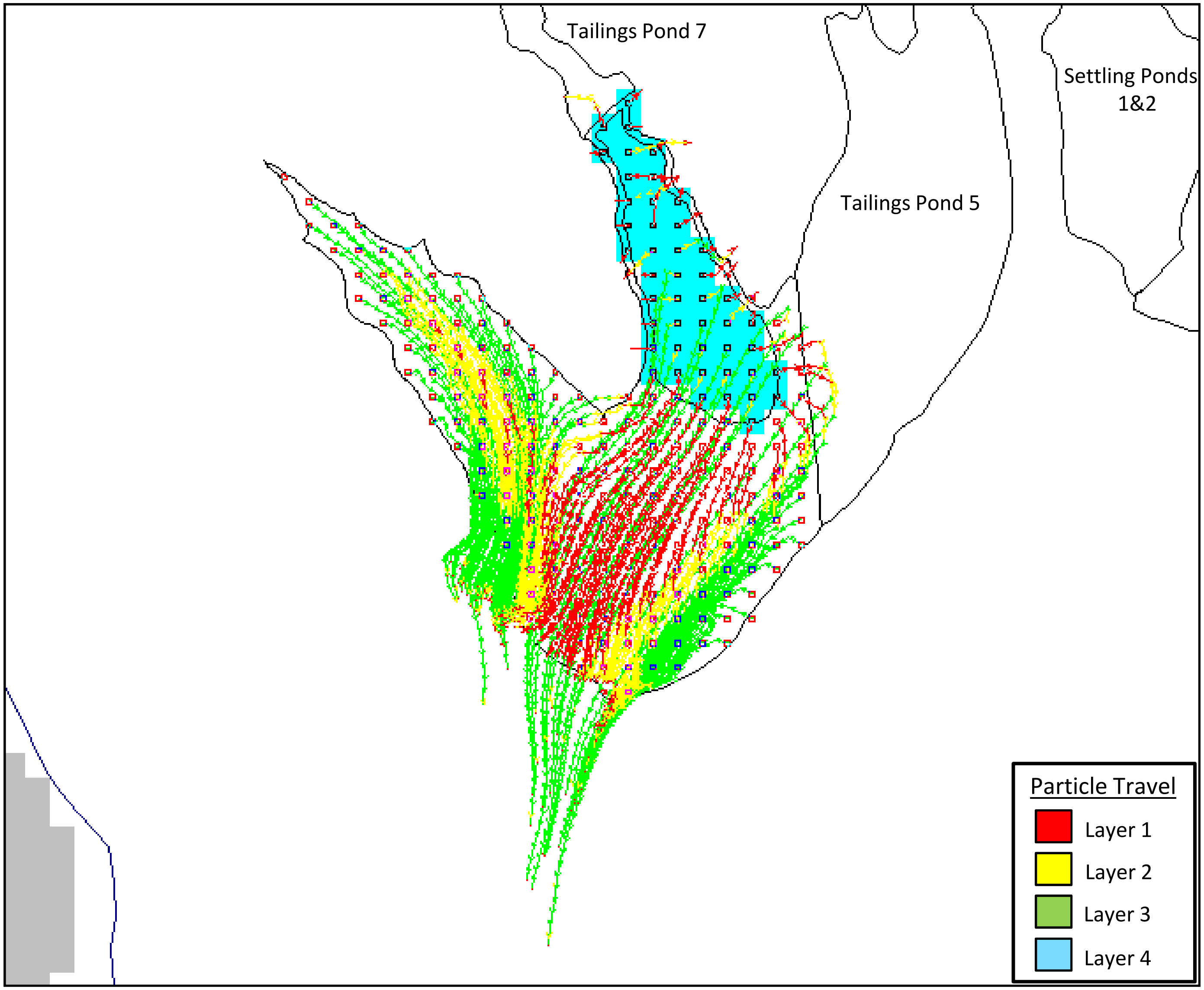



**Figure C-2**
Flow lines from Tailings Pond 6.

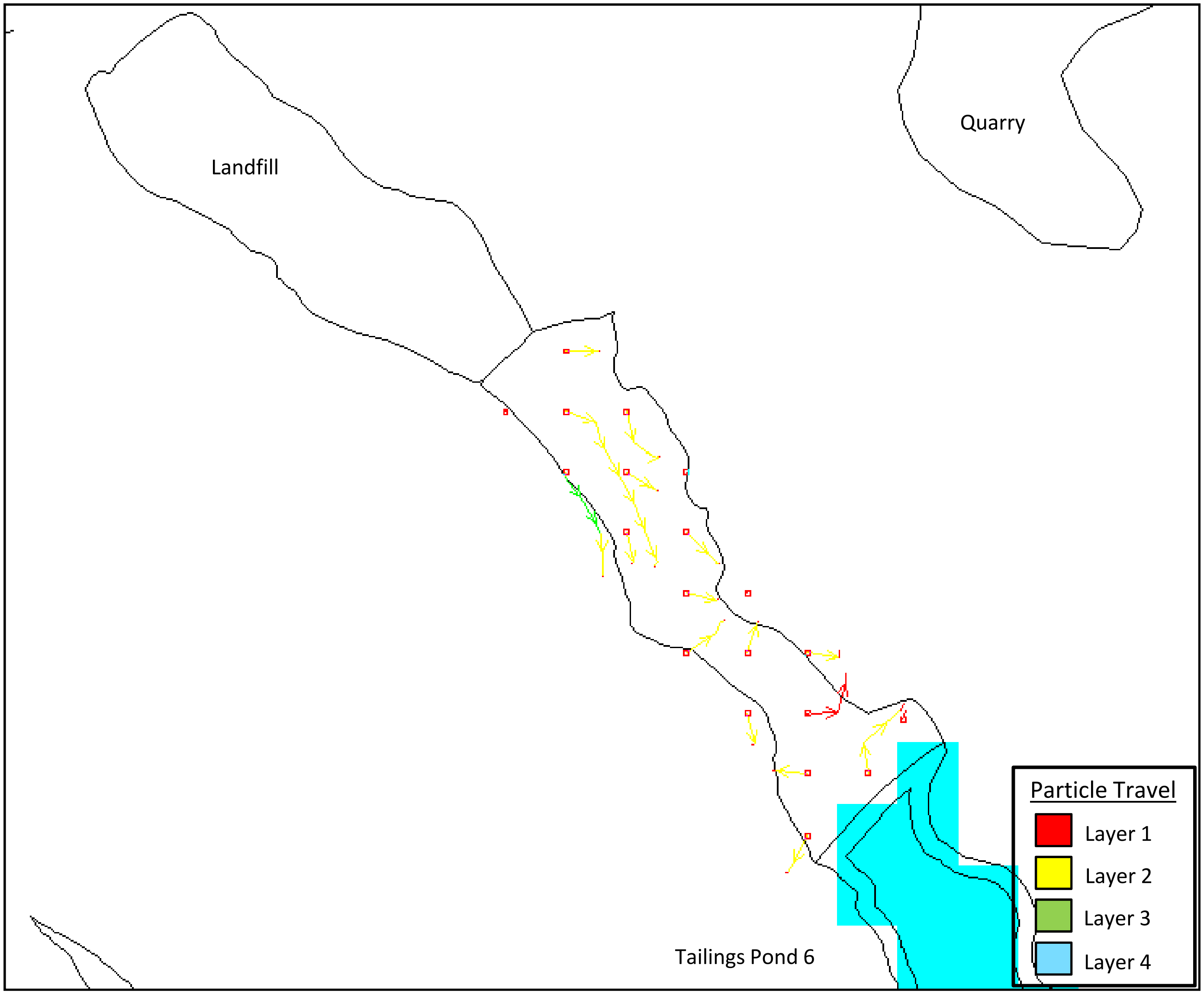



**Figure C-3**
Flow lines from Tailings Pond 7.

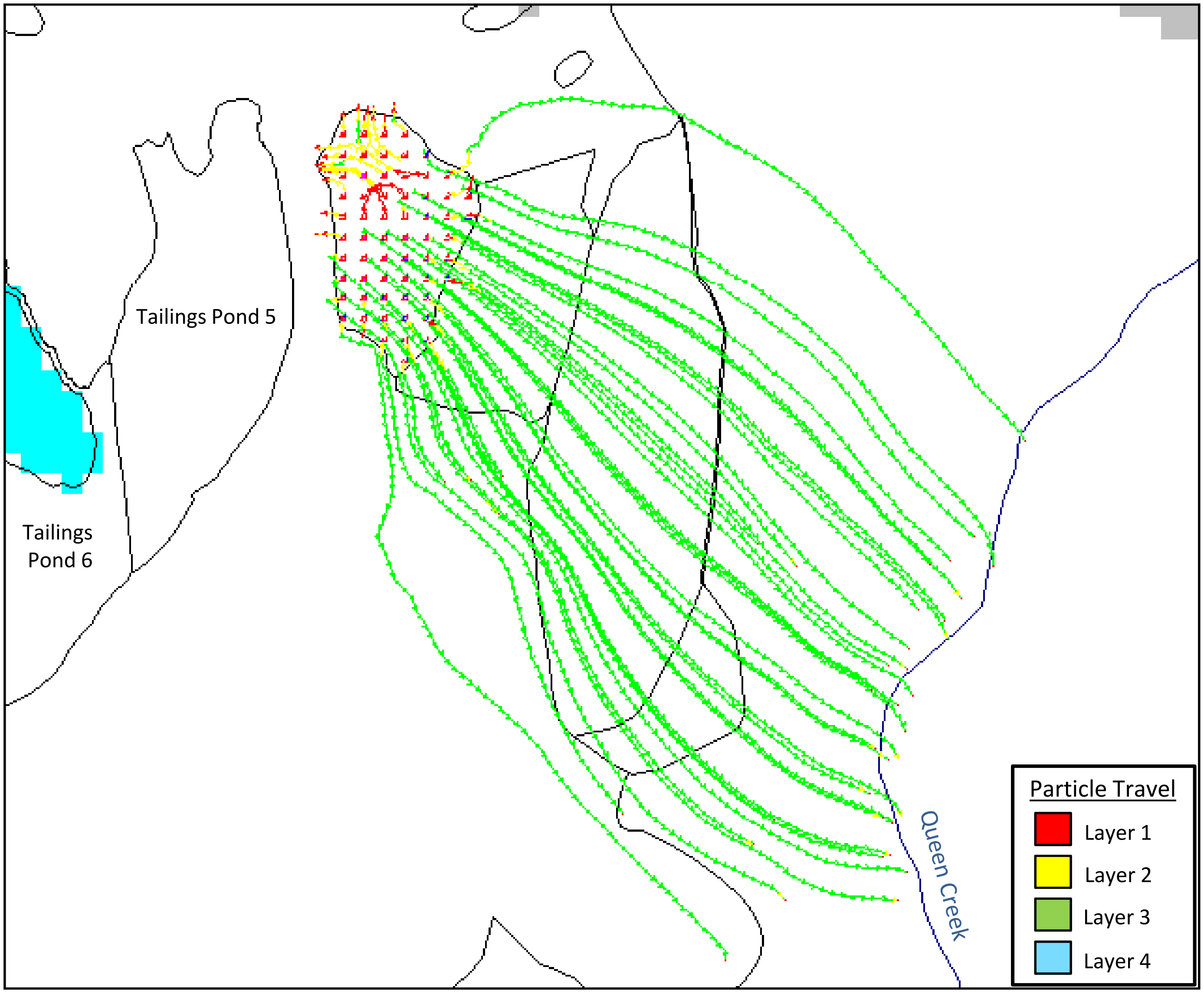



**Figure C-4**

Flow lines from Settling Ponds 1 & 2.

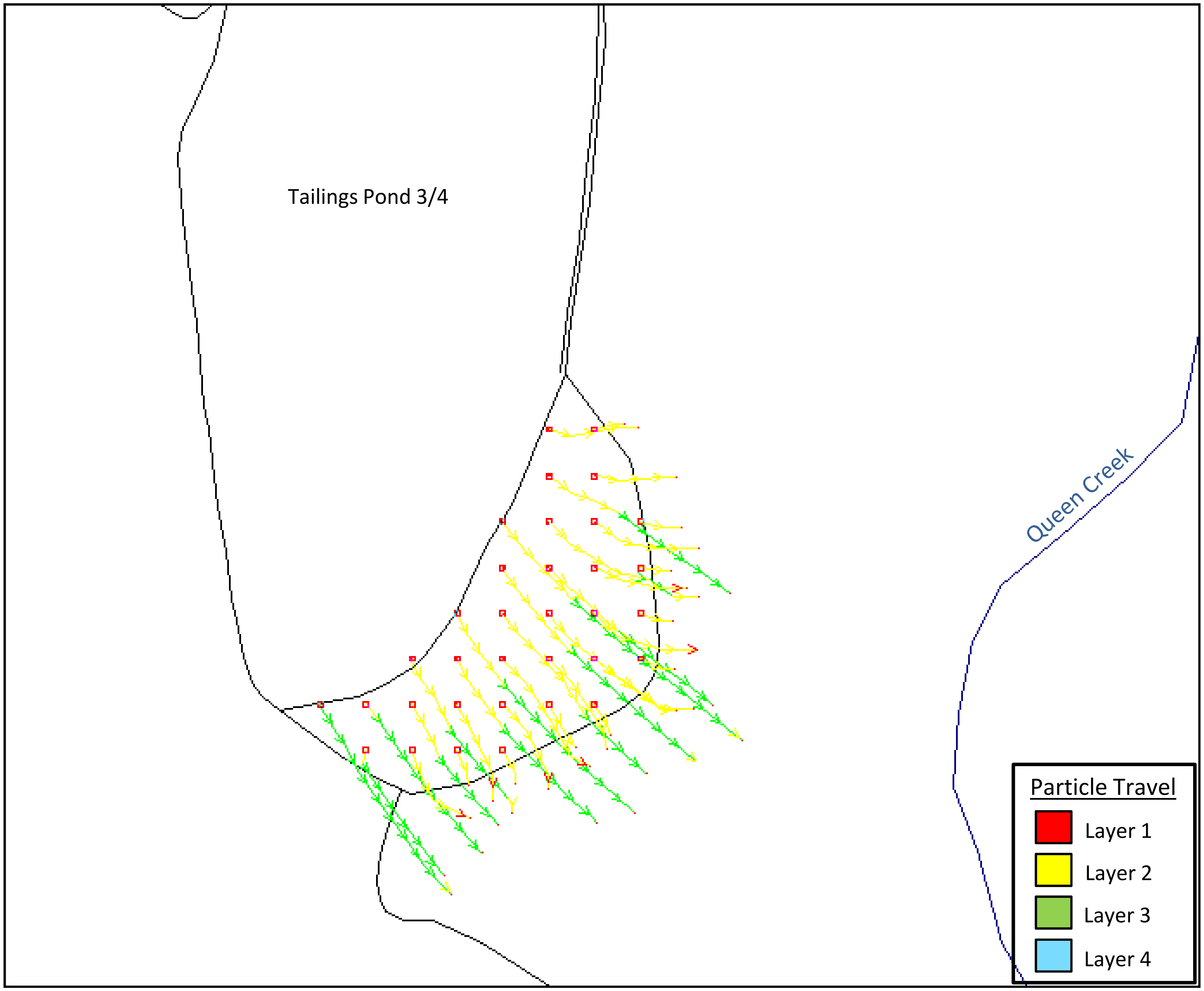



**Figure C-5**
Flow lines from Smelter Pond.

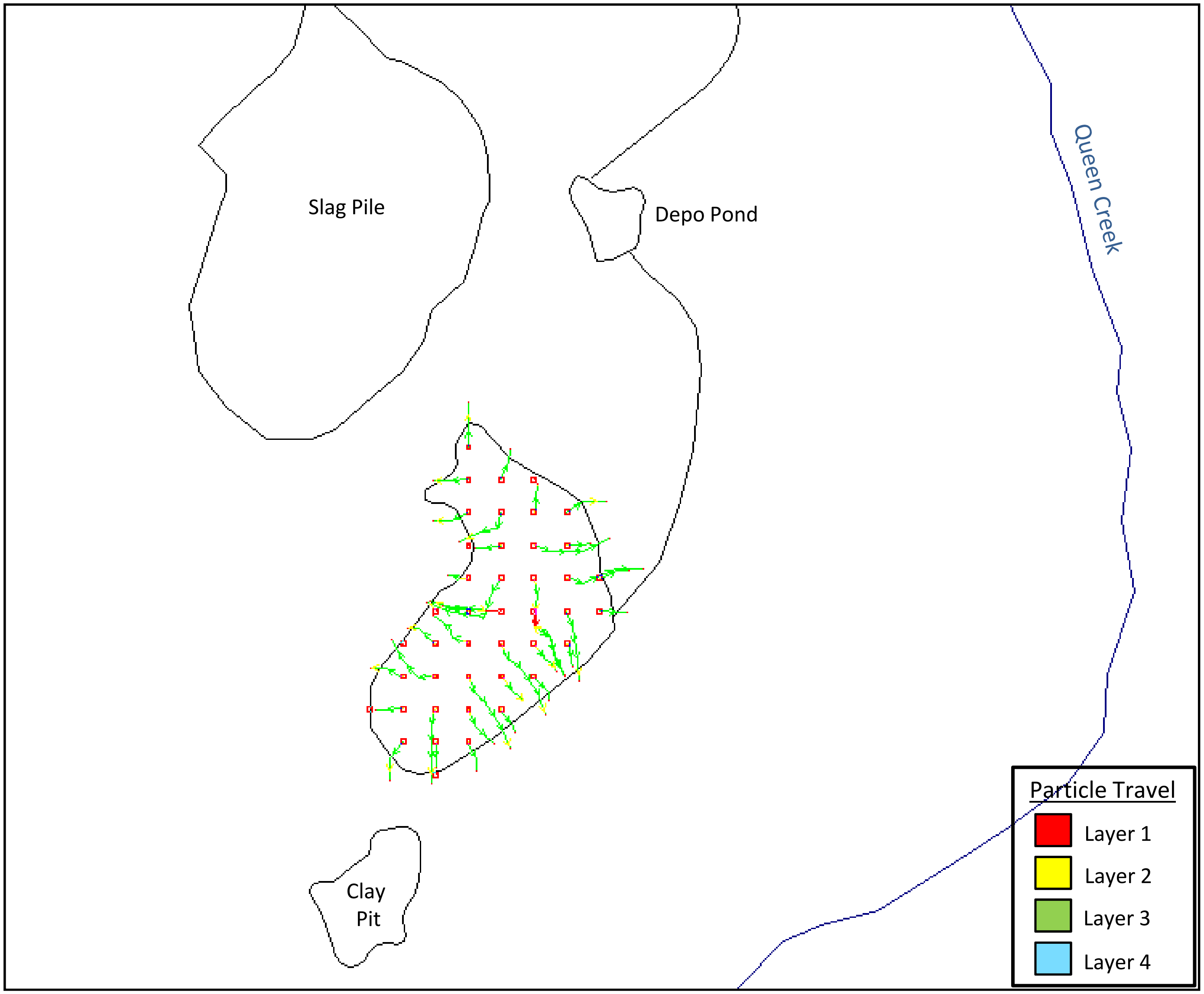



**Figure C-6**
Flow lines from Indian Ponds.