GROUNDWATER FLOW MODELING CONDUCTED FOR SIMULATION OF PROPOSED ROSEMONT PIT DEWATERING AND POST-CLOSURE ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

VOLUME 1: TEXT AND TABLES
GROUNDWATER FLOW MODELING CONDUCTED FOR SIMULATION
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<td>als</td>
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<td>Groundwater Site Inventory</td>
</tr>
<tr>
<td>msl</td>
<td>mean sea level</td>
</tr>
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<td>M&amp;A</td>
<td>Montgomery &amp; Associates</td>
</tr>
<tr>
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<td>Pima Association of Governments</td>
</tr>
<tr>
<td>PEST</td>
<td>parameter estimation and optimization modeling</td>
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<tr>
<td>PRISM</td>
<td>Parameter-elevation Regressions on Independent Slopes Model</td>
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<td>United States Geological Survey</td>
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REVISED GROUNDWATER FLOW MODELING CONDUCTED FOR SIMULATION
OF PROPOSED ROSEMONT PIT DEWATERING AND POST-CLOSURE
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXECUTIVE SUMMARY

Rosemont Copper Company is proposing an open-pit mining and mineral processing operation in the northern Santa Rita Mountains, along the western edge of Cienega Creek basin in Pima County, Arizona. Construction, operations, and post-closure activities will occur for approximately 25 to 30 years, commencing in 2011. The bottom of the proposed pit is projected to be at an altitude of 3,050 feet above mean sea level (msl). This is below the current groundwater level in the proposed pit area and will necessitate the removal of groundwater during mining operations. To understand the impacts to the fractured bedrock groundwater system and to determine the potential for development of a pit lake, groundwater model investigations were conducted by Montgomery & Associates (M&A).

The groundwater flow model was designed to simulate conditions prior to pit development, during pit dewatering, and for a 1,000-year post-closure period of groundwater level recovery and potential pit lake development. In support of the model, M&A conducted initial investigations in the proposed mine area that included exploration drilling, hydraulic testing, groundwater level monitoring, field verification of geologic maps, and literature reviews. The fractured bedrock in and around the Rosemont Project area was considered to behave as an equivalent porous media on a large-scale, with the understanding that groundwater flow on a local-scale is primarily through fractures and faults. The model study area encompasses most of Cienega Creek basin in order to evaluate potential groundwater impacts that may occur in the basin fill aquifer east from the mine.

The groundwater flow system in the Rosemont Project area, and for a majority of the Cienega Creek basin, is currently considered to be in a state of equilibrium. The groundwater flow model was calibrated to current groundwater level conditions and to drawdown and recovery response observed during a 30-day multi-well aquifer test that included five wells in the Rosemont Project area. Projected pit inflows during mining range between 500 and 600 gpm for most of the mining period. A pit lake is projected to develop following mine closure. The following table shows the projected maximum extent of the
5-foot groundwater level drawdown contour, the projected pit lake stage, and the projected pit lake depth at the end of mine closure and at 20, 50, and 1,000 years after mine closure:

<table>
<thead>
<tr>
<th>TIME</th>
<th>PROJECTED MAXIMUM EXTENT OF THE 5-FOOT GROUNDWATER LEVEL DRAWDOWN CONTOUR&lt;sup&gt;a&lt;/sup&gt; (miles)</th>
<th>PROJECTED PIT LAKE STAGE&lt;sup&gt;b&lt;/sup&gt; (feet msl)</th>
<th>PIT LAKE DEPTH (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine Closure</td>
<td>3.2</td>
<td>---&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0</td>
</tr>
<tr>
<td>20 years after mine closure</td>
<td>4.2</td>
<td>3,618</td>
<td>568</td>
</tr>
<tr>
<td>150 years after mine closure</td>
<td>9.6</td>
<td>3,977</td>
<td>927</td>
</tr>
<tr>
<td>1,000 years after mine closure</td>
<td>11.5</td>
<td>4,097</td>
<td>1,047</td>
</tr>
</tbody>
</table>

<sup>a</sup> Projected maximum extent of the 5-foot groundwater level drawdown contour is to the east-northeast along Barrel Canyon, and into upper Davidson Canyon 1,000 years after mine closure.

<sup>b</sup> The pit lake is projected to form after cessation of dewatering operations upon mine closure.

Model projections indicate substantial dewatering of the fractured bedrock in the immediate vicinity of the proposed pit during mine activity and following mine closure. At 1,000 years after mine closure, model projections, including predictive sensitivity projections, indicate the pit lake will be a complete hydraulic sink, ensuring passive containment of the pit lake water. More distant from the proposed pit, extent of the groundwater level drawdown contour is less reliable due to the unknown degree of hydraulic connection, variations in aquifer properties, and discrete features inherent in the fracture rock system around the Rosemont Project area. Model projections, including predictive sensitivity projections, indicate groundwater level drawdown 1,000 years after end of mining will reach riparian and perennial streamflow areas but the quantity of resulting reductions in riparian evapotranspiration and streamflow will be slight.
1.0 INTRODUCTION

In accordance with arrangements with Rosemont Copper, Montgomery & Associates (M&A) has conducted groundwater flow modeling investigations for simulation of mine dewatering and post-closure conditions for the Rosemont Project. The Rosemont Project is a proposed open-pit mining and mineral processing operation located in the northern Santa Rita Mountains, along the western edge of Cienega Creek basin in Pima County, Arizona, as shown on Figure 1. Rosemont Copper is currently in the development process for the Environmental Impact Statement (EIS) and is in the process of obtaining necessary permits, including an Arizona Aquifer Protection Permit (APP).

Mining is proposed to occur for an approximate 22-year period commencing in 2011. At the end of mining operations, the bottom of the open pit would be at an altitude of about 3,050 feet above mean sea level (msl) and the pit would encompass an area of approximately 700 acres. Location and extent of the pit at closure, as well as the extent of planned tailings and waste rock impoundments, are shown on Figure 2. The pit will extend below the present groundwater table, necessitating removal of groundwater inflow during mining operations. It is anticipated that groundwater inflow to the pit will be removed via pumping using dewatering wells, pit sumps, and/or pit wall drains. After cessation of dewatering operations,
a pit lake is expected to form as a result of groundwater inflow, direct precipitation, and surface runoff into the pit.

The majority of the proposed pit will be completed in a structurally deformed, faulted, and fractured bedrock complex. In the southeast area of the proposed pit, upper excavated levels will intercept strongly-cemented basin-fill deposits. Hydraulically, the bedrock complex and cemented basin-fill deposits are characterized as having low conductivity. In the bedrock complex, groundwater movement occurs primarily in discontinuous fractures and discrete faults. In the cemented basin-fill deposits, groundwater flow occurs primarily in the pore space between sediment grains; however, the pore space has been largely filled by cementation. Results of hydraulic testing in the area of the proposed pit indicate there are weak to strong degrees of hydraulic connection in structurally controlled parts of the bedrock complex inside and surrounding the proposed pit location, which likely will result in groundwater inflows to the pit. However, at distances away from the proposed pit area, long-term hydraulic testing indicates limited hydraulic connectivity. Hydraulic connectivity in the larger bedrock complex and cemented basin-fill deposits system tends to be low and as such, will mitigate lateral extent of drawdown impacts.

For purposes of this report, the Rosemont Project area has been defined as the area approximately incorporating all planned operations and areas of recent exploration drilling and hydraulic testing. Locations of recent exploration drilling and hydraulic testing are presented in Section 5.0. The model study area is substantially larger than the Rosemont Project area to enable a better understanding and representation of the hydraulic connection between the fractured bedrock flow system in and around the Rosemont Project area and the surrounding regional groundwater flow system. The model study area incorporates the Rosemont Project area, extends west to incorporate the full width of the northern Santa Rita Mountain range, extends north to incorporate Davidson Canyon, and extends south and east to incorporate most of Cienega Creek basin (Figure 2). This encompasses areas of potential concern along Cienega Creek and Davidson Canyon.
Investigations by M&A included exploration drilling, hydraulic testing, groundwater level monitoring, literature reviews, and development of a numerical groundwater flow model. The finite-difference code MODFLOW-SURFACT (HydroGeoLogic, 1996) was used for groundwater model investigations. The model is designed to simulate groundwater conditions prior to pit development, during pit dewatering, and during post-closure groundwater level recovery and potential pit lake development. The model predicts pit dewatering requirements, pit lake formation timeframe, groundwater inflow rates that will contribute to the pit lake water balance, equilibrium pit lake water level, and whether the pit lake will be a hydrologic sink or a flow-through pit lake. The model is also used to evaluate the potential for groundwater impacts to the local low-conductivity flow system in the area of the pit and to the adjacent regional system.
2.0 LOCATION OF STUDY AREA

The proposed Rosemont facilities are located in the Helvetia/Rosemont Mining District on the eastern slope of the northern Santa Rita Mountains, approximately 30 miles southeast of Tucson, Arizona, 7 miles south of the community of Corona de Tucson (located on the opposite side of the Santa Rita ridgeline from the Rosemont Project area), and 12 miles north-northwest of the town of Sonoita (Figure 2). The pit and associated tailings and waste rock impoundments are in the drainage areas of Barrel Canyon, including McCleary and Wasp Canyons, which are tributary to Davidson Canyon, situated on Rosemont patented mining claims, Rosemont unpatented mining claims, Rosemont fee land, and U.S. Forest Service land. The site is accessible from Highway 83, approximately 10 miles south of Interstate-10. For purposes of this report, a Rosemont Project area has been defined as the area approximately incorporating all planned mine facilities and areas of recent exploration drilling and hydraulic testing. Locations of recent exploration drilling and hydraulic testing are presented in Section 5.0.

The model study area encompasses upper Cienega Creek basin, lower Cienega Creek basin including Davidson Canyon, and a small portion of the Tucson (upper Santa Cruz) basin (Figure 2). Mountain ranges within in the model study area include the Santa Rita, Empire, Whetstone, and Mustang Mountains. Land surface elevations range from about 6,284 feet msl at Weigles Butte (Santa Rita Mountains) to about 3,100 feet msl in the northwestern part of the model study area in the Tucson basin.
3.0 HYDROGEOLOGIC FRAMEWORK

3.1 HYDROGEOLOGIC INVESTIGATIONS

M&A conducted extensive drilling and hydraulic testing to characterize the hydrogeology of the Rosemont Project area. Detailed evaluations of the hydrogeologic conditions in the area are presented in M&A reports (2007, 2009a, and 2009b). The occurrence, thickness, geometry, and structural features of the rock units in the proximity of the Rosemont Project area are also described in regional reports by Drewes (1971, 1972a and 1972b), Hardy (1997), Ferguson and others (2001), Johnson and Ferguson (2006), Daffron and others (2007), Ferguson (2009) and Ferguson and others (2009). Information on geologic conditions and structure for the immediate vicinity of the proposed Rosemont open pit was provided by Rosemont Copper (written communication, 2008). Geologic map information in the Rosemont Project area was verified in the field by Rosemont and M&A geologists. The hydrogeologic conditions in the vicinity of the Rosemont Project area were described in earlier reports by Harshbarger and Hargis (1976), Harshbarger & Associates (1980 and 1981), and Hargis & Montgomery (1981 and 1982).

Regional geology of Cienega Creek basin was evaluated using studies by the U.S. Geological Survey (Finnell, 1971; and Drewes, 1980) and the Arizona Geological Survey (Johnson and Ferguson, 2007; Spencer and others, 2001; Ferguson and others, 2001; Ferguson, 2009; and Ferguson and others, 2009). Characterization of hydrogeology for these investigations was further supported by geologic and drillers’ logs from selected wells in the regional model study area.
3.2 HYDROGEOLOGY OF THE ROSEMONT PROJECT AREA

Hydrogeology in the Rosemont Project area is characterized as fractured and faulted Paleozoic sedimentary and Mesozoic sedimentary and volcanic rocks, bounded on the west by competent Precambrian intrusive rocks comprising the core of the Santa Rita Mountains, and bounded to the southeast by unfractured, strongly cemented basin-fill deposits. A geologic features map for the project area is shown on Figure 3. Strata encountered during drilling in the immediate vicinity of the proposed mine have been inclined, folded, and faulted during several periods in geologic history, and have also been chemically and physically altered to varying degrees by intrusive activity, metamorphism, and copper mineralization in the area. Most of the porosity and hydraulic conductivity in formations penetrated by wells in the Rosemont Project area is secondary, being strongly controlled by fracture and fault zones. Cementation associated with carbonate rocks and alteration associated with intrusive activity have eliminated much of the primary porosity and hydraulic conductivity. Except at shallow alluvium wells constructed in Barrel Wash, all of the rock units encountered during drilling (M&A, 2009a) are moderately to strongly lithified. However, some borehole instability occurred where abundantly fractured or faulted zones were encountered. Wells completed in these zones have larger hydraulic conductivity and produce water at larger rates than wells completed in less fractured or faulted zones.

The majority of the proposed pit will be completed in a structurally deformed, faulted, and fractured bedrock complex. In the southeast area of the proposed pit, upper excavated levels will intercept strongly-cemented basin-fill deposits. The bedrock complex and cemented basin-fill deposits are characterized as having low hydraulic conductivity. In the bedrock complex, groundwater movement is controlled by discontinuous fractures and discrete faults. In the cemented basin-fill deposits, groundwater flow typically occurs in the pore space between sediment grains; however, the pore space has been largely filled by cementation. Results of hydraulic testing in the area of the proposed pit indicate there are weak to strong degrees of local hydraulic connection in the bedrock complex inside and
surrounding the proposed pit location, which likely will result in groundwater inflows to the pit. However, at distances from the proposed pit area, long-term hydraulic testing indicates limited hydraulic connectivity. Hydraulic connectivity within and between the larger bedrock complex and cemented basin-fill deposits system tends to be low and as such mitigate lateral extent of drawdown impacts. To the west, the Precambrian granodiorite core of the Santa Rita Mountains is competent, with minimal fracturing or faulting and low hydraulic conductivity, based on drillhole data (J. Cornoyer, verbal communication, 2009).

### 3.3 REGIONAL HYDROGEOLOGY

The mountain ranges surrounding the Cienega Creek basin are made up chiefly of well-lithified pre-Tertiary bedrock. This includes Precambrian intrusive and metamorphic rocks, Paleozoic sedimentary rocks, Mesozoic sedimentary and volcanic rocks, and Laramide intrusive rocks. Most of the pre-Tertiary rocks are well-lithified and competent, having little or no primary porosity or permeability. Groundwater, where present in the bedrock complex, occurs chiefly in joints, fractures, and fault openings. The hydraulic conductivity of the rock in any given area is a function of the fracture density, fracture size, and degree of fracture interconnection. Water wells drilled in the bedrock areas generally have much smaller yields than wells drilled in alluvial basins.

The basins are filled with thick sequences of sedimentary deposits of Tertiary to Quaternary age. The deepest Tertiary sediments in the basins may include well-cemented older deformed units deposited prior to the formation of the basin. Above these are progressively younger, less deformed sediments deposited after basin formation. The youngest sediments of Quaternary (Recent) age are flat-lying and generally not cemented. Groundwater is relatively more abundant in the central parts of the alluvial basins within the model study area than in the other rock units.
3.4 MODEL HYDROGEOLOGIC UNITS

For model simulation purposes, the geologic units within the model study area are grouped into the ten hydrogeologic units. Simplifying assumptions are made to assemble similar units, based on generalized lithology, into distinct groups that have similar hydraulic properties, age, lithologic properties, and areal extent within the model area.

The ten hydrogeologic units in the model study area, listed according to age, are defined as:

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

A Rosemont Project area map depicting distribution of the 10 hydrogeologic units is shown on Figure 4. Comparison of the project area geologic features map (Figure 3) illustrates how individual geologic units correspond to the 10 assigned hydrogeologic units. Figures 5 and 6 depict both geologic and corresponding hydrogeologic units along sections A-A’ and B-B’, respectively, through the project area.

Distribution of the 10 hydrogeologic units over the model study area is shown on Figure 7. Figure 8 depicts hydrogeologic units along sections C-C’ and D-D’, through the model study area. Geologic sections generated by Rosemont geologists and augmented by recent exploration drilling were used to develop a three-dimensional distribution of the 10 hydrogeologic units for the model study area. Distributions of hydrogeologic units at decreasing elevations from 5,400 to 2,400 feet msl, depicted at 200-foot intervals, are shown
on Figures 9 through 24, respectively. Hydrogeologic units at the 5,400 foot msl altitude (Figure 9) include the highest observed groundwater levels in the model area. The proposed pit bottom is at the 3,050 foot msl elevation.

### 3.4.1 Recent Alluvium (Qal)

The Recent alluvium generally consists of unconsolidated sand, gravel, and silt deposits along ephemeral wash channels or occurring as a thin veneer of unsaturated sediment overlying older rock units in the upland areas. Groundwater intermittently or ephemerally present in the wash channel deposits occurs under unconfined conditions. When water is present during or after storm runoff, these deposits provide short-term storage of water which infiltrates downward into older rocks and/or which migrates downstream through the Recent alluvium.

In the lower Cienega Creek basin south of and adjacent to Interstate-10, 15 miles northeast of the proposed pit, a thick coarse-grained zone of Recent alluvium is present in an area of shallow groundwater. In this area, the Recent alluvium is an important aquifer and has the largest known hydraulic conductivity in the model area. Groundwater occurs in the Recent alluvium along much of upper Cienega Creek. The Recent alluvium along other drainage channels, including Davidson Canyon and Barrel Canyon, is intermittently or ephemerally saturated.

### 3.4.2 Late Tertiary and Quaternary Basin-Fill Deposits (QTg, QTg1, and QTg2)

The Late Tertiary and Quaternary basin-fill deposits comprise the principal aquifer in the upper Cienega Creek basin and Tucson basin. Aquifer hydraulic parameters in these sediments are highly variable.
The deepest Tertiary sediments in the model area include some well-cemented, older, deformed units deposited prior to the formation of the basin, but younger than the Pantano Formation. Above these are progressively younger, less deformed sediments deposited in conjunction with down-faulting that occurred during formation of the regional basins. The younger sediments tend to be less cemented and have larger permeability. Therefore, aquifer permeability within the basin-fill deposits tends to be largest in the younger, shallower sediments and tends to decrease with depth. Aquifer permeability can also be lower in basin-fill deposits where silt and clay content is large. Sediments deposited in areas with low relief and flatter topography tend to have proportionately larger silt and clay contents. This condition is more common toward the interior of an alluvial basin where sediments are typically deposited under low energy conditions.

For purposes of groundwater flow modeling, the basin-fill deposits in the model area are subdivided into three different hydrogeologic units, based on inferred or known permeability. The younger and more permeable basin-fill deposits are designated as QTg on the surface and subsurface maps. Sequences of basin-fill deposits with a smaller permeability than QTg were designated as QTg1. These sediments include older, cemented basin-fill, or basin-fill with large clay content. Basin-fill sediments occurring in the southeast part of the pit area, designated as QTg2, are more strongly cemented than QTg1 sediments, due to age and proximity to Paleozoic carbonate rocks. The cemented QTg2 sediments were deposited substantially after faulting and mountain-building activity in the area, and the sediments are not substantially fractured or faulted, contributing to their low hydraulic conductivity.

The depth of basin-fill deposits in the upper and lower Cienega Creek basins and Tucson basin and is interpreted from two basic sources of information: site-specific geologic and lithologic data obtained from drilling and regional depth-to-bedrock maps developed from gravity data. Where drilling data is available and considered to be reliable, well logs are used to infer the thickness of basin-fill deposits (and alluvium) and the depth to
underlying bedrock. Drilling information, where available, is used to refine the interpretations of gravity data obtained from the depth to bedrock map developed by Oppenheimer and Sumner (1980), and from gravity mapping of the lower Cienega Creek basin (Ellett, 1994).

### 3.4.3 Early to Mid-Tertiary Sedimentary and Volcanic Rocks (Tsp)

The Early to Mid-Tertiary sedimentary and volcanic rocks are mostly associated with the Pantano Formation in the model area. The Pantano either directly underlies much of lower Cienega Creek or underlies younger sediments near the creek. Besides the lower Cienega Creek basin and Davidson Canyon area, small exposures of Pantano Formation are found in the northern Santa Rita Mountains, east of the Rosemont Project area, and in the southwest part of the Whetstone mountains. Except for the area around the lower Cienega Creek basin to the north and northeast of the Empire Mountains, the Pantano Formation is not considered hydrogeologically significant in the model area. The low permeability of the shallow Pantano Formation in the lower Cienega Creek basin forces overlying groundwater to the surface.

### 3.4.4 Upper Cretaceous and Early Tertiary Intrusive Rocks (KTi)

The Upper Cretaceous and Early Tertiary (Laramide) intrusive rocks are generally restricted to the northern Santa Rita and Empire Mountains. These units have very low primary porosity or permeability, but will store and transmit small quantities of water where fractured or faulted. The Laramide intrusive rocks consist of quartz monzonites, granodiorites, quartz latite porphyries, and diorites.
3.4.5 Upper Cretaceous Volcanic and Sedimentary Rocks (Kv)

The Upper Cretaceous volcanic and sedimentary rocks are an important unit in the northeast part of the Santa Rita Mountains but are relatively uncommon in other parts of the model area. They are well-lithified and have very low primary porosity and permeability, except where fractured or faulted.

The Upper Cretaceous volcanic and sedimentary sequence consists of the Salero Formation, the Hilton Ranch conglomerate, and the Fort Crittenden Formation. There is a substantial unconformity between the Upper Cretaceous sediments and the underlying Lower Cretaceous Bisbee group sediments. The Fort Crittenden Formation is the basal unit of the Upper Cretaceous sequence. It consists of boulder conglomerate and pebbly sandstone. The Fort Crittenden is not found at all locations in the model area and is not present in the vicinity of the proposed Rosemont Project area. The Hilton Ranch conglomerate, found in the Empire Mountains, is considered correlative with the Fort Crittenden Formation (Schafroth, 1968). The Fort Crittenden Formation is overlain by volcanic breccias of the Salero Formation, without any apparent break in deposition (Ferguson and others, 2001). The Salero Formation in the Santa Rita Mountains consists of a basal unit of andesitic to dacitic lava and breccia, overlain by a thick sequence of silicic ash-flow tuff and welded tuff called the Mt. Fagan Rhyolite. In approximately 75 percent of the area where it occurs, the Mt. Fagan Rhyolite contains very large lithic blocks composed of older units, including rocks of the Bisbee Group, the Fort Crittenden Formation, and the basal andesite. The Mt. Fagan Rhyolite grades upward into a sequence of sedimentary and tuffaceous rocks which are mapped as part of the Salero Formation (Drewes, 1981).

3.4.6 Lower Cretaceous Sedimentary Rocks (Bisbee Group) (Ksd)

The Lower Cretaceous age sedimentary rocks of the Bisbee Group outcrop over large areas of the model study area and are a very important hydrogeologic unit in the area. Rocks
of the Bisbee Group tend to have very low primary porosity and permeability. An exception to this is the Glance Conglomerate, which locally appears to have moderate primary permeability. Bisbee Group rocks are deformed over much of the model study area, but less so than the Paleozoic rocks. In some areas, they are locally fractured, providing secondary permeability.

The Bisbee Group is a mixture of non-marine and marginal marine sedimentary units. The Bisbee Group is made up of five formations in the model area. These are, from youngest to oldest, the Turney Ranch Formation, Shellenberger Canyon Formation, Apache Canyon Formation, Willow Canyon Formation, and Glance Conglomerate (Schafroth, 1968). The Turney Ranch Formation is an intercollated sequence of thin to thick bedded sandstones, siltstones and shales. The Shellenberger Canyon Formation consists of arkosic sandstone, thin-bedded siltstones, and shales. The Apache Canyon Formation is made up of thin bedded, organic-rich limestones, siltstones, and shales. The Willow Canyon Formation is primarily an arkosic sandstone and arkosic sandstone conglomerate. In the Rosemont Project area, the Willow Canyon includes a local andesite unit which can be a few tens of feet up to a few hundred feet thick. The Glance Conglomerate has two facies, one of which is comprised of eroded Paleozoic carbonate rock, while the other facies is comprised largely of Precambrian granitic rock fragments.

Bisbee Group rocks, particularly the Willow Canyon Formation, were penetrated by a minimum of eight wells in the vicinity of the proposed Rosemont Project on the east side of the Santa Rita Mountains. Aquifer testing showed that hydraulic conductivities in these wells vary by more than three orders of magnitude. Because rocks of the Bisbee Group have little to no primary permeability, the large range of variation in hydraulic conductivity is attributed to variations in the degree of faulting and fracturing present at the completed depth in each well. Similar variations in permeability are apparent from aquifer testing conducted at wells completed in Paleozoic units and in the Salero Formation.
The Bisbee Group rocks outcrop extensively along the eastern and northern slopes of the Santa Rita Mountains. They cover a large area around the Empire Mountains and in the west-central part of the Whetstone Mountains. In addition, Bisbee Group rocks are known to underlie the basin-fill deposits in much of the upper Cienega Creek and Tucson basins.

### 3.4.7 Paleozoic Sedimentary and Altered Sedimentary Rocks (Pz)

The Paleozoic sedimentary rocks outcrop in all of the mountain ranges within the model area. These units have little to no primary porosity and permeability, but will store and transmit water where fractured or faulted. They tend to be much more deformed and fractured than younger rocks in the model area. Early Mesozoic rock units are rare and outcrop over very small areas in the model area. Because these units occur with the Paleozoic rock and tend to have similar hydraulic characteristics, the Paleozoic and Early Mesozoic rocks were grouped into the same model hydrogeologic unit.

The Paleozoic rocks in the model area include limestone, dolomitic limestone, and dolomite, along with lesser amounts of sandstone, conglomerate, shale and siltstone. Many of the limestone rocks in the Rosemont Project area have been altered and/or metamorphosed to skarn or marble. The Paleozoic Formations present in the model area, from youngest to oldest are: the Naco Group (Permian and Pennsylvanian), Black Prince Limestone (Mississippian or Pennsylvanian), Escabrosa Limestone (Early Mississippian), Martin Limestone (Late Devonian), Abrigo Formation (Middle to Late Cambrian), and Bolsa Quartzite (Middle Cambrian). The Naco group is subdivided into: Rain Valley Formation (Permian), Concha Limestone (Permian), Scherrer Formation (Permian), Epitaph Formation (Permian), Colina Limestone (Permian), Earp Formation (Pennsylvanian/Permian), and the Horquilla Limestone (Pennsylvanian).

Paleozoic rocks outcrop occur within and north of the Rosemont Project area, along the eastern slopes of the Santa Rita Mountains where they are extensively faulted and are
steeply dipping at angles typically in the range of 60 to 80 degrees. Limestone units of the
Naco group, particularly the Horquilla Limestone, are the host rock for copper mineralization
in the Rosemont area. Mineralizing fluids severely altered the Paleozoic rocks in the vicinity
of the intrusion that created the orebody. Paleozoic rocks are also abundant in the Empire,
Whetstone, and Mustang Mountains, and northern part of the Canelo Hills.

3.4.8 Precambrian Basement Rocks (pCb)

The Precambrian basement rocks are the oldest rock units known to occur in the
model area. They were heavily eroded in the Late Precambrian era and were exposed when
the earliest Paleozoic marine rocks were deposited. These crystalline rocks have little to no
primary porosity or permeability and are a generally considered a barrier to groundwater
movement, except where fractured or faulted. The primary Precambrian rock units in the
model area are the Continental Granodiorite and the Pinal Schist (Drewes, 1980).

The Continental Granodiorite is the principal Precambrian rock unit in the model
area. It outcrops extensively on the western slopes of the Santa Rita Mountains near the
Rosemont Project area. The Continental Granodiorite also outcrops in the pediment area
north of the Empire Mountains and in the northern part of the Whetstone Mountains. The
Pinal Schist is less abundant in the model area. It is present in small areas on the west side of
the Santa Rita Mountains, the Whetstone Mountains, and north part of the Empire
Mountains.

3.5 FAULTING AND FRACTURING IN MODEL AREA

Geologic structure and faults identified in and around the Rosemont Project area from
previous geologic investigations are delineated on Figure 3. The density of faulting and
fracturing is greatest in the area of maximum structural deformation along the ridge and
eastern flank of the Santa Rita Mountains in the Rosemont Project area. Here the Paleozoic rock units which outcrop are heavily faulted and fractured, with dips generally between 60 and 90 degrees. The density of faulting and fracturing decreases with distance to the east of the ridge. Mesozoic rocks of the Bisbee Group outcropping east of the Paleozoic units tend to be less faulted and fractured and are less steeply dipping than the Paleozoic units, with dips generally between 30 and 60 degrees.

Results of hydraulic testing and measured groundwater levels in the Rosemont Project area and the larger model area were evaluated to determine whether faulting acts as a substantial barrier(s) or conduit(s) for groundwater movement. Identification and characterization of individual faults that substantially impact groundwater movement is difficult based on available data. There is a strong relationship between degree of fracturing in the bedrock complex and hydraulic conductivity; variation in fracture intensity results in zones of variable hydraulic conductivities in the Rosemont Project area. Occurrence of these heterogeneities, in terms of aquifer regions delineated essentially by geologic structure and lithology, is documented in M&A (2009b).

Investigations have identified the high-angle faulted zone in the Paleozoic units along the Santa Ritas and the low-angle fault between the Willow Canyon Formation and the underlying Paleozoic units as two structural features which have a substantial degree of control over movement of groundwater in the Rosemont Project area. The high-angle faulted zone is identified as the “Backbone Fault” and the low-angle fault is identified as the “Flat Fault”; both are shown on Figures 5 and 6. The entire Backbone Fault and portions of the Flat Fault are considered to be higher conductivity zones relative to the surrounding rock formation. The Flat Fault intersects the Backbone Fault and aquifer data indicate a hydraulic connection between the faults.

The Backbone Fault is a complex structural assemblage of thrust faults, high angle normal faults and tear faults which forms the western edge of the east dipping block of
Paleozoic sediments that include the Rosemont copper deposit (Anzalone, 1995). The faults dip in an easterly direction at variable angles up to 90 degrees (Figures 5 and 6). This fault system is associated with a zone of increased hydraulic conductivity in both a north-south and vertical direction, parallel to the ridge. Hydraulic conductivity perpendicular to the fault lineage is smaller than the north-south and vertical conductivities.

The Flat Fault at the base of the Willow Canyon Formation in the proposed pit area originated as a large displacement normal fault. Subsequent tilting of the strata in the area rotated this fault to a low angle, giving it the appearance of a low-angle thrust fault. The fault is present on the surface, at the contact between the Willow Canyon and the Paleozoic units. The fault dips in an easterly direction at variable angles up to about 20 degrees and may facilitate movement of groundwater east from the Santa Ritas. The Willow Canyon Formation, which overlies the fault, has a smaller average hydraulic conductivity than the fault and acts as a confining unit. Artesian conditions are present in two wells (PC-2 and PC-5) which are screened across the fault. Conclusions about the extent of the Flat Fault zone of relatively higher conductivity are as follows:

- Based on results of aquifer testing, this low-angle fault forms an apparent zone of increased hydraulic conductivity over the approximate northern-half of the pit area.
- In the south portion of the pit, lack of response to the PC-5 long-term pumping test in observation wells PC-3 and PC-4, as well as results of model calibration to the pumping tests, indicate that the hydraulic influence of the Flat Fault does not substantially extend to the south.
- In the north portion of the pit, response to PC-5 pumping observed in well PC-6 indicate larger hydraulic conductivity associated with the Flat Fault. Lack of response in observation well HC-5B prior to pumping in well HC-5A indicated a lack of connection between PC-5 and HC-5B; therefore, in the model the extent of the flat fault to the north is limited to slightly north of PC-6.
• East from the pit, the hydraulic conductivity of the Flat Fault is unknown. Measured groundwater levels and steep hydraulic gradients in the pit area, and results of steady-state model calibration (described later), do not support the concept that the Flat Fault acts as a higher conductivity drain extending substantially to the east from the pit area. The Flat Fault is believed to decrease in conductivity east from the pit, with depth. This is consistent with the concept that the Flat Fault is more conductive in vicinity of the faulting along the east side of the Santa Ritas (in the pit area).

Based on interpretation of groundwater levels and geologic data, the Davidson Canyon fault is determined to represent a higher hydraulic conductivity zone relative to the surrounding rock formations. The fault is inferred to occur northeast from the proposed pit, trending north along the Canyon (Figure 3). The fault separates the Santa Rita and Empire Mountains, consisting of at least two major faults where the west side is down-dropped as much as 3,000 meters near Interstate-10 (Ferguson and others, 2001). The eastern fault can be traced south across the northern and western pediment of the Empire Mountains, approximately 1 mile east of Davidson Canyon. The western fault trace is concealed by alluvium (Ferguson and others, 2001).
4.0 GROUNDWATER CONDITIONS

4.1 OCCURRENCE OF GROUNDWATER

Groundwater in the Rosemont Project area is found in relatively limited quantities in:
(1) older Tertiary, Mesozoic, and Paleozoic rocks of the Santa Rita Mountains; (2) Late
Laramide and Precambrian crystalline rocks of the Santa Rita Mountains; and (3) strongly
cemented basin-fill deposits on the western margin of basin fill deposits in Cienega Creek
basin. In the regional setting, groundwater occurs in these rock types along the margins of
Cienega Creek basin, with the majority of groundwater stored in basin-fill deposits and in
shallow Recent alluvium occurring along the principal surface water drainage channels.

4.1.1 Older Tertiary, Mesozoic, and Paleozoic Sedimentary Rocks

The older Tertiary, Mesozoic, and Paleozoic rocks are generally consolidated and
have a weakly permeable rock matrix. Groundwater in these rock units occurs chiefly in
joints, fractures, and faults. Groundwater in the older Tertiary and Mesozoic rocks occurs
under unconfined to semi-confined conditions. Groundwater in the Paleozoic rocks probably
occurs under unconfined to locally confined conditions. In some cases, groundwater levels
in drillholes and wells that penetrate the Paleozoic rocks in and near the proposed pit area are
higher than in the Mesozoic rocks by a few feet to several tens of feet. In a few cases in the
Rosemont pit area, groundwater levels in the Paleozoic rocks are above land surface, causing
the drillholes or wells to flow or seep when uncapped. These elevated groundwater levels
may be associated with the presence of the Flat Fault and/or other faults in the vicinity of the
Rosemont pit.

Based on pumping tests conducted in the Rosemont Project area in 2007 and 2008
(M&A, 2009a), well yields from wells that penetrate the older Tertiary, Mesozoic, and
Paleozoic rock units range from less than 1 to more than 50 gpm. Due to the discontinuous nature of rock units and of faults and fractures, effects of locally enhanced permeability may be limited to small areas.

### 4.1.2 Precambrian and Laramide Intrusive Rocks

Granitic and granodioritic rocks in the model area are generally Precambrian and Laramide in age. These rocks make up the core of the Santa Rita and Whetstone mountain ranges, and are also present in the north end of the Empire Mountains. As with most mountain ranges in southern Arizona, these crystalline rock units have extremely low permeability and groundwater storage. The rocks contain retrievable groundwater chiefly in fractures (Montgomery and Harshbarger, 1992). Very few wells in the model study area are completed in these rock units, and reported well yields range from near zero to a few gallons per minute. These granitic rock units are expected to act as a barrier to groundwater flow in the Rosemont Project area.

### 4.1.3 Basin-Fill Deposits

The basin-fill deposits occur in the upper Cienega Creek basin between the Santa Rita and Whetstone Mountain ranges and extend between the Cienega Creek “narrows” and the community of Sonoiita, and as far west as the Rosemont Project area. Basin-fill deposits also occur north and west of the Santa Rita Mountains in the upper Santa Cruz (Tucson) basin (Figure 7). The basin-fill deposits are partially saturated and generally unconfined. In the Empire Ranch area, Harshbarger & Associates (1975) indicate the basin-fill deposits are semi-confined, likely due to confining layers created by discontinuous clay strata. In the vicinity of the Rosemont Project, the basin-fill deposits are strongly cemented, unfractured, and poorly permeable. In the upper Cienega Creek basin, thickness of basin-fill deposits ranges from 250 to more than 1,500 feet (Harshbarger & Associates, 1975). Contours of depth to bedrock are shown on Figure 7. The deeper sequences of the basin-fill deposits are
probably underlain by older Tertiary sedimentary and volcanic rock units. Wells that penetrate the basin-fill deposits typically yield from near zero in areas where the deposits are very thin and/or strongly cemented (margins of the basin) to several hundred gpm in the areas where the deposits are thick and/or less cemented (central parts of the basin). In general, well yields increase with distance from the Rosemont Project area and with the thickness of the deposits.

4.1.4 Recent Alluvium

The Recent alluvial deposits generally consist of unconsolidated sand, gravel, and silt in varying proportions, along the main surface water channels and their principal tributaries. Along Barrel Wash and tributary ephemeral drainage channels in the Rosemont Project area, groundwater is present on a temporary basis in the Recent alluvial deposits, generally during or following substantial or prolonged storm events. Similar conditions occur along Davidson Canyon north and east of Rosemont, although there may be some areas locally along Davidson Canyon where groundwater is present in the Recent alluvium on a relatively permanent basis. Along the perennial reaches of Cienega Creek, groundwater is generally always present in the Recent alluvium. Where and when saturated, groundwater occurs under unconfined conditions, and locally provides water supply to floodplain vegetation. In the model study area, the thickness of Recent alluvium may range from a few feet along smaller drainage channels to nearly 200 feet along Cienega Creek (Boggs, 1980). Except along Cienega Creek, the Recent alluvium does not generally provide a reliable source of water supply to wells. Along Cienega Creek, wells completed in the Recent alluvium yield from about 10 to 400 gpm (Boggs, 1980; Ellett, 1994).
4.2 GROUNDWATER LEVELS AND GROUNDWATER MOVEMENT

4.2.1 Rosemont Project Area

Based on measurements obtained in approximately 70 wells, piezometers, and drillholes during the period from 1975 through 2008, the measured piezometric groundwater levels in the immediate vicinity of the proposed pit ranged from about 34 feet above land surface (als) at well (D-18-16)30cdc[PC-2] in the proposed pit area to more than 400 feet below land surface (bls) at drillhole (D-19-16)4dbb [DH-1541], located southeast of the proposed Rosemont Project (M&A, 2009a; Hargis & Montgomery 1981 and 1982; Harshbarger & Associates, 1980; and Harshbarger & Hargis, 1976). Most of the drillholes installed by Anamax in the 1970s have since been abandoned or destroyed and are not available for measuring current groundwater levels. Historic and recent groundwater level measurements in Rosemont Project area wells, piezometers, and drillholes are summarized in M&A (2009a). These data indicate that recent groundwater levels are generally higher than in 1975. Because precipitation in 1975 was generally much lower than average, it is reasonable to assume that groundwater recharge was also lower than average.

Contours of August through September 2008 groundwater level altitudes for the Rosemont Project area have been reproduced from the M&A report (2009a) and are shown on Figure 25. Elevation of groundwater level in the Rosemont Project area ranged from more than 5,400 feet msl near the ridgeline west of the proposed pit to about 4,249 feet msl near monitor well (D-18-16)15aaa[RP-7], approximately 3 miles northeast of the proposed pit. Data for wells and piezometers constructed in the Rosemont Project area during 2007 and 2008 are summarized in Table 1. Construction data for these wells and other selected wells in the model study area are summarized in Table 2. The direction of groundwater movement in the bedrock areas appears to be strongly influenced by topography. The general direction of groundwater movement in the area of the proposed facilities is toward the east from the topographic divide, but gradually transitions to the northeast with distance.
to the east. West of the topographic divide along the Santa Rita ridge, groundwater movement is generally toward the west.

Zones of relatively larger hydraulic conductivity were encountered along the Backbone Fault and the west portion of the Flat Fault (Figures 5 and 6) during a 30-day aquifer test conducted during December 2008. The steeply dipping structure of the Backbone Fault zone is believed to enhance groundwater recharge and downward movement of groundwater along the east side of the Santa Ritas, in the area of the proposed pit. The Flat Fault is believed to enhance groundwater movement at depth, from west to east across the proposed pit area. Artesian conditions encountered at wells PC-2 and PC-5 support the concept that the Willow Canyon Formation, which overlies the Flat Fault, acts as a confining unit to groundwater movement associated with the Flat Fault.

4.2.2 Model Study Area

Based on groundwater level data for several hundred wells included the Arizona Department of Water Resources (ADWR) Groundwater Site Inventory (GWSI), along with data presented in M&A (2009a), the measured piezometric groundwater levels in the model study area range from 34 feet als at well (D-18-16)30cdc[PC-2] in the proposed Rosemont Project area to nearly 700 feet bsls in the northwest part of the study area near Corona de Tucson. Groundwater levels in the vicinity of proposed pit are less than 300 feet bsls, with groundwater levels at more than half the wells being less than 100 feet bsls. In general, groundwater levels in the model study area tend to be shallowest at topographically lower elevations and/or where perennial or intermittent surface water is present, such as along Cienega Creek. In the northernmost part of the Las Cienegas Conservation Area (Empire Ranch), groundwater levels are commonly less than 10 feet bsls. Elsewhere along Cienega Creek, groundwater levels are a few to several tens of feet bsls. A few deep wells in the Las Cienegas Conservation Area in the upper Cienega Creek basin have anomalously high groundwater levels that are above land surface, indicating that confined to semi-confined
conditions occur locally at depth. Groundwater levels in the model study area tend to be
deepest near the basin margins and on mountain slopes. In areas of very low transmissivity
and low well yield, groundwater levels in frequently pumped wells can be artificially
depressed by several tens to hundreds of feet, due to incomplete recovery of water levels
between pumping cycles.

Contours of groundwater level altitude for the model study area are shown on
Figure 26. These contours are developed chiefly using groundwater level data from the
ADWR GWSI database, and groundwater level data from M&A (2009a), Hargis &
Montgomery (1981 and 1982), Harshbarger & Associates (1980), and Harshbarger & Hargis
(1976). In areas where limited or no groundwater level data are available, selected
groundwater levels reported in the ADWR 55 and 35 well registries are used as a guide for
developing groundwater level contours. In the immediate Rosemont Project area, contours
are slightly modified from those shown on Figure 25, reflecting improved understanding of
the groundwater flow system in this area.

Elevation of groundwater level in the model study area ranges from more than
5,400 feet msl, just southwest of the proposed pit, to less than 2,600 feet msl in the northwest
corner of the study area in the Tucson basin. West of Cienega Creek, direction of
groundwater movement is generally eastward to northeastward. East of Cienega Creek,
direction of groundwater movement is generally toward the northwest. In the northeastern
part of the study area, near the downstream end of Cienega Creek, the direction of
groundwater flow transitions toward the west. In the northwestern part of the study area,
direction of groundwater flow transitions to the northwest.

Approximately 3 to 4 miles northeast from the proposed pit and continuing
downstream along Davidson Canyon Wash, groundwater levels indicate a trough coincident
with intersection of the Canyon with groundwater level and with the Davidson Canyon fault
zone, which is assumed to have a higher permeability than the surrounding bedrock (Figure 26).

Alteration of groundwater recharge in the Project area due to proposed tailings and waste rock facilities, and infiltration from constructed drains and a retention basin, is described in Section 7.4.2.

4.3 GROUNDWATER RECHARGE AND DISCHARGE

4.3.1 Precipitation Recharge

Historical information on precipitation in the vicinity of the Rosemont Project area is limited with respect to location and periods of record. Average annual precipitation for the Rosemont town site was estimated at approximately 16 inches by Sellers and Hill (1974) from 1931 through 1970. Based on records available from the Western Regional Climate Center (2009), average annual precipitation for Helvetia for the period 1916 through 1950 was 19.73 inches. More recent data shows that average annual precipitation for the Santa Rita Experimental Range from 1950 through 2005 was 22.18 inches. The average annual precipitation for Canelo 1 NW (located 12 miles southeast from Sonoita, near the town of Canelo) for the period 1910 through 2007 was 18.10 inches (Western Regional Climate Center, 2009). More than half of the precipitation recorded at these stations fell during the months of July, August, and September. The months with the least recorded precipitation are April, May, and June.

Rosemont Copper installed an onsite weather station that began recording meteorological data in April 2006. This station is monitored and maintained by Applied Environmental Consultants. The monitoring program includes data processing and instrument audits, calibrations, and maintenance. The station records site specific weather data including temperature, precipitation, wind speed, and wind direction. Equipment for
monitoring pan evaporation was added to this station in mid-2008. The station is located at the approximate center of the proposed open pit at an elevation of 5,350 feet msl. Average annual precipitation at the Rosemont weather station during the brief period of record (2006-2009) is 17.12 inches.

Precipitation data obtained from weather stations located within an approximate 30-mile radius of the Rosemont site were evaluated and analyzed by Tetra Tech (2009). Tetra Tech determined the average annual precipitation for the Rosemont site to be 17.37 inches, based on a fairly short period of record. Average annual precipitation on the Santa Rita Experimental Range was is 22.19 inches for a much longer period of record. To be conservative, for the purposes of this model, the Santa Rita Experimental Range average annual precipitation number was incorporated into the model.

4.3.2 Groundwater Recharge

Previous Investigations

Total annual recharge in the Cienega Creek basin has been estimated in previous hydrologic studies. M&A (1985) estimated that annual recharge in the basin may range from 6,900 to 19,500 acre-feet per year (AF/yr). ADWR (2004) estimated that annual recharge in the basin may range from 8,500 to 25,500 AF/yr. Freethey and Anderson (1986) estimated an annual recharge rate of 11,000 AF/yr.

For the upper Cienega Creek basin, Knight (1996) estimated an annual recharge rate of 12,000 AF/yr and Bota (1997) estimated an annual recharge rate of about 15,000 AF/yr.

For the lower Cienega Creek basin, M&A (1985) estimated that the annual recharge rate may range from about 3,200 to 9,000 AF/yr and also estimated that lower basin recharge is 46 percent of total basin recharge. Chong-Diaz (1995) initially estimated an annual
recharge rate of 2,610 AF/yr, and following model calibration, revised this estimate to 2,200 AF/yr.

**Current Investigation**

For purposes of estimating groundwater recharge via precipitation for the model study area, the method described by Anderson (1995) was used to convert precipitation volume to recharge. The Anderson method is an empirically-based regression analysis of results from numerous groundwater simulations for alluvial basins in southern Arizona to estimate the average basin-wide recharge during an average year. The basins considered by Anderson were alluvial basins, primarily in the southern Arizona Basin and Range province that were treated as relatively pervious alluvial deposits (gravels, sands, silts and clays) over impervious rock. Anderson calibrated their regression equation using numerical groundwater flow simulation results for 12 basins in southeast, south central and western (Colorado River area) Arizona.

An annual precipitation volume estimate of 405,000 AF/yr was calculated for the model study area using Parameter-elevation Regressions on Independent Slopes Model (PRISM) data (Prism Group, 2008) for the years 1971-2000. PRISM is a system that uses point data and a digital elevation model (DEM) to generate gridded estimates of climate parameters including distribution of precipitation (Daly and others, 1994). Total estimated recharge for the model study area computed using the PRISM derived distribution of precipitation and the Anderson method for determining portion of precipitation which can be applied to recharge is 10,100 AF/yr.

Applying the Anderson method to the United States Geological Survey (USGS) delineation of Cienega Creek basin, excluding Tucson basin, yields an estimated recharge rate of 10,426 AF/yr. The model domain does not cover the entire Cienega Creek basin; however, it can be assumed most of the estimated 10,426 AF/yr recharge will inflow to the model domain.
4.3.3 Groundwater Inflow

Previous studies indicate that no substantial amount of groundwater enters the Cienega Creek basin from adjoining areas (Knight, 1996; Bota, 1997).

4.3.4 Groundwater Discharge

Groundwater discharge from the Cienega Creek basin occurs chiefly by four processes: evapotranspiration, groundwater outflow, groundwater pumping, and discharge to surface streams.

Evapotranspiration

The most substantial component of groundwater discharge in the model study area is evapotranspiration (Knight, 1996; Bota, 1997). Evapotranspiration occurs chiefly from riparian areas along Cienega Creek and other areas of shallow groundwater, and to a lesser extent, directly from surface water. M&A (1985) estimated evapotranspiration to be 2,400 AF/yr in upper Cienega Creek basin, 900 AF/yr in the lower Cienega Creek basin, for a total of 3,300 AF/yr for the entire basin. Evapotranspiration in the upper Cienega Creek basin was estimated by Knight (1996) and Bota (1997) to be 2,897 AF/yr. In the lower Cienega Creek basin, evapotranspiration was initially estimated in the Chong-Diaz (1995) groundwater modeling investigation to be 2,610 AF/yr which was revised during model development and calibration to 2,200 AF/yr.

For this investigation, evapotranspiration is further evaluated in order to better quantify distribution over the model study area. Riparian areas, plant types, plant cover density, and riparian plant distributions are estimated from aerial photograph interpretations, previous vegetation mapping by Harris and others (2000), and from field visits by M&A personnel. For simplicity, the selected riparian areas along Cienega Creek and Davidson Canyon are divided into seven zones based on similar vegetation characteristics, such as
plant type and plant cover density. Riparian zones are shown on Figure 27. Riparian vegetation in the study area is divided into plant functional groups (PFGs), which are groupings of plants that have similar responses to environmental conditions and have similar impacts on ecosystem processes (Maddock and Baird, 2003). Annual groundwater consumption for each PFG is estimated based on evapotranspiration measurements obtained by Leenhouts and others (2006) and Maddock and Baird (2003) for riparian plants in the San Pedro River basin and other parts of the desert southwest U.S. The relative distribution of each PFG and plant cover density in each selected riparian zone is summarized in Table 3. Plant functional groups and estimated annual evapotranspiration rates, normalized from a 7-month growing season, are specified for this evaluation as follows:

- Mesquite forest at 1.3 feet per year (ft/yr)
- Cottonwood-willow forest at 1.9 ft/yr
- Sacaton grass at 1.0 ft/yr
- Wetland plants at 1.3 ft/yr
- Shallow-rooted understory at 0.7 ft/yr
- Soil evaporation at 2.0 ft/yr

Groundwater discharge due to riparian evapotranspiration is estimated to be 3,100 AF/yr in upper Cienega Creek, 1,030 AF/yr in lower Cienega Creek, and 115 AF/yr in Davidson Canyon, for a total of 4,245 AF/yr in the model study area, as summarized in Table 3.

**Groundwater Outflow**

Groundwater outflow from the model study area occurs chiefly to the north and northwest into the Tucson basin. Groundwater outflow from the lower Cienega Creek basin was estimated by M&A (1985) to range from about 3,900 to 4,900 AF/yr, chiefly in the Recent alluvium of Cienega Creek. Based on groundwater flow modeling conducted by Chong-Diaz (1995), groundwater outflow from the lower Cienega Creek basin was estimated to be 2,511 AF/yr. Ellett (1994) hypothesizes that about 2,902 AF/yr of the groundwater
discharging from the upper basin flows eastward between the Mustang and Whetstone Mountains to the San Pedro Valley, while the remaining 4,359 AF/yr flows to the lower Cienega Creek basin. Although the eastward discharge from the upper Cienega Creek basin is a possibility, this current investigation did not find evidence to support that hypothesis. Ellett’s estimated discharge to lower Cienega Creek basin is consistent with the Chong-Diaz (1995) estimate of 4,350 AF/yr.

**Groundwater Pumping**

Groundwater pumping in the upper Cienega Creek basin was estimated by Knight (1996) to be 400 to 500 AF/yr. Most of the pumping is from wells in the Sonoita-Elgin area. These wells are distant from the focus area of the study, in the vicinity or outside of the Cienega Creek basin boundary, and their inclusion in the model was not considered consequential to representation of the groundwater flow system for purposes of projecting groundwater level changes that may result from Rosemont pit dewatering.

Groundwater pumpage for agricultural purposes at Empirita Ranch, in the lower Cienega Creek basin, was estimated by M&A (1985) to be 340 AF/yr; however, Empirita Ranch pumping was retired in 1991 when Pima County purchased the Empirita Ranch properties. Other groundwater pumping, chiefly from domestic wells, in the lower basin may be on the order of 100 AF/yr, based on information presented in ADWR (2006a). This domestic pumping was not included in the model due to the small and dispersed nature of the pumping and due to the speculative information available about the pumping; historic groundwater level data do not show declining trends in the general area of the domestic pumping.

**Groundwater Interaction with Surface Streams**

Average annual perennial baseflow in streams is considered representative of groundwater discharge to streams. Perennial flow occurs chiefly along four or five isolated
reaches of Cienega Creek, and has historically occurred along a short reach of Davidson Canyon, above its confluence with Cienega Creek, as shown on Figure 7. Perennial base flow in each of these reaches is diminished by evapotranspiration and/or channel infiltration losses, such that the base flow of the perennial reaches is eliminated at their downstream ends. Because there are no perennial stream reaches that flow out of the model study area, net groundwater discharge via surface streams within the study area is effectively zero. Thus, for purposes of this study, groundwater discharge out of the Cienega Creek basin occurs only via groundwater pumpage, underflow, and evapotranspiration.

Cienega Creek flows northward through much of the model study area, transitioning to the west in the northern part of the study area (Figure 7). The creek is located approximately 9.5 miles east and 13.5 miles north of the proposed mine facilities. Location of groundwater discharge to streams and associated perennial reaches along Cienega Creek is estimated using an inventory of perennial streams in the study area from a survey conducted by PAG (2000a). Approximately 7.7 miles of perennial streamflow occurs along upper Cienega Creek including a 4.9-mile stretch at the “narrows”, a bedrock high which forces groundwater to the surface in Cienega Creek (Figure 7). Approximately 2.5 miles of perennial streamflow occurs along lower Cienega Creek. Perennial reaches are interrupted by intermittent reaches in both the upper and lower basins. The gaining (groundwater discharge to stream) portions of a perennial reach are assumed to be at the upstream end of the known extent of the perennial reach; and losing (infiltration from stream to aquifer) portions of the reach are assumed to be at the downstream end of the known extent. Based on historic information, base flow ranged from 1 to 3 cubic feet per second (cfs) in upper Cienega Creek (east from proposed mine site) (M&A, 1985; PAG, 1998) and about 1.0 cfs in lower Cienega Creek in a reach outside (north) of the model domain boundary (PAG, 1993-2008 monitoring data, written communication, 2009).

Streamflow in Davidson Canyon, northeast of the Rosemont Project area, is chiefly ephemeral; however, intermittent and perennial reaches occur immediately south of
Interstate-10 and near the confluence with Cienega Creek (PAG, 2000a), and are associated with springs in the alluvial channel at bedrock constrictions. The perennial stream reach nearest to the proposed mine site is associated with an unnamed spring located approximately 11.5 miles northeast of the proposed mine facilities. Flow is from a spring into the stream channel at this location. Flow from the spring and in the channel is believed to result from a bedrock constriction along the channel which causes upwelling of groundwater flow (Tetra Tech, 2010a). In recent years perennial flow along Davidson Canyon has not been observed within the model domain. This spring has been monitored by Pima County since 1996 (PAG, 2005).

**Groundwater Discharge to Springs**

Spring flow in the Rosemont and Davidson Canyon areas can be attributed to: (1) discharge of shallow subsurface fracture flow which is directly dependent on storm and runoff events and which may or may not be in direct hydraulic connection with the groundwater flow system; (2) discharge of groundwater via fractures that intersect land surface, (3) discharge from the Recent alluvium or other shallow aquifer where forced to land surface by a low permeability rock unit; and/or (4) discharge of groundwater along low-permeability fault zones that force groundwater to land surface. These spring types are described in Fetter (1994).

Within the model study area, 74 seeps and springs have been observed or reported, as shown on Figure 7. Approximately 13 of these have been identified as perennial (PAG, 2000b), reportedly having springflow throughout the year (Figure 26). A detailed discussion of geologic and topographic controls on seeps and springs in the Rosemont and Davidson Canyon areas is provided in Tetra Tech (2010a).

**Rosemont Area**

Within a 5-mile radius of the Rosemont Project, 20 seeps and springs were identified and monitored during hydrogeologic investigations. Detailed seep and spring observation data
obtained during the period 2006 through 2010 are provided in Table 4. Locations of the seeps and springs are shown on Figure 26.

Of the 20 seeps and springs monitored, 5 are indicated by PAG (2000b) as perennial, having sustained spring flow throughout the year or most of the year. These springs include Helvetia, MC-2, Rosemont, Deering, and Questa Springs. Recent monitoring indicates that Questa Spring is actually intermittent (Table 4). Also, Tetra Tech (2009) indicates that Deering and MC-2 may be intermittent. However, to be conservative, Deering, Questa, and MC-2 were considered perennial in this model investigation.

Another five springs are classified as intermittent springs, with spring flow or moist conditions occurring much of the time, but with substantial periods of no flow. Approximately one-half (10) of the seeps/springs identified are classified as ephemeral, with spring flow occurring only during or shortly after precipitation events (Table 4).

Most of the seeps or springs identified as ephemeral in Table 4 are probably not in direct contact with the regional groundwater system. Thus, these seeps or springs are expected to have a low potential to be impacted by dewatering of the Rosemont pit. Some of seeps or springs identified as intermittent in Table 4 may be in seasonal or periodic contact with the regional groundwater system, although it is expected that a large part of their flow is from stormwater and/or recently recharged groundwater; thus they probably have a somewhat greater potential to be impacted by pit dewatering. The springs identified as perennial are more likely in direct communication with the regional groundwater flow system and have the largest potential to be impacted by pit dewatering.

Rosemont Spring in particular has a large potential to be impacted, due to the similarity of its water quality to groundwater at nearby wells. Questa Spring also has similar water quality to groundwater from nearby wells, although its potential to be impacted is substantially lower than Rosemont Spring, due to its distance from the pit.
Springflow at groundwater-fed seeps or springs which occur within the area of projected substantial drawdown could be substantially reduced. However, in most cases, the physical cause for the presence of any given seep or spring (spring type) and the extent to which they are dependent on the regional groundwater system is poorly defined or unknown. The potential for any given seep or spring in the Rosemont area to be impacted by pit dewatering is therefore uncertain (Tetra Tech, 2010a). Even with additional investigation, such as detailed geologic mapping and extensive water quality testing, the potential for impacts to most seeps and springs is uncertain.

**Davidson Canyon Area**

Downstream from the Rosemont area in the lower part of the Davidson Canyon drainage, additional seeps and springs have been identified and/or reported. Most of these appear to be ephemeral in nature, flowing for short time periods during and after precipitation events. The more substantial springs in this area include Davidson and Escondido Springs. Davidson Spring was not monitored due to lack of property access. Information obtained from PAG (2000b) indicates Davidson Spring is not perennial. Escondido Spring is a reportedly perennial spring (PAG, 2000b) located in Davidson Wash, a short distance upstream from the Davidson Canyon-Cienega Creek confluence. Recent visits to Escondido Spring by M&A and Tetra Tech personnel indicate this spring is actually intermittent. Although groundwater levels in the vicinity of Escondido Spring are very shallow, the potential for this spring to be impacted by Rosemont pit dewatering is expected to be very low, due to its substantial distance (14 miles) from the pit.

An evaluation of seeps and springs in the Davidson Canyon drainage is provided in Tetra Tech (2010a). As in the Rosemont area, the physical cause for the presence of seeps or springs in Davidson Canyon and the extent to which they may be dependent on the regional groundwater system is poorly defined or unknown. The potential for any given seep or spring in the Davidson Canyon area to be impacted by pit dewatering is therefore uncertain (Tetra Tech, 2010a). Even with additional investigation, such as detailed geologic mapping and extensive
water quality testing, the potential for impacts to most seeps and springs is uncertain. However, in general, the potential for seeps and springs in Davidson Canyon area to be impacted by pit dewatering is expected to be substantially lower than those in the Rosemont area, due to substantial distance from the mine and the probable discontinuity of the groundwater flow system(s) throughout the study area.

**Whetstone Mountains Area**

PAG (2000b) identifies an additional seven perennial springs in the Whetstone Mountains, in the east-central part of the model domain. Locations of these springs are shown on Figure 26. These springs were not monitored during recent hydrogeologic investigations. Due to their distance from the Rosemont Project (15 to 17 miles), intervening hydrogeologic conditions and elevations these springs will not be impacted by pit dewatering.

**4.4 HISTORIC GROUNDWATER LEVELS**

Data for evaluation of groundwater level trends in the model study area are compiled from several sources, including the ADWR GWSI database, Harshbarger and Hargis (1976), Hargis & Montgomery (1981 and 1982), PAG water level monitoring data for the Cienega Creek Natural Preserve (PAG, written communication, 2008), M&A (2009a), and Rosemont Copper files. Hydrographs of groundwater level altitude for selected wells with relatively long historical periods of record are shown on Figure 28. Inspection of these hydrographs indicates that although groundwater levels at some wells have experienced small seasonal or annual fluctuations, water levels in general have not shown definite upward or downward trends over the long term, except at some wells in the northwestern part of the model study area which is experiencing impacts from pumping in the Tucson basin. Groundwater level drawdown impacts from existing pumping in the Corona de Tucson and Vail areas do not appear to extend into Cienega Creek basin.
As shown on Figure 28, groundwater levels in the Cienega Creek basin have remained very stable over the past several decades, with only minimal seasonal or annual fluctuations. In some locations, there is evidence that groundwater levels declined slightly from the mid-1980s through 2005. However, groundwater levels in the mid-1980s were generally higher than normal due to heavier precipitation, runoff, and recharge, while recent groundwater levels may be slightly lower than normal due to on-going drought conditions.

Wells that are located near lower Cienega Creek and lower Davidson Canyon show the annual and/or seasonal effects of fluctuating surface water flow and associated groundwater recharge on groundwater levels. These seasonal fluctuations are most pronounced at wells (D-16-17)31dcb[Davidson 2], (D-16-17)33abb[Cienega Well], (D-16-17)35dbc[EM-3], and (D-17-17)1ddd2[EE-1].

For a given well, groundwater level data points that appear anomalously low or that do not fit the water level trend indicated by the other data are frequently a result of measurements being made during or following pumping at the well, such that the measurements reflect transient, non-static conditions. These transient, non-static conditions are most pronounced at wells (D-17-15)2dcd, (D-17-15)36bda, (D-17-16)34aac, (D-17-18)9bcc, (D-18-17)36cbc, (D-19-16)14bdd, (D-19-16)15aba, (D-19-17)17bbc, (D-20-16)24dad1, and (D-20-18)17bcb. Many of these wells are located in areas with large numbers of domestic wells, and the transient non-static groundwater levels observed may be partly or wholly a result of pumping at neighboring wells.

In areas where well yields and hydraulic conductivity are small, complete recovery of groundwater levels following a pumping event may require days, months, or years. Wells at which incomplete water level recovery is most pronounced include (D-17-15)13bdc, (D-17-16)34aac, and (D-19-17)36cba.
As shown on Figure 28, groundwater levels in the northwest part of the model area near the communities of Vail and Corona de Tucson area have declined an average rate of 0.5 to 1.0 feet per year over the past several decades, probably due to pumping by Tucson Water, Vail Water Company, and/or other groundwater users in the Tucson basin. Groundwater level hydrographs for wells (D-16-15)34aaa and (D-16-16)17abd reflect the declining groundwater level trend in this area.
5.0 HYDRAULIC PARAMETERS

Hydraulic properties used for development of the groundwater model include hydraulic conductivity, specific yield, and specific storage. Data for hydraulic conductivity are derived from transmissivity data typically obtained from pumping tests. Transmissivity is a measure of the ability of an aquifer to transmit groundwater and is equal to the product of hydraulic conductivity and saturated thickness of the aquifer. Transmissivity is the rate of groundwater movement under a 1:1 hydraulic gradient through a vertical section of an aquifer 1 foot wide and extending the full saturated thickness of the aquifer (Theis, 1935); hydraulic conductivity is the rate of groundwater movement under a 1:1 hydraulic gradient for a unit area of aquifer (Heath, 1989). Units for transmissivity are feet squared per day (ft²/d) and units for hydraulic conductivity are feet per day (ft/d). Transmissivity and derived hydraulic conductivity data were obtained from the extensive hydraulic testing conducted in 2007 and 2008 in the Rosemont Project area. Additional transmissivity data were obtained from previous hydraulic testing conducted elsewhere in the model area.

Specific yield and specific storage values were calculated from some of the hydraulic testing conducted in the Rosemont Project area and from previous hydraulic testing in the model area. Specific yield is the ratio of the volume of water which a saturated porous medium will yield by gravity drainage to the volume of the porous medium (Lohman and others, 1972). Specific yield is generally applied to unconfined or “water table” aquifers. Storage coefficient is the product of specific storage and the saturated thickness of the aquifer. Storage coefficient is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Lohman, 1972). Storage coefficient and specific storage are generally applied to confined or “artesian” aquifers.
5.1 ROSEMONT PROJECT AREA

During 2007 and 2008, a phased hydrogeologic characterization drilling and testing program was conducted at 21 sites in the vicinity of the proposed Rosemont facilities. Thirty-four (34) wells and piezometers were constructed at the 21 sites to characterize hydrogeologic parameters and ambient groundwater conditions, including water quality, in the vicinity of the proposed mine facilities. These wells and piezometers include: wells constructed for hydrogeologic characterization in the pit area (PC wells and PZ piezometers), hydrogeologic characterization outside the immediate pit area (HC wells), and groundwater monitor wells (RP wells). Hydraulic testing at the wells included initial short-term testing at all wells, packer testing at selected wells, and a 30-day aquifer test with 5 wells pumping simultaneously. Results of the drilling and testing program are summarized in M&A (2007, 2009a, and 2009b), and interpretation of the testing results for incorporation into the groundwater model is described herein.

5.1.1 Short-Term Pumping Tests

Short-term 24-hour and 12-hour constant-yield pumping tests were conducted at each well following construction. At each of the PC wells, a 24-hour constant-discharge pumping test was conducted to estimate composite transmissivity and average hydraulic conductivity. During the pumping tests, hydraulic heads were monitored in adjacent PZ piezometers and groundwater levels were measured at nearby observation wells. At the HC and RP wells, 12-hour constant-discharge pumping tests were conducted. At a few of the wells, pumping tests were attempted but were terminated in less than 12 hours, due to small groundwater yield and excessive groundwater level drawdown. During the 12-hour pumping tests, groundwater levels were monitored in nearby observation wells. Results and data from the short-term pumping tests are summarized in M&A (2007 and 2009a).

Results of short-term pumping test analyses are summarized in Table 5 and shown on Figure 29. Results of the short-term pumping tests at the PC, HC, and RP wells indicate that
transmissivities are variable, ranging from less than 0.1 to about 3,600 ft$^2$/d, with the majority of values occurring in the low end of this range. Correlation of the short-term pumping test results to hydrogeologic units tested by the wells are presented in Table 5 and on Figure 30. Because the short-term tests include such a large number of wells, a detailed review of results is not included here. The following is a summary of short-term pumping test results which are pertinent to development of the model:

- Testing in pit characterization wells PC-3 and PC-4, located in the southern portion of the ultimate pit, indicates a hydraulic conductivity of less than 0.01 ft/d. These wells are completed in Basin Fill (QTg2) and Willow Canyon Formation (Ksd).
- Pit characterization wells PC-6, PC-7, and PC-8 and hydrologic characterization wells HC-1A and HC-1B are completed in the Paleozoic (Pz) rocks within the Backbone Fault zone. Results of the short-term aquifer tests indicate hydraulic conductivities within the Backbone Fault zone have the following ranges:

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Hydraulic Conductivity (feet per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-6</td>
<td>0.06 to 0.17</td>
</tr>
<tr>
<td>PC-7</td>
<td>0.025 to 0.114</td>
</tr>
<tr>
<td>PC-8</td>
<td>0.073</td>
</tr>
<tr>
<td>HC-1A</td>
<td>0.4 to 2.2</td>
</tr>
<tr>
<td>HC-1B</td>
<td>2.0 to 2.3</td>
</tr>
</tbody>
</table>

Outside of the Backbone Fault zone, most wells completed in upper Cretaceous volcanic and sedimentary rocks (Salero Formation), and lower Cretaceous sedimentary rocks (Bisbee Group), have low to moderate hydraulic conductivity of less than 0.1 ft/d, with the exception of well RP-6 with a conductivity of 1.6 ft/d.
5.1.2 Packer Testing

Pit Characterization wells PC-5, PC-6, PC-7, and PC-8 were constructed with multiple perforated intervals, separated by blank casing with annular seals outside the casing. Multiple packer tests were conducted at each of these wells. Constant-discharge tests were conducted at three depth intervals in well PC-5 and at well PC-8. Constant-discharge tests were conducted at four depth intervals in well PC-6 and at well PC-7. The first test at each well was the initial 24-hour constant-discharge test conducted with all perforated intervals of the well open. The subsequent tests at each well were 12-hour constant-discharge tests conducted in isolated interval zones. The zones were isolated using a single inflatable packer installed above the submersible pump. For the first zonal test, the packer was set and inflated within the uppermost blank/sealed casing interval of the well such that the uppermost perforated interval of the well was sealed off from the well and pump, causing all pumped water to be produced from the lower perforated intervals. For each subsequent zonal test(s), the packer was deflated and reset at progressively deeper blank/sealed zones. As the zonal testing progressed in this manner, the thickness of aquifer contributing flow to the well became progressively smaller. Using the principle of superposition, this manner of testing allows computation of aquifer transmissivity and hydraulic conductivity for each perforated interval of a given well.

Results of packer testing are presented in Table 5 and on Figure 29. Simulated hydraulic conductivities are within the range of measured hydraulic conductivities from the interval packer testing, as shown in Table 5, and in sections A-A’ and B-B’ (Figures 5 and 6). Correlation of the short-term pumping test results to hydrogeologic units tested by the wells are presented in Table 5 and on Figure 30. Construction data and lithologic data for each of the wells, and analyses of packer tests, are given in M&A (2009a). Interpretation of the packer test data and application in the model development is summarized below:
• Well PC-5 exhibits relatively high hydraulic conductivity (1.23 ft/d) for the perforated interval from 946 to 1,447 feet below land surface (bls). This calculated hydraulic conductivity is 1 to 2 orders of magnitude larger than other perforated intervals in this and other nearby wells, and is interpreted to be associated with the Flat Fault.

• Well PC-5 exhibits much lower hydraulic conductivity in the perforated intervals above and below the Flat Fault. The perforated interval from 109 to 901 feet bls screened in the Willow Canyon Formation (Ksd) had a measured hydraulic conductivity of less than 0.02 ft/d. The perforated interval from 1,521 to 2,001 feet bls screened in Paleozoic (Pz) rocks did not have a measurable conductivity during the test due to inability to maintain pumping and is interpreted to be below the influence of the Flat Fault.

• Wells PC-6, PC-7, and PC-8 exhibit hydraulic conductivities in the range of 0.02 to 0.35 ft/d. These wells are interpreted to be screened in the Backbone Fault zone with the variation in conductivity due to variation in the degree of faulting or fracturing.

5.1.3 Long-Term, Multi-Well Pumping Test

During the period November 2008 through January 2009, a long-term, multi-well pumping test was conducted at selected PC, HC, and RP wells. This test was conducted to support further evaluation of the groundwater system in the Rosemont Project area, specifically to define hydraulic parameters and determine local-scale groundwater system connectivity. Test procedures and results of testing and analyses for the long-term test are presented in M&A (2009b).

Five wells were pumped during a period of 30 days from November 19 through December 19, 2008. The test involved pumping wells PC-5, RP-6, HC-1B, HC-5A, and RP-3B for durations of 12 to 30 days and observing groundwater level changes at the
pumped wells and nearby wells and piezometers, and observing flow rates and conditions at springs. Initiation of pumping at the first well, PC-5, began on November 19, 2008; start-up of pumping at each of the other wells was staggered by 2 to 3 days. Except for well RP-3B, pumping at all wells was terminated on December 19, 2008, at the end of the 30-day pumping period. Well RP-3B was shut-down after 12 days of pumping, due to low permeability of the groundwater system in the area of this well, resulting in large groundwater level decline and inability to maintain a constant pumping rate. The 5 pumping well locations are shown on Figure 31. In addition to the five pumping wells, 46 observation wells and piezometers, five springs, and McCleary Dam underflow were monitored during the long-term, multiple-well test. Monitoring results for springs, with the exception of spring MC-2, showed no discernible change in flow rate during the long-term test. Flow at spring MC-2 ceased during pumping, likely due to its close proximity to pumped well HC-5A. At McCleary Dam, no change in surface water flow conditions could be attributed to the long-term test. After pumping stopped, groundwater level conditions were monitored for a 30-day recovery period from December 19, 2008 to January 18, 2009.

Measured drawdown at each well monitored during the test at the end of the 30-day pumping period is shown on Figure 31. Aquifer parameters computed from the long-term pumping test data are summarized in Table 5 and shown on Figure 29. Correlation of the short-term pumping test results to hydrogeologic units tested by the wells are presented in Table 5 and on Figure 30.

Water level measurements at wells and piezometers were obtained prior to, during, and after the long-term testing period. Antecedent water level trends were approximated as linear trends, and were removed from hydrographs (M&A, 2009b). In some wells groundwater level fluctuations occurred which could not be accounted for and were not consistent with pumping test response. These wells were classified as non-responsive and test results were not analyzable.
Wells generally exhibited “dual-porosity” behavior, typical of fractured rock. Range of hydraulic conductivity determined from the testing is from 0.013 to 1.14 ft/d, with the largest values associated with the identified conductive Flat Fault and Backbone Fault features. Based on drawdown response observed during the long-term test, no evidence was found indicating conductive, continuous fault features or zones which would substantially promote propagation of drawdown in the pit area to distant areas in central Cienega Creek basin or lower Davidson Canyon. Discussion of pumping well and associated observation well responses, and interpretation of the results for model development, is provided in M&A (2009b) and summarized below.

**PUMPED WELL PC-5**

Pumped well PC-5 is completed in the Willow Canyon Formation (hydrogeologic unit Ksd) and underlying Paleozoic rocks, including the Flat Fault (Figure 5). This well is located immediately northeast of the ultimate pit boundary, in an area with numerous potential observation wells and piezometers. Well PC-5 was pumped for 30 days at 43.1 gpm. Drawdown response data for pumped well PC-5 and nearby observation wells are tabulated below, in order of increasing distance from well PC-5. Drawdown response at the end of the 30-day pumping test is shown on Figure 31. Hydrographs of observed drawdown and recovery for well these wells and piezometers are shown on the figures listed in the following table:

<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>DISTANCE FROM PUMPED WELL PC-5 (feet)</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>DRAWDOWN AT END OF 30-DAY PUMPING PERIOD (feet)</th>
<th>PRINCIPAL DRAWDOWN ATTRIBUTED TO:</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-5 (PUMPED)</td>
<td>Ksd and Pz (including Flat Fault)</td>
<td>22.85</td>
<td>PC-5</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>PZ-5 (600)</td>
<td>61</td>
<td>Ksd</td>
<td>7.51</td>
<td>PC-5</td>
<td>33</td>
</tr>
<tr>
<td>PZ-5 (1150)</td>
<td>61</td>
<td>Pz (including Flat Fault)</td>
<td>6.34</td>
<td>PC-5</td>
<td>34</td>
</tr>
<tr>
<td>PZ-5 (1800)</td>
<td>61</td>
<td>Pz</td>
<td>14.21</td>
<td>PC-5</td>
<td>35</td>
</tr>
<tr>
<td>PC-1</td>
<td>1,092</td>
<td>Ksd</td>
<td>0.99</td>
<td>PC-5</td>
<td>36</td>
</tr>
<tr>
<td>WELL IDENTIFIER</td>
<td>DISTANCE FROM PUMPED WELL PC-5 (feet)</td>
<td>PRINCIPAL HYDROGEOLOGIC UNITS</td>
<td>DRAWDOWN AT END OF 30-DAY PUMPING PERIOD (feet)</td>
<td>PRINCIPAL DRAWDOWN ATTRIBUTED TO:</td>
<td>SHOWN ON FIGURE NUMBER</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>PC-2</td>
<td>1,371</td>
<td>Ksd and Pz (including Flat Fault)</td>
<td>2.93</td>
<td>PC-5</td>
<td>37</td>
</tr>
<tr>
<td>PC-6</td>
<td>2,195</td>
<td>Pz (including Flat Fault and Backbone Fault)</td>
<td>1.73</td>
<td>PC-5 and HC-5A</td>
<td>38</td>
</tr>
<tr>
<td>PC-3</td>
<td>3,272</td>
<td>QTg2 and Ksd</td>
<td>No response</td>
<td>---</td>
<td>39</td>
</tr>
<tr>
<td>PC-7 (485)</td>
<td>3,490</td>
<td>Pz (including Flat Fault and Backbone Fault)</td>
<td>1.98</td>
<td>PC-5</td>
<td>40</td>
</tr>
<tr>
<td>PC-7 (790)</td>
<td>3,490</td>
<td>Pz (including Backbone Fault)</td>
<td>2.24</td>
<td>PC-5</td>
<td>41</td>
</tr>
<tr>
<td>PC-7 (1245)</td>
<td>3,490</td>
<td>Pz (including Backbone Fault)</td>
<td>2.07</td>
<td>PC-5</td>
<td>42</td>
</tr>
<tr>
<td>PC-7 (1680)</td>
<td>3,490</td>
<td>Pz (including Backbone Fault)</td>
<td>1.86</td>
<td>PC-5</td>
<td>43</td>
</tr>
<tr>
<td>PC-7 (1800)</td>
<td>3,490</td>
<td>Pz (including Backbone Fault)</td>
<td>2.16</td>
<td>PC-5</td>
<td>44</td>
</tr>
<tr>
<td>PC-7</td>
<td>3,541</td>
<td>Ksd and Pz (including Flat Fault and Backbone Fault)</td>
<td>2.00</td>
<td>PC-5</td>
<td>45</td>
</tr>
<tr>
<td>HC-3A</td>
<td>3,621</td>
<td>Qal</td>
<td>No response</td>
<td>---</td>
<td>46</td>
</tr>
<tr>
<td>HC-3B</td>
<td>3,635</td>
<td>Ksd</td>
<td>0.46</td>
<td>PC-5</td>
<td>47</td>
</tr>
<tr>
<td>HC-3C</td>
<td>3,649</td>
<td>Ksd</td>
<td>0.57</td>
<td>PC-5</td>
<td>48</td>
</tr>
<tr>
<td>PC-4</td>
<td>5,396</td>
<td>QTg2 and Ksd</td>
<td>No response</td>
<td>---</td>
<td>49</td>
</tr>
<tr>
<td>PC-8</td>
<td>5,454</td>
<td>Pz (including Backbone Fault)</td>
<td>No response</td>
<td>---</td>
<td>50</td>
</tr>
<tr>
<td>PC-8 (450)</td>
<td>5,566</td>
<td>Pz (including Backbone Fault)</td>
<td>0.21</td>
<td>PC-5 and HC-1B</td>
<td>51</td>
</tr>
<tr>
<td>PC-8 (1150)</td>
<td>5,566</td>
<td>Pz (including Backbone Fault)</td>
<td>0.16</td>
<td>PC-5 and HC-1B</td>
<td>52</td>
</tr>
<tr>
<td>PC-8 (1650)</td>
<td>5,566</td>
<td>Pz (including Backbone Fault)</td>
<td>No response</td>
<td>PC-5 and HC-1B</td>
<td>53</td>
</tr>
<tr>
<td>PC-8 (1925)</td>
<td>5,566</td>
<td>Pz (including Backbone Fault)</td>
<td>No response</td>
<td>PC-5 and HC-1B</td>
<td>54</td>
</tr>
</tbody>
</table>

Response of observation wells to PC-5 pumping, are interpreted as follows:

- Drawdown response is partially controlled by the Flat Fault and the Backbone Fault zone. Observation wells and piezometers PC-6, PC-7, PZ-7, PC-8, and PZ-8 are located in the area of the Backbone Fault zone. Pumped well PC-5, and observation wells and piezometers PC-2, PC-6, and PC-7 intersect the Flat Fault.
• Data indicates the Flat Fault in vicinity of the proposed pit acts as a higher conductivity zone, connecting pumped well PC-5 to other wells and piezometers that intersect the Flat Fault and the connected Backbone Fault.

• Approximately equal drawdown response at all piezometer depths in PZ-7 indicates the Backbone Fault is vertically conductive.

• Drawdown response at observation well PC-2 was greater than drawdown response at PC-1 though it is farther away from pumping well PC-5. This was interpreted to result from PC-2 intersecting the Flat Fault and being in greater communication with PC-5.

• Observation well PC-6 is approximately equidistant from pumped wells PC-5 and HC-5A. Drawdown response at PC-6 due to each pumped well is interpreted to be approximately equal.

• Observation wells PC-3 and PC-4, completed in Basin Fill (QTg2) and Bisbee Group (Ksd) rocks, did not show response to long-term pumping. This is consistent with low hydraulic conductivity for these wells, as determined from short-term single well tests (M&A, 2009a).

• Responses at the PZ-8 piezometers exhibit low drawdown response to transducer noise ratio, and interpretations of drawdown are problematic. Response at only the uppermost PZ-8 piezometers may indicate response from HC-1B pumping.

**PUMPED WELL HC-1B**

Pumped well HC-1B is completed in the Glance Conglomerate (Ksd). This well is located about 1 mile southwest of the ultimate pit boundary, within the Backbone Fault zone. Well HC-1B was pumped for 25 days at 43.0 gpm. Drawdown response data for pumped well HC-1B and nearby observation wells are tabulated below, in order of increasing distance from well HC-1B. Drawdown response at the end of the 30-day pumping test is shown on **Figure 31**. Hydrographs of observed drawdown and recovery for well these wells and piezometers are shown on the figures listed in the following table:
Response of observation wells to HC-1B pumping, are interpreted as follows:

- Hydraulic conductivity computed for HC-1A is similar to HC-1B for short-term test.

- Hydraulic conductivity computed for HC-1A is similar to HC-1B for the long-term test.

- Hydraulic conductivities computed from the 30-day test were an order of magnitude smaller than hydraulic conductivities computed from the short-term test at HC-1B, possibly indicating depletion of groundwater storage in structural features during long-term test.

- Responses at the PZ-8 piezometers exhibit low drawdown response to transducer noise ratio, and interpretations of drawdown are problematic. Response at only the uppermost PZ-8 piezometers may indicate response from HC-1B pumping through the Backbone Fault.

- Response at corehole 1445 exhibits low drawdown response to transducer noise ratio. Drawdown interpretation is difficult to confirm and may be attributable to
natural variations in groundwater level trends which occur in the fractured rock flow system in the highest altitudes of the Santa Ritas, which are highly influenced by recharge events. Corehole 1445 is closest to pumping well HC-1B, but the response can be interpreted to be consistent with combined pumping from wells HC-1B, PC-5, and HC-5A. Any interpretation of a potential hydraulic connection through the granodiorite (pC\(\text{b}\)) is considered inconsistent with the typically impermeable hydraulic character. If a hydraulic connection exists, it is likely due to a shallow fault feature in the granodiorite which is not structurally significant; corehole 1445 has a limited saturated thickness of approximately 70 feet.

**PUMPED WELL HC-5A**

Pumped well HC-5A is completed in the Willow Canyon Formation (hydrogeologic unit Ksd). This well is located about 1 mile northeast of the ultimate pit boundary and about 1 mile east of the Backbone Fault zone. Well HC-5A was pumped for 23 days at 39.7 gpm. Drawdown response data for pumped well HC-5A and nearby observation wells are tabulated below, in order of increasing distance from well HC-5A. Drawdown response at the end of the 30-day pumping test is shown on Figure 31. Hydrographs of observed drawdown and recovery for these wells are shown on the figures listed in the following table.

<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>DISTANCE FROM PUMPED WELL HC-5A (feet)</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>DRAWDOWN AT END OF 23-DAY PUMPING PERIOD (feet)</th>
<th>PRINCIPAL DRAWDOWN ATTRIBUTED TO:</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-5A (PUMPED)</td>
<td></td>
<td>Ksd</td>
<td>72.31</td>
<td>HC-5A</td>
<td>59</td>
</tr>
<tr>
<td>HC-5B</td>
<td>32</td>
<td>Ksd</td>
<td>6.92</td>
<td>HC-5A</td>
<td>60</td>
</tr>
<tr>
<td>PC-6</td>
<td>2,707</td>
<td>Pz (including Flat Fault and Backbone Fault)</td>
<td>1.73</td>
<td>PC-5 and HC-5A</td>
<td>38</td>
</tr>
<tr>
<td>HC-4A</td>
<td>7,874</td>
<td>Kv</td>
<td>No response</td>
<td>---</td>
<td>61</td>
</tr>
<tr>
<td>HC-4B</td>
<td>7,844</td>
<td>Kv</td>
<td>No response</td>
<td>---</td>
<td>62</td>
</tr>
</tbody>
</table>

Response of observation wells to HC-5A pumping, are interpreted as follows:
• Hydraulic conductivity computed for HC-5B is similar to HC-5A for the long-term test. This is inconsistent with short-term test results which indicated that hydraulic conductivity at HC-5A is four orders of magnitude larger than at HC-5B.

• Drawdown response at HC-5B was interpreted to be consistent with lower conductivity at depth and a horizontal to vertical hydraulic conductivity ratio of 1:1 in the Willow Canyon Formation.

• Observation well PC-6 is approximately equidistant from pumped wells PC-5 and HC-5A. Drawdown response at PC-6 due to each pumped well is interpreted to be approximately equal.

• Lack of response in HC-4A indicates low permeability to the northeast through the Ksd and Kv. Substantial water level variations were observed prior to the start of the test for observation well HC-4B and apparent groundwater level declines, including apparent decline through the recovery period, are not consistent with the pumping test timing or the lack of response observed in HC-4A. The declines are attributed to background trends; it was concluded HC-4B should be considered non-responsive.

**PUMPED WELL RP-3B**

Pumped well RP-3B is completed in the Salero Formation (hydrogeologic unit Kv). This well is located about 2.5 miles east of the ultimate pit boundary, in east dipping rocks overlain by basin-fill deposits. Well RP-3B was pumped for 12 days at 27.8 gpm; pumping was terminated due to large drawdown and inability to maintain a constant pumping rate. Few observation wells are located near RP-3B and no response to pumping was observed in any wells, with the exception of RP-3A. Drawdown response data for pumped well RP-3B and nearby observation wells are tabulated below, in order of increasing distance from well RP-3B. Drawdown response at the end of the 30-day pumping test is shown on **Figure 31**. Hydrographs of observed drawdown and recovery for these wells are shown on the figures listed in the following table.
Response of observation wells to RP-3B pumping, are interpreted as follows:

- Very small response observed in immediately adjacent partially penetrating observation well RP-3A is interpreted to indicate low vertical hydraulic conductivity and low ratio of vertical to horizontal hydraulic conductivity.
- Lack of response in other observation wells suggests low hydraulic conductivity. Apparent water level declines in RP-4A and HC-2A are attributed to non-linear background trends. Observed declines continuing through the recovery period in RP-4A and HC-2A are not consistent with the pumping test timing and are attributed to background trends; it was concluded RP-4A and HC-2A should be considered non-responsive.

### PUMPED WELL RP-6

Pumped well RP-6 is completed in the Salero Formation (hydrogeologic unit Kv). This well is located on a topographic divide between Mulberry and Barrel canyons, about 2 miles west of Davidson Canyon. Well RP-6 was pumped for 28 days at 47.2 gpm. Few observation wells are located near RP-6, and no response to pumping was observed in any
wells. Drawdown response data for pumped well RP-6 and nearby observation wells are tabulated below, in order of increasing distance from well RP-6. Drawdown response at the end of the 30-day pumping test is shown on Figure 31. Hydrographs of observed drawdown and recovery for these wells are shown on the figures listed in the following table.

<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>DISTANCE FROM PUMPED WELL RP-6 (feet)</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>DRAWDOWN AT END OF 28-DAY PUMPING PERIOD (feet)</th>
<th>PRINCIPAL DRAWDOWN ATTRIBUTED TO:</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP-6 (PUMPED)</td>
<td>Kv</td>
<td>22.96</td>
<td>RP-6</td>
<td>---</td>
<td>75</td>
</tr>
<tr>
<td>Mulberry Stock</td>
<td>2,705</td>
<td>Kv</td>
<td>No response</td>
<td>---</td>
<td>76</td>
</tr>
<tr>
<td>RP-7</td>
<td>4,194</td>
<td>Kv</td>
<td>No response</td>
<td>---</td>
<td>77</td>
</tr>
<tr>
<td>HV-2</td>
<td>4,836</td>
<td>Ksd (possibly some Qal)</td>
<td>No response</td>
<td>---</td>
<td>78</td>
</tr>
<tr>
<td>RP-8</td>
<td>23,062</td>
<td>Ksd</td>
<td>No response RP-6</td>
<td>---</td>
<td>79</td>
</tr>
</tbody>
</table>

Response of observation wells to RP-6 pumping, are interpreted as follows:

- Lack of response of observation wells is consistent with low hydraulic conductivity for Salero Formation wells. Water level in well HV-2 is shallow (typically less than 20 feet), and is highly variable. Water level may be influenced by a nearby ephemeral stream containing Quaternary alluvium (Qal). Apparent water level decline in RP-8 is attributed to non-linear background trends. Observed declines continuing through the recovery period in HV-2 and RP-8 are not consistent with the pumping test timing and are attributed to background trends; it was concluded HV-2 and RP-8 should be considered non-responsive.

### 5.1.4 Summary

Using the most applicable analytical methods, a range of hydraulic parameter estimates were derived, specifically for transmissivity, hydraulic conductivity, and storage parameters. Estimates of hydraulic parameters derived using analytical methods are
presented in Table 5 and shown on Figure 29. These estimates incorporate results of both the short-term, single-well testing and long-term, multi-well testing programs summarized in the preceding sections. Table 5 also includes data on the geologic and hydrogeologic units in which each of the tested wells are completed. The range of hydraulic conductivity from hydraulic tests, grouped by hydrogeologic unit, is shown on Figure 30.

For many locations in the Rosemont Project area, the short-term test results were the only aquifer parameters available and these were utilized as the basis for model representation of aquifer parameters at those locations. In general, hydraulic parameters computed from results of the long-term, multi-well test confirm the preliminary estimates derived from analysis of the short-term tests. Typical of a fractured and faulted bedrock flow system, calculated hydraulic parameters for the bedrock system are highly variable, indicating the influence of local fracture and fault features. Transmissivity values are moderate in strongly faulted and fractured parts of the bedrock complex in the proposed pit area. In the southeast area of the proposed pit, where upper excavated levels will intercept cemented, older basin-fill deposits, transmissivity values are low. In general, with distance away from the faulted and fractured bedrock complex in the area of the proposed pit and at depth, the groundwater system is characterized as poorly permeable, where groundwater movement is controlled primarily by discontinuous fractures and discrete faults.

The ratio of horizontal hydraulic conductivity (Kh) to vertical hydraulic conductivity (Kz) was generally estimated to be 1:1 in the pumping test analyses; although variation of this property in the analytical methodology is not well constrained. Rocks in the Rosemont Project area are known to have very low primary hydraulic conductivity because they are strongly cemented and have been altered and compacted. Differences in the primary hydraulic conductivity ratio of Kh:Kz are masked by the much larger secondary hydraulic conductivity of the faults and fractures present in the rock, which may have both vertical and horizontal components and which more strongly control groundwater movement. The PZ-7 and PZ-8 grouted piezometers were installed in areas of steeply dipping, highly fractured
Paleozoic rock. The rocks are tilted 60 to 90 degrees from their orientation at the time of original deposition, and any Kh to Kz anisotropy originally present is now substantially rotated. As part of the model calibration process, some discrete areas of Kh to Kz anisotropy was introduced into the model; these are described in Section 7.0.

5.2 UPPER CIENEGA CREEK BASIN

Pumping test data and aquifer parameter values for wells in upper Cienega Creek basin (ranging from 4 to 13 miles southeast of the proposed pit), including the Empire Ranch area (now Las Cienegas National Conservation Area), are available from several sources. Pumping test data and aquifer parameters for the Empire Ranch area are given in Geraghty & Miller (1970 and 1972) and Harshbarger and Associates (1975). These pumping tests were 24 to 48 hours in duration. Aquifer parameters reported were subsequently utilized and interpreted in several University of Arizona Masters Theses including Boggs (1980), Huth (1997), and Bota (1997).

Harshbarger and Associates (1975) indicates the presence of a large groundwater reservoir in the basin-fill deposits in a zone about 4 miles wide by 9 miles long, generally paralleling Cienega Creek. Computed transmissivity of the basin-fill deposits in this zone ranges from about 12,000 to 50,000 gpd/ft (1,604 to 6,685 ft²/d); average transmissivity in this zone is estimated to be approximately 30,000 gpd/ft (4,011 ft²/d). Outside of this zone, the thickness of basin-fill deposits is much smaller, and reported transmissivity ranges from about 500 to 13,000 gpd/ft (67 to 1,738 ft²/d) (Harshbarger and Associates, 1975).

Reported storage coefficients in the Empire Ranch area range from $7 \times 10^{-5}$ to $1.9 \times 10^{-2}$, based on a long-term pumping and recovery test conducted at well EP-1 (Harshbarger and Associates, 1975). Harshbarger and Associates (1975) and Arizona Water Commission (1972) estimated a long-term unconfined storage coefficient (specific yield) of
about 0.05. Other estimates of long-term unconfined storage coefficient (specific yield) for the basin-fill deposits in upper Cienega Creek basin include 0.01 to 0.1 (Boggs, 1980; and Bota, 1997).

### 5.3 LOWER CIENEGA CREEK BASIN

Pumping test data and aquifer parameter values for wells in lower Cienega Creek basin (approximately 15 miles northeast of the proposed pit) are given in M&A (1985). Aquifer parameters reported in this report were subsequently utilized and interpreted in University of Arizona masters theses, including Ellett (1994) and Chong-Diaz (1995).

For the Recent Alluvium along Cienega Creek in the lower basin, M&A (1985) indicates that transmissivity ranges from about 78,000 through 230,000 gpd/ft (10,428 to 30,749 ft²/d), and the specific yield estimated from short term pumping tests ranges from about 0.04 through 0.33.

For the basin-fill deposits aquifer, M&A (1985) indicates a computed transmissivity of 7 gpd/ft (0.9 ft²/d), based on a single pumping test at well (D-17-18)17cdd2[EE-2]. Neither M&A (1985) nor Chong-Diaz (1995) provides estimates of long-term storage coefficient (specific yield) for the unconfined basin-fill deposits in the lower Cienega Creek basin. However, considering the relatively small computed transmissivity, it is expected that the long-term storage coefficient is similar to that for basin-fill deposits in the upper basin, and possibly smaller.

For the Pantano Formation and older rock units, M&A (1985) and Chong-Diaz (1995) did not provide computations or estimates of aquifer parameters. However, evaluation of well yields in the study area suggests the unit has very small transmissivity, hydraulic conductivity, and storage coefficient. One well was completed and tested in older
rock units that are probably either Pantano Formation or other Tertiary sedimentary rocks (Clear Creek Associates, 2001). Computed transmissivity at this well was about 5,297 gpd/ft (708 ft²/d), and the resulting average hydraulic conductivity was computed to be about 2 ft/d (15 gpd/ft²).

In the regional groundwater flow model for the Tucson AMA (Mason and Bota, 2006), assigned transmissivity values of the Pantano Formation in the Vail and Corona de Tucson areas range from about 94 to 2,005 ft²/d, and long-term storage coefficient (specific yield) ranges from about 0.07 to 0.09.

**5.4 TUCSON BASIN**

Pumping test data and aquifer parameter values for wells completed in basin-fill deposits in the Vail and Corona de Tucson areas of the Tucson basin are available from several sources. Pumping test data and aquifer parameters for two production wells in the Corona de Tucson area were obtained from Tucson Water (M. Liberti, written communication, 2006). Pumping test data and aquifer parameters for four production wells in the Vail area were obtained from Clear Creek Associates (2001). Information on assigned transmissivity, hydraulic conductivity, and storage coefficient values were also obtained from the regional flow model for the Tucson AMA (Mason and Bota, 2006).

Pumping test data obtained from Tucson Water indicate transmissivity for wells (D-16-15)23ccc[H-002A] and (D-16-15)23ddd[H-003A] near Corona de Tucson ranges from about 120,000 to 250,000 gpd/ft (16,043 to 33,422 ft²/d). Based on the saturated thickness of basin-fill deposits penetrated by these wells (566 ft for well H-002A and 478 ft for well H-003A), average hydraulic conductivity is computed to range from about 212 to 523 gpd/ft² (28 to 70 ft/d).
Data presented in Clear Creek Associates (2001) indicate transmissivity for the Vail Water Company wells completed in basin-fill deposits ranges from about 91,567 to 145,655 gpd/ft (12,240 to 19,473 ft²/d). Computed average hydraulic conductivity was reported to range from 29 to 58 ft/d (217 to 434 gpd/ft²).

In the regional groundwater flow model for the Tucson AMA (Mason and Bota, 2006), assigned hydraulic conductivity values for the basin-fill deposits aquifer (Layer 2) range from about 1.3 to 52 ft/d. Assigned long-term storage coefficient (specific yield) values range from about 0.10 to 0.13.
6.0 SUMMARY OF CONCEPTUAL GROUNDWATER FLOW MODEL

Conceptualization of the groundwater flow system in the Rosemont Project area and surrounding regional flow system has been described in the preceding chapters which summarize results and conclusions derived from field investigations, available historic data, and knowledge of groundwater flow in fractured/faulted rock and porous media. The conceptual model provides the basis for development of the numerical model. Important components of the conceptual model are described below.

6.1 LOCAL ROSEMONT PROJECT AREA

Groundwater flow in the bedrock is chiefly through interconnected fractures and faults. On a large scale, the bedrock groundwater flow system is assumed to behave as an equivalent porous medium, which can be simulated with finite-difference codes such as MODFLOW-SURFACE. Results of hydraulic testing and observations of groundwater level conditions in the Rosemont Project area generally support this conclusion, although known conductive localized fault features in the vicinity of the pit appear to substantially control local groundwater movement, requiring that these features be explicitly incorporated into the model representation of the flow system. Other fault features may control groundwater movement, but data are not available to demonstrate either the occurrence of such features or their extent of hydraulic influence on a regional scale. Conceptualization of the groundwater flow system in the Rosemont Project area is summarized as follows:

- Groundwater recharge along the Santa Rita Mountains, combined with low permeability bedrock and strongly cemented basin-fill sediments, sustains the higher groundwater levels and steep gradients observed in the proposed pit area;
Groundwater moves from the higher altitudes in the area of the proposed pit to the east and northeast.

- Groundwater recharge is relatively larger in the higher elevations of the project area, due to higher precipitation at these altitudes; however, recharge rates in the Precambrian granodiorite comprising the core of the Santa Ritas are substantially smaller due to very low permeability of the rock unit.
- Results of pumping tests and groundwater observations indicate enhanced groundwater movement occurs through the Backbone Fault, both vertically and north-south along the fault zone. East-west hydraulic conductivity of the Backbone Fault, perpendicular to the Fault lineation, is considered relatively low.
- The Backbone Fault is considered to be an area of relatively higher recharge. Intersection of the Backbone Fault with the conductive Flat Fault conveys groundwater east through the pit area. Conductivity of the Flat Fault east from the pit is assumed to decrease, which tends to keep groundwater levels elevated in the pit area.
- Hydraulic conductivity of the basin-fill sediments in and adjacent to the bedrock complex is low, due to strong cementation and lack of faulting or fracturing, resulting in poor hydraulic connection of these deposits to surrounding areas, reduced groundwater flow toward the pit, and limiting drawdown impacts in areas south and east of the proposed pit.
- Hydraulic conductivity of the upper Cretaceous, lower Cretaceous, and Paleozoic rock units in the Rosemont Project area are generally very low, which will restrict groundwater inflow to the pit and limit groundwater level drawdown at distance from the pit.
- The model will not be able to accurately simulate the very small discharge from springs and seeps in the project area, and determination of the hydraulic connection of springs to the deeper groundwater system, as opposed to shallow fracture flow, is uncertain in most cases. For springs and seeps that may be dependent on the deeper groundwater system, drawdown which may occur at the
springs as a result of pit dewatering may reduce their discharge. Perennial springs and seeps which may be connected to the groundwater system are identified in this study.

6.2 REGIONAL GROUNDWATER FLOW SYSTEM

- Historic data indicate groundwater levels in the Rosemont project area and in the Cienega Creek basin are relatively stable and the groundwater system can be considered in a state of equilibrium for purposes of numerical model development.
- Groundwater recharge via precipitation and groundwater discharge via ET are the chief components of the groundwater balance in Cienega Creek basin.
- Regionally, groundwater recharge occurs predominantly in the basin-fill material along the mountain fronts, and to a lesser extent in the bedrock groundwater systems of the mountains and in the central basin.
- Groundwater movement in Cienega Creek basin is generally from south to north; groundwater inflow to the Cienega Creek basin is generally believed to be minimal.
- The Cienega Creek basin-fill aquifer is poorly connected to the bedrock groundwater system in the vicinity of the Rosemont Project, due to the low permeability of the bedrock and strongly cemented, unfractured basin-fill sediments.
- Hydraulic conductivity of the sedimentary and volcanic rock units is generally low and will limit extent of groundwater level drawdown at distance from the pit.
- A fault structure and resulting fractured rocks along Davidson Canyon is believed to have resulted in a higher permeability zone relative to the adjacent rock.
- Occurrence of perennial streamflow in Cienega Creek is characterized as groundwater discharge to the Creek; loss of perennial flow is characterized as
groundwater recharge. A small component of groundwater outflow from upper Cienega Creek basin occurs as streamflow through the “narrows”.

- Streamflow in Davidson Canyon is intermittent, but has been perennial in the past.
- Over the long-term mine-dewatering and pit-lake formation will have a minimal impact on the regional flow system due to the relatively low quantity of groundwater removed from the pit via pumping during excavation and via lake evaporation after mine closure.
- Over the long-term the groundwater system will reach an equilibrium condition where a majority of the evaporation rate from the pit lake will be offset by a decrease the ET rate.
7.0 GROUNDWATER FLOW MODEL

The Rosemont Project groundwater flow model was developed for simulation of local and regional groundwater level impacts due to pit-dewatering, post-closure groundwater level recovery, and potential post-closure pit lake development. Simulation of post-closure pit lake formation includes prediction of pit lake filling times, quantity of groundwater contributing to the pit lake water balance, pit lake equilibrium water level, and determination of whether the pit lake will remain a hydraulic sink into the future. Construction of the model is based on available hydrogeologic data described previously in the report. The Rosemont model was constructed using MODFLOW-SURFACT (version 3.0, HydroGeoLogic Inc., 1996), including the LAK2 package (Council, 1999) for simulation of the pit lake, and Groundwater Vistas, a graphical modeling interface (Rumbaugh and Rumbaugh, 2007).

The groundwater system in the Rosemont Project area is simulated as an equivalent porous medium, combined with explicit representations of the Backbone Fault, the Flat Fault, and the Davidson Canyon fault zone in the model. Results from the long-term testing showed multi-directional drawdown response in observation wells, generally supporting the concept that the groundwater system can be considered to behave as an equivalent porous medium. Results of this investigation indicate the three faults simulated in the model act as relatively higher zones of hydraulic conductivity in discrete locations in the bedrock flow system. Other hydraulically significant discrete features were not identified based on the available data.

The model was calibrated to observed groundwater levels, estimates of recharge to the groundwater system, estimates of groundwater outflow from upper Cienega Creek basin, estimates of evapotranspiration, and estimates of hydraulic parameters for the flow system. The model was also calibrated to groundwater level drawdown response during the 30-day pumping test. The primary mechanism for improving the model calibration was to adjust
hydraulic conductivity, aquifer storage, and recharge, using both manual and automated inverse techniques.

Using the calibrated model, simulations were conducted for steady-state pre-mining conditions, a 22-year pit excavation period, and a 1,000-year post-mining period which includes the pit lake formation. Sensitivity of the model calibration to variation of specific model parameters was evaluated for the steady-state conditions. Sensitivity of model predictions for lake formation and groundwater impacts to variation of specific model parameters was also evaluated.

### 7.1 MODEL GRID AND BOUNDARY CONDITIONS

The finite-difference grid and boundary conditions for the model are shown on [Figure 80](#). North, east, and south of the pit, model boundaries are located at sufficient distances from the pit area so as to minimize artificial effects from the model boundaries. The west boundary is specified approximately on the west edge of the Precambrium granodiorite comprising the core of the Santa Rita Mountains which is has very small or no permeability. The model covers an area of 457 square miles, and consists of ten layers with 203 rows and 168 columns. Grid cell dimensions range from 200 by 200 feet in the proposed pit area to 800 by 800 feet at the edge of the model. There are 295,630 active model cells.

The base of the model domain is set at an altitude of 1,000 feet msl. Model layers are flat in the pit area to facilitate implementation of the lake package used to simulate the possible formation of a pit lake following the cessation of mining activities. Due to the lower altitudes in the valley floor areas of the model study area, model layer bottoms would intersect land surface if model layers were maintained flat throughout the model domain. To avoid this situation, the bottom of model layer 1 was adjusted to linearly slope away from the pit area to a minimum of 200 feet below the lowest point in the surrounding valleys. Model
layer 1 ranges in thickness from 71 to 2,633 feet with the thicker sections under the various mountainous peaks and the thinnest sections under the mountain slopes. Model layers 2 through 6 vary in thickness from approximately 200 to 400 feet. Model layers 7 through 10 vary in thickness from approximately 200 to 700 feet.

In the pit area, the bottom of model layer 1 was set at an altitude of 4,800 feet msl, approximately 300 feet below the lowest land surface altitude. East to west thickness of model layer 1 ranges from approximately 300 to 1,370 feet. Model layers 2 through 6 were assigned thicknesses of 300 feet. The bottom of model layer 7, representing the bottom of the proposed pit area, was set at an altitude of 3,050 feet msl with a thickness of 250 feet. Model layers 8 and 9 were assigned thicknesses of 700 feet. Model layer 10, the base of the model, was set at an altitude of 1,000 feet msl with a thickness of 650 feet in the pit area.

Simulated boundaries for the model are coincident with the study area boundary, except in the southwest and southeast portions of the model domain where they are coincident with the Cienega basin boundary (Figure 80). Boundaries are a combination of: (1) general head boundaries (GHB; a head-dependent flux boundary where flow across the boundary is dependent on variation in simulated groundwater level at the boundary) with specified heads located one-half mile from the model boundary, based on estimated equilibrium groundwater levels at these locations, and hydraulic conductivity of the aquifer at the model boundaries; (2) constant head boundaries based on estimates of equilibrium groundwater levels; and (3) no flow boundaries. GHB boundaries were specified in all saturated model layers at boundary locations where projected groundwater level change from pit-dewatering occurred. Constant head boundaries were specified in all other model boundary cells, with the exception of unsaturated layer 1 and 2 boundaries which were specified as no-flow. A vertical gradient was not specified for the boundaries.
7.2 STEADY-STATE INITIAL CONDITIONS

Measured groundwater levels and altitudes of perennial springs used as targets for the steady-state model calibration are shown in Table 2 and on Figure 26. A description of the groundwater level calibration targets is presented in Section 4.2.2. Measured groundwater levels from wells screened across multiple model layers are assigned as targets to the layer for which the water level is most representative. Targets are assigned to deeper layers where the overlying layer is unsaturated, such as in parts of lower Cienega Creek basin and Tucson basin. Piezometers completed at depth in the Rosemont Project are also used as calibration targets. Deeper targets occur in model layers 2, 3, 4, 5, and 6 as shown on Figure 26.

7.3 SIMULATED MODEL PARAMETERS

Hydraulic parameters specified for hydrogeologic units in the model are hydraulic conductivity, specific yield, and specific storage. Results of hydraulic testing, interpretation of geologic data by Rosemont and M&A staff, and interpretation of observed groundwater level conditions are used to characterize hydrogeologic units in the model. Simulated parameters are specified within ranges consistent with calculated values from aquifer testing, where available. Hydrogeologic units specified in the model are described in Section 3.4 and shown in plan view for the 10 model layers on Figures 81 through 90 and in section view on Figures 5, 6, 91 and 92. The ten hydrogeologic units represent a generalized approximation of zonal variation in hydraulic properties in the model study area.

7.3.1 Hydraulic Conductivity

Hydraulic conductivity was varied during model calibration to match observed groundwater level conditions, observed transient drawdown response for the 30-day pumping test, observed streamflow, estimated ET, and estimated recharge. Initial adjustment of
simulated hydraulic conductivities for model calibration to observed groundwater levels utilized the inverse parameter estimation code PEST (Doherty, 2005). Subsequently, hydraulic conductivities were manually adjusted to calibrate the model to measured groundwater level response for the 30-day aquifer test, to incorporate fault zones, to calibrate the model to estimated evapotranspiration rates, and to calibrate the model to estimated and observed perennial streamflow rates and extent in Davidson Canyon and Cienega. An important component of calibrating the model to the 30-day pumping test is matching the no-drawdown response observed in many wells during the testing; indicating low hydraulic conductivity in much of the tested area.

For the inverse calibration hydraulic conductivity was permitted to vary both between and within the hydrogeologic units, resulting in representation of the final horizontal and vertical distribution of hydraulic conductivity as a continuous field, but also showing distinct changes between units. This continuous field distribution recognizes there is substantial natural variation within hydrogeologic units, including variation of fracture occurrence, density, and permeability in the bedrock areas.

Final distribution of simulated hydraulic conductivity resulted in a reasonable match to observed groundwater levels, measured drawdown during the 30-day aquifer test, and streamflow, ET, and recharge boundary conditions. Simulated distribution of hydraulic conductivity for model layers 1 through 10 is shown on Figures 81 through 90. Two sections of simulated hydraulic conductivities with associated geologic and hydrogeologic sections in the Rosemont Project area are shown on Figures 5 and 6. Two sections of simulated hydraulic conductivities in the model domain are shown on Figures 91 and 92.

A chart comparing simulated hydraulic conductivity values with calculated aquifer test values for each hydrogeologic unit, and for the Backbone and Flat Faults, is shown on Figure 30. Correlation of hydrogeologic units to calculated hydraulic conductivity from aquifer tests is presented in Table 5.
Except as noted below, vertical hydraulic conductivity (Kz) was simulated equivalent to horizontal hydraulic conductivity (Kx and Ky). With the exception of response to pumping well RP-3B discussed below in the Kv hydrogeologic unit section, results of pumping test data were inconclusive as to any horizontal to vertical anisotropy. Much of the bedrock is substantially rotated from original bedding plans, and fracture dominated permeability is typically biased along stress directions rather than horizontal and vertical directions. Results of aquifer testing in the bedrock did not demonstrate decreased hydraulic conductivity at depth.

Specification of hydraulic conductivity values in the model is described as follows.

- **Quaternary and Recent Alluvium (Qal)** – Pumping tests conducted in the six wells screened in the Qal hydrogeologic unit indicate hydraulic conductivities greater than 100 ft/d. Model simulated horizontal hydraulic conductivity values range from 1 to 68 ft/d. Model simulated hydraulic conductivity values in Qal are decreased from pumping test values because the thickness of layer 1 in the model is greater than the actual thickness of this unit. Tributaries to Cienega Creek with mapped recent alluvium are assigned lower hydraulic conductivity values than along Cienega Creek to account for the decrease in thickness. Simulated horizontal to vertical hydraulic conductivity ratio is 10:1.

- **Late Tertiary to Early Quaternary Basin-Fill Deposits – Higher Permeability (QTg) (Cienega Basin)** – The 13 wells screened in the QTg hydrogeologic zone in which pumping tests were conducted are also screened in QTg1. Pumping tests conducted in these wells indicate hydraulic conductivities range from 0.81 to 4.23 ft/d. This range is higher than the range for wells screened only in QTg1 discussed below. Model simulated horizontal hydraulic conductivity values in the QTg range from 1.01 to 4.17 ft/d and in the QTg1 range from 0.02 to 0.95 ft/d. Simulated hydraulic conductivity values in QTg align well with pumping test data.
for wells screened in both QTg and QTg1. Simulated horizontal to vertical hydraulic conductivity ratio is 10:1.

- **Late Tertiary to Early Quaternary Basin-Fill Deposits – Higher Permeability (QTg) (Tucson Basin)** – The Tucson basin lies within the northwest corner of the model study area. The Tucson basin has been modeled by the ADWR using the Tucson Active Management Area (AMA) model (ADWR, 2006b). Layer 2 of the Tucson AMA model corresponds approximately to a small corner of layer 3 of the Rosemont model. Hydraulic conductivities in layer 2 of the Tucson AMA model range from 10 to 45 ft/d. Layer 3 of the Tucson AMA model is simulated using transmissivity with values ranging from 500 to 1300 ft²/d. Layer 3 of the Tucson AMA model is assumed to correspond to layers 4 through 10 of the Rosemont model. The total thickness of this area of the Rosemont model is approximately 1,400 to 1,600 ft. Horizontal hydraulic conductivities in layers 1 through 10 of the Tucson basin portion of the Rosemont model are assigned a value of 2 ft/d. Simulated horizontal to vertical hydraulic conductivity ratio is 10:1.

- **Late Tertiary to Early Quaternary Basin-Fill Deposits – Lower Permeability (QTg1)** – Pumping tests in the 11 wells screened in the QTg1 hydrogeologic unit indicate hydraulic conductivities range from 0.02 to 0.78 ft/d. Simulated horizontal hydraulic conductivity values in the QTg1 range from 0.02 to 0.95 ft/d, aligning well with the pumping test data for this unit. Simulated horizontal to vertical hydraulic conductivity ratio is 10:1.

- **Late Tertiary to Early Quaternary Basin-Fill Deposits – Lowest Permeability (QTg2)** – The 2 wells screened in the QTg2 hydrogeologic zone in which pumping tests were conducted are also screened in Ksd. Both wells are located in the southeast corner of the proposed pit area and pumping tests indicate very low hydraulic conductivities from 0.001 to 0.0046 ft/d. Simulated horizontal hydraulic conductivity in QTg2 is 0.003 ft/d, aligning well with the pumping test hydraulic conductivity values. Simulated hydraulic conductivity values for Ksd
are described below. Simulated horizontal to vertical hydraulic conductivity ratio is 10:1.

- **Early to Mid-Tertiary Sedimentary and Volcanic Units (Pantano Formation) (Tsp)** – Only one well with pumping test data is screened in the Pantano Formation and this unit is very limited in extent within the model area. Test results from this indicate a very low hydraulic conductivity of 0.002 ft/d. Simulated hydraulic conductivity values range from 0.04 to 0.09 ft/d.

- **Upper Cretaceous and Early Tertiary Intrusive Rocks (KTi)** – No wells with pumping test data are screened in the KTi hydrogeologic unit. Model simulated hydraulic conductivity for model layer 1 ranges from 0.001 to 0.1 ft/d. Model simulated hydraulic conductivity for model layers 2 through 10 is 0.0006 ft/d. A higher hydraulic conductivity is simulated in layer 1 to account for surficial basin fill material along the margin of the Tucson basin and increased near-surface fracturing and permeability.

- **Upper Cretaceous Sedimentary and Volcanic Rocks (Kv)** – Pumping tests in the 10 wells screened only in the Kv hydrogeologic unit indicate hydraulic conductivities range from 0.0008 to 1.6 ft/d. Pumping tests in the two wells screened in Kv and QTg1 indicate hydraulic conductivities range from 0.04 to 0.2, which is within the range of test results for wells screened only in Kv. The range is due to the variation of fracture and fault occurrence, density, permeability, and inter-connectivity. Simulated hydraulic conductivity values in Kv range from 0.0007 to 3 ft/d, aligning well with the pumping test data for this unit. The lower hydraulic conductivity values are simulating part of the Santa Rita Mountains north-northeast of the proposed pit and the higher hydraulic conductivity values are simulating part of the Davidson Canyon fault zone described in Section 3.5 and discussed in more detail below. To decrease simulated response in monitoring well RP-3A from pumping in well RP-3B, simulated horizontal to vertical hydraulic conductivity ratio is 10:1.
Lower Cretaceous Sedimentary Units (Bisbee Group) (Ksd) – Pumping tests in the 17 wells screened only in the Ksd hydrogeologic unit indicate hydraulic conductivities range from 0.0004 to 4 ft/d. Pumping tests in the 10 wells screened in Ksd and Pz indicate hydraulic conductivities range from 0.04 to 1, which is within the range of test results for wells screened only in Ksd. The range is due to the variation of fracture and fault occurrence, density, permeability, and interconnectivity. Simulated hydraulic conductivity values in Ksd range from 0.0003 to 4 ft/d, aligning well with the pumping test data for this unit. The lower hydraulic conductivity values are simulating part of the Santa Rita Mountains south and north-northeast of the proposed pit. The higher hydraulic conductivity values are in layer 1 to account for surficial basin fill material along the margin of the Tucson basin and increased near-surface fracturing and permeability and are simulating part of the Davidson Canyon fault zone described in Section 3.5 and discussed in more detail below.

Paleozoic Sedimentary and Metamorphic Formations (Pz) – Pumping tests in the 19 wells screened only in the Pz hydrogeologic unit indicate hydraulic conductivities range from 0.02 to 1 ft/d. Pumping tests in the 10 wells screened in Ksd and Pz indicate hydraulic conductivities range from 0.04 to 1, which is within the range of test results for wells screened only in Pz. The range is due to the variation of fracture and fault occurrence, density, permeability, and interconnectivity. Simulated hydraulic conductivity values in Pz range from 0.001 to 4 ft/d, aligning well with the pumping test data for this unit. The values of hydraulic conductivity within the simulated range that are higher than the range of pumping test results reflect higher conductivities simulating part of the Davidson Canyon fault zone described in Section 3.5 and discussed in more detail below and the western portion of the Flat Fault described in Section 3.5 and discussed in more detail below.

Precambrian Igneous and Metamorphic Crystalline Formations (pCb) – Only one well is screened in the pCb hydrogeologic unit. Corehole 1445 was a
monitoring well during the 30-day aquifer test conducted in the Rosemont Project area in late 2008. Test results indicate a hydraulic conductivity of 0.2 ft/d, but the interpretation of the drawdown response at this corehole is questionable and not believed representative of the impermeable \( pC \) hydrogeologic unit. Model Simulated hydraulic conductivity for model layer 1 ranges from 0.0001 to 1 ft/d. Simulated hydraulic conductivity for model layers 2 through 10 ranges from 0.0001 to 0.0008 ft/d. A higher hydraulic conductivity is simulated in layer 1 to account for alluvial fill materials on the west side of the model and increased near-surface fracturing and permeability.

Investigations have identified three fault zones believed to influence groundwater movement in the model area: the Davidson Canyon fault zone, the Backbone Fault, and the Flat Fault.

- **Davidson Canyon Fault Zone** – Davidson Canyon lies to the northeast of the pit area and west of the Empire Mountains. Hydraulic conductivity was initially assigned to Davidson Canyon by extrapolating pumping test results from the 30-day test area to the southwest. Hydraulic conductivity was then increased in a narrow zone extending in depth from layer 1 through layer 4, a thickness of approximately 1,200 feet, to a range from 0.5 to 4 ft/d. Increase in this hydraulic conductivity results in a good match of simulated groundwater levels to observed conditions along lower Davidson Canyon. This zone coincides roughly with the north-south trending Davidson Canyon fault zone along the west flanks of the Empire Mountains (Section 3.5). Hydraulic conductivities on either side of this simulated fault zone range from about 0.001 to 0.02 ft/d.

- **Backbone Fault** – The high-angle faulted zone in the steeply dipping \( Pz \) and \( Ksd \) hydrogeologic units running north-south along the Santa Rita Mountains through the proposed pit area is assigned a \( Kx \) horizontal (east-west) hydraulic conductivity value of 0.01 ft/d, a \( Ky \) horizontal (north-south) hydraulic conductivity
conductivity value of 0.1 ft/d, and a Kz vertical hydraulic conductivity value of 0.1 ft/d. The Kx and Ky anisotropy reflects the steeping dipping nature of the units in this faulted zone with Ky and Kz being parallel to the plane of deposition and Kx being perpendicular to the plane of deposition. The increase in Kz hydraulic conductivity results in a substantially improved match of simulated to observed drawdown response in piezometer PZ-7 to PC-5 pumping. The increased Kz also permits higher simulated recharge in the Backbone Fault which, combined with the Flat Fault, creates higher groundwater levels observed at depth and supports artesian conditions measured east from the Backbone Fault.

- **Flat Fault** – The low-angle fault between the Pz and Ksd hydrogeologic units in the proposed pit area was assigned a hydraulic conductivity value of 2 ft/d. To the east and at depth, the Flat Fault was assigned a hydraulic conductivity value of 0.035 ft/d. The higher conductivity west portion of the Flat Fault results in an improved match of simulated to observed drawdown response to PC-5 pumping and improved match to measured groundwater levels observed at depth. Hydraulic conductivity in the east portion of the Flat Fault is decreased to account for reduced fault connectivity at depth and to maintain higher groundwater levels observed in the pit area.

### 7.3.2 Storage

Simulated specific yield and specific storage are determined based on published data for the basin-fill deposits, published data for similar fractured rock systems, limited data from pumping tests, and model calibration to the 30-day pumping test. Storage is not evaluated as part of the steady-state model calibration. For each model layer, storage is simulated as specific yield when groundwater levels are below the top of a model layer and as specific storage when groundwater levels are above the top of a model layer. Specific yield and specific storage values were adjusted using PEST (Doherty, 2005) by inversion to measured groundwater level response to pumping during the 30-day multi-well aquifer test.
conducted in late 2008 (M&A, 2009b) and by manual manipulation. Specific yield and specific storage are assigned for each of the hydrogeologic units, based on their general hydraulic properties and on results of pumping tests where available. Adjusted storage parameter values for the recent alluvium, basin-fill deposits, and bedrock units are summarized as follows:

- **Recent alluvium**
  - Specific yield – 0.15
  - Specific storage – 2.0 x 10^-6

- **Basin-fill deposits**
  - Specific yield – 0.1
  - Specific storage – 2.0 x 10^-6

- **Bedrock**
  - Specific yield – 0.01
  - Storage coefficient – 2.0 x 10^-7

- **Backbone and Flat Faults**
  - Specific yield – 0.025
  - Specific storage – 2.0 x 10^-7

### 7.4 RECHARGE FROM PRECIPITATION

#### 7.4.1 Pre-Mining Recharge

Simulated recharge rates for pre-mining and the 22-year mining period are shown on Figure 93. Initial distribution of recharge rates was based on the Anderson method (1995) using PRISM (Prism Group, 2008) derived precipitation data. However, results of steady-state model calibration demonstrate that the Cienega Creek basin groundwater flow system could not transmit this quantity of flow. For the final calibrated model simulation, the
relative distribution of recharge was approximately maintained from that derived from the PRISM distribution of precipitation, but volume of recharge was reduced by approximately one-third of the 10,100 AF/yr rate estimated for the model domain using the Anderson method.

Total simulated recharge for the model domain is 6,500 AF/yr, including 3,156 AF/yr in upper Cienega Creek basin, 1,642 AF/yr in lower Cienega Creek basin, and 1,702 AF/yr in the Tucson basin. Adjustments were made to the PRISM-derived distribution as part of the model calibration process, including:

- In the exposed Precambrian granodiorite (pCb) occurring in the Santa Rita Mountains and north of the Empire Mountains, recharge rate was reduced by approximately 50 percent from initial estimates to account for the very low permeability of the rock and associated low recharge potential. Simulated recharge rate in the highest altitudes of the Santa Rita Mountains, south from the proposed pit, is 0.19 in/yr.

- In the exposed intrusive rocks in the Empire Mountains and Santa Rita Mountains (KTi), the recharge rate was reduced by approximately 50 percent from initial estimates to account for the very low permeability of the rock and associated low recharge potential. Almost all of this recharge reduction occurred in the Tucson basin, with small portions in upper and lower Cienega Creek basins. Simulated recharge in the Empire Mountains, northeast from the proposed pit, is 0.22 in/yr.

- In the exposed area of the Backbone Fault recharge rate was increased fourfold to account for the vertically conductive heavy faulting in the paleozoics and associated high recharge potential. Simulated recharge rate in the Backbone fault is 1.36 in/yr.

- An additional 1,159 AF/yr and 806 AF/yr of recharge was simulated in the basin fill deposits along mountain fronts in upper Cienega Creek basin and in Tucson basin, respectively. The low permeability of the bedrock did not support the
quantities of recharge estimated from the PRISM precipitation distribution; some of this recharge was redistributed to mountain front locations where the alluvial material will accept more recharge.

In general, the highest distribution of simulated recharge occurs in the higher altitudes of Cienega Creek and Tucson basins, and in the mountain front recharge areas. The highest simulated recharge rate is 2.04 in/yr in the mountain front areas, and the lowest is 0.09 in/yr in the central basin areas (Figure 93). Simulated recharge rate at the center of the proposed pit, east from the Backbone Fault, is 0.33 in/yr.

A net simulated inflow of 1,497 AF/yr to upper Cienega Creek basin via the GHB and constant head boundaries is considered analogous to basin recharge, as there are conceptually no other inflow boundaries in Cienega Creek basin. Inflow via GHB and constant head boundaries in the lower Cienega Creek basin, which are analogous to mountain front recharge, is approximately 1,102 AF/yr. Tucson basin does not derive any additional mountain front recharge from model boundaries.

Simulated recharge is summarized as follows:

- Upper Cienega Creek basin – 4,653 AF/yr including 1,497 AF/yr from GHB and constant head inflows
- Lower Cienega Creek basin – 2,654 AF/yr including 1,012 AF/yr from GHB and constant head inflows
- Tucson basin – 1,702 AF/yr

Potential recharge to the upper Cienega Creek basin is constrained by estimates for quantity of groundwater discharge from upper to lower Cienega Creek basins. Discharge from the upper basin primarily occurs at the “narrows” via base flow in Cienega Creek and as subflow in the Recent alluvium associated with the Creek. Simulated Cienega Creek base
flow at the narrows is approximately 2 cfs (Section 7.6) is consistent with the 1 to 3 cfs estimates of base flow in Cienega (M&A, 1985; PAG, 1998), and may be high given that drought conditions have reduced base flow since the referenced studies were conducted. Simulated subflow between basins in the alluvium along the narrows is approximately 0.95 cfs, which is a reasonable quantity given the limited thickness of alluvium and groundwater gradient. Total simulated surface flow and alluvial subflow from the upper to lower Cienega Creek basins through the narrows, at the boundary between upper and lower Cienega Creek basins, is 1.8 cfs or approximately 1,300 AF/yr. Additional groundwater flow from upper Cienega Creek basin through the intrusive igneous and sedimentary rocks of the Empire Mountains, including Davidson Canyon, is relatively small due to the low permeability of the rock material, and direction of groundwater flow does not indicate substantial movement of groundwater in this direction. Therefore, total discharge from upper Cienega Creek basin, including simulated evapotranspiration discharge of 3,050 AF/yr (Section 7.5), is 4,350 AF/yr. This represents the approximate limit of recharge that can be simulated in the upper basin. Simulated recharge in the upper Cienega Creek basin is 4,653 AF/yr.

Recharge in lower Cienega Creek basin, including the Davidson Canyon drainage, was applied in a similar manner to upper Cienega Creek basin. The reasonable match of simulated to observed groundwater levels in the lower basin (Section 7.7.1), combined with the use of hydraulic conductivities derived from aquifer testing, supports the recharge distribution simulated in the model.

### 7.4.2 Post-Mining Recharge

After the end of the 22-year mining period, simulated recharge is altered to account for constructed tailings and waste rock impoundments and infiltration from constructed drains under the tailings impoundment. A location map of the constructed facilities which affect post-mining simulated recharge is shown on Figure 94. Based on results of a study by
AMEC (2009), recharge from precipitation was simulated as zero for the tailings and waste rock areas. AMEC estimated tailings draindown decreases from an initial rate of approximately 13.6 AF/yr (8.4 gpm) to zero at 500 years after end of mining. Projected draindown recharge from the tailings is shown on Figure 95. No groundwater recharge occurs in the open pit and estimated recharge from retention basins is assumed negligible due to the low vertical conductivity of the bedrock, limited precipitation events, and high evaporation rate.

For this study, determination of recharge potential for the constructed drains in the tailing area took into account both the vertical hydraulic conductivity of the bedrock underlying the drains and the occurrence of rainfall events. The low simulated vertical conductivity of the bedrock material underlying the drains, ranging from 0.0009 to 0.07 ft/d, substantially limits the maximum potential recharge rate which could occur into the bedrock beneath the drains. Further, the average days of measurable precipitation at the Rosemont weather station is 63 based on water year 2008 and 2009 data provided by Tetra Tech (2010), of which many are small rainfall events which would likely result in minimal flow to the drains. For the predictive simulation, we assumed a simplified, conservatively low estimate of annual recharge volume from the drains of 7.53 AF/yr (4.66 gpm). Recharge rate (length/time) is uniformly simulated over the area of each drain recharge cell (Figure 94) as equivalent to the average pre-mining recharge rate for all the drain recharge cells.

At start of the tailings draindown (post-mining year 1), alteration of simulated recharge due to the constructed facilities and the open pit results in a net decrease in simulated recharge of 73.1 AF/yr (45.3 gpm) from initial pre-mining conditions.
7.5 EVAPOTRANSPIRATION

Evapotranspiration is simulated for riparian areas along Cienega Creek and northern Davidson Canyon using the MODFLOW EVT package which allows evapotranspiration discharge to vary in response to groundwater level changes at the discharging model cell. For the calibrated model, simulated steady-state groundwater discharge due to evapotranspiration is 3,050 AF/yr in upper Cienega Creek, 1,957 AF/yr in lower Cienega Creek including 171 AF/yr in Davidson Canyon, for a total of 5,007 AF/yr. For purposes of this study, Davidson Canyon was assumed to extend to a point immediately above the confluence with Cienega Creek. Davidson Canyon simulated annual ET rates and extinction depths for the seven evapotranspiration zones, and are an additional zero recharge zone, (Section 4.3.4) are shown on Figure 96, along with the estimated rates presented on Figure 27. Extinction depth for each zone was calculated as a weighted average of the different plant types in each zone, as specified by Leenhouts and others (2006) and Maddock and Baird (2003). Distribution of the simulated rates match reasonably well with estimates for the seven zones, and the total simulated rate is 18 percent larger than the estimated 4,245 AF/yr total rate for the model area (Section 4.3.4).

7.6 GROUNDWATER INTERACTION WITH STREAMS

Groundwater-surface water interaction of base flow in selected stream reaches within the model domain is simulated using the MODFLOW STR package. Based on the PAG (2000b) stream inventory, two perennial reaches along Cienega Creek and one perennial reach along Davidson Canyon are represented as having base flow in the model. Simulation of base flow in these reaches is considered adequate for purposes of approximately representing groundwater discharge to and recharge from perennial reaches in the Cienega Creek and Davidson Canyon areas. The Cienega Creek reaches are located in upper Cienega
Creek basin south of Interstate-10 at the “narrons” and in lower Cienega Creek north of Interstate-10 (Figure 7); both reaches are interrupted by stretches of intermittent flow.

The Davidson Canyon reach is associated with discharge from an unnamed spring discharging to the channel, located about 11.5 miles north from the proposed mine (Figure 7). Discharge from the spring is not simulated explicitly in the model; simulated groundwater discharge to the stream channel is analogous to the spring discharge. Other known perennial stream reaches in the study area were not simulated because groundwater discharge and recharge in these reaches are very small.

Simulated perennial sections of Cienega Creek and Davidson Canyon for the pre-mining steady-state model are shown on Figure 97, along with the observed perennial reaches. Comparisons of wetted length and flows of simulated reaches to observed perennial reaches are as follows:

- Extent of simulated perennial reaches for Cienega Creek in the upper basin approximately matches observed perennial reaches. Simulated flow at the narrows is approximately 2.04 cfs (Figure 97) which approximately matches the 2 cfs average of previous estimates (M&A, 1985; PAG, 1998).

- Extent of simulated perennial reaches for Cienega Creek in the lower basin approximately matches observed perennial reaches. Simulated streamflow is approximately 2.4 cfs at the northernmost reach in the model domain which is larger than the 1 cfs base flow measurements by PAG from August 1993 through June 2008 (data obtained from PAG, 2008), which were measured farther downstream, outside of the model domain boundary. For the calibrated model, simulated surface outflow from the model domain occurs via lower Cienega Creek, compared to observed conditions indicating the reach is intermittent at this location. The intent was to simulate groundwater infiltration of this surface flow immediately inside the model boundary so the water would exit the model as
underflow; this could not be accomplished with the calibrated model. However, simulation of surface flow at the boundary is acceptable for purposes of this investigation as it occurs in an area outside of projected groundwater impacts from mining activities (Section 7.11.3) and does not affect the ability of the model to quantify projected changes in surface flow in Cienega Creek.

- Extent of the simulated perennial reach for Davidson Canyon approximately matches the perennial reach observed in the past; the reach is presently intermittent. Simulated flow is approximately 0.24 cfs (Figure 97) which is consistent with the small flows which occurred in the past and larger than the recent intermittent flow conditions observed at this reach.

Hydraulic conductivity used to calculate simulated streambed conductance was specified as 100 ft/day. This conductivity is conservatively high and will not mitigate reductions in simulated streamflow due to potential drawdown in the vicinity of the stream channel.

7.7 STEADY-STATE MODEL CALIBRATION AND SENSITIVITY ANALYSIS

The steady-state model is calibrated to measured groundwater levels as shown on Figure 26, and as described in Sections 7.3 through 7.6, to estimates of recharge to the groundwater system, estimates of groundwater outflow from upper Cienega Creek basin, estimates of evapotranspiration, and estimates of hydraulic parameters for the flow system. The groundwater system is assumed to be in a state of equilibrium, meaning that the quantity of groundwater in storage is not changing substantially from year to year. Results of the steady-state model calibration to observed groundwater levels and sensitivity analysis are summarized in the following sections.
7.7.1 Calibration to Steady-State Groundwater Levels

The primary mechanism for improving the correspondence between simulated and observed steady-state groundwater levels was to adjust model hydraulic conductivity and distribution of recharge. Contours of simulated groundwater level altitude for the steady-state calibration, and the difference, or “residual”, calculated by subtracting the simulated groundwater altitude from the observed groundwater altitude targets at each measurement location, are shown on Figure 98. The residual mean, the average difference between observed and simulated groundwater altitudes, is 26.2 feet. As the residual mean approaches zero, the simulated groundwater altitudes more closely match the observed conditions. The absolute residual mean, the average of the absolute value of difference between observed and simulated groundwater altitudes, is 58.0 feet and represents the magnitude of the difference between observed and simulated groundwater altitudes. The residual standard deviation is 80.6 feet, and the residual standard deviation divided by the range of observed data is 2.8 percent. Values for the residual standard deviation divided by the observed data range should be below 10 percent for an acceptably calibrated model.

A graph of observed versus simulated groundwater elevations is shown on Figure 99. Data points for the target locations are grouped around the 45-degree line, without substantial bias to either side of the line, indicating a good calibration. A few of the simulated groundwater levels at the highest altitudes of the Santa Rita Mountains are above and below the observed target altitude by more than 100 feet. It is expected that the model would have difficulty reproducing observed levels in this area, as these rocks are believed the least permeable (lowest hydraulic conductivity), resulting in groundwater being poorly connected, or disconnected, from the system simulated in the model. Simulated groundwater levels from 4,200 to 3,200 feet msl show some limited bias to be lower than observed targets; however, this area is in lower Cienega Creek basin and does not compromise model projections in Davidson and upper Cienega Creek basin. Simulated groundwater levels
below 3,200 feet are in Tucson basin and the poor fit of some of the data points in this area
does not compromise model projections.

7.7.2 Steady-State Sensitivity Analysis

A sensitivity analysis is typically part of the documentation of model calibration
(ASTM, 1993). The purpose of a sensitivity analysis is to document relative sensitivity of
the model calibration to variation of model parameters. This provides information about
which parameters are most important to the model calibration.

For the steady-state sensitivity analysis, hydraulic conductivities were varied for all
10 hydrogeologic units, and for the Backbone Fault, the Flat Fault, and the Davidson Canyon
Fault. The simulated Backbone and Flat Fault zones were excluded from variations of the
10 hydrogeologic units. Recharge was varied separately for the combined bedrock area
(including QTg2), for the Backbone Fault zone, and for the basin fill deposits. Parameter
variation ranges include:

- Simulated hydraulic conductivity was increased and decreased up to 1 order of
  magnitude for bedrock hydrogeologic units Tsp, KTi, Kv, Ksd, Pz, and pCb, and
  the low-permeability basin fill unit QTg2; a range of ten sensitivity runs were
  conducted for each area.
- Simulated hydraulic conductivity was increased and decreased up to 30 percent
  for basin hydrogeologic units Qal, QTg, and QTg1; a range of six sensitivity runs
  were conducted for each area.
- Simulated Kx horizontal hydraulic conductivity (east-west alignment) was
  increased up to 1 order of magnitude for the Backbone Fault, resulting in isotropic
  hydraulic conductivity for the Backbone Fault zone; a range of five sensitivity
  runs were conducted.
• Simulated Kz vertical hydraulic conductivity and Ky horizontal hydraulic conductivity (north-south alignment) was decreased up to 1 magnitude for the Backbone Fault, resulting in isotropic hydraulic conductivity for the Backbone Fault zone; a range of five sensitivity runs were conducted.
• Simulated hydraulic conductivity was decreased up to 1 order of magnitude in the east side of the Flat Fault; a range of five sensitivity runs were conducted.
• Simulated hydraulic conductivity was decreased up to 1 order of magnitude in the west side of the Flat Fault; a range of five sensitivity runs were conducted.
• Simulated hydraulic conductivity is decreased in the Davidson Canyon fault zone to approximately match the surrounding rock formations; a single sensitivity run was conducted.
• Simulated recharge was increased and decreased up to 30 percent for the combined bedrock area (including QTg2), for the Backbone Fault zone, and for the basin fill deposits; a range of six sensitivity runs were conducted for each area.

Results of varying hydraulic conductivity in the bedrock hydrogeologic units and the QTg2 unit are presented on Figure 100. Sensitivity is plotted in terms of percentage change from the base simulation (Section 7.1.1) residual standard deviation of 80.6 feet. The results indicate the base simulation calibration is optimized for the varied parameters; changes to the parameters do not improve the steady-state model calibration.

The lower cretaceous Ksd hydrogeologic unit shows the most sensitivity to hydraulic conductivity variations (Figure 100). A 1-magnitude increase and decrease in hydraulic conductivity for the Ksd unit results in a 215 and 147 percent increase in the residual standard deviation, respectively. This unit is the most substantial bedrock hydrogeologic unit in the model domain and controls much of the groundwater movement east from the pit. Representative hydraulic conductivities were determined for the simulated Ksd units based
on calibration and testing the Willow Canyon formation; results of the steady-state sensitivity analysis indicate the simulated values are appropriate, based on the available data.

The next most sensitive parameter is the hydraulic conductivity of the Precambrian granodiorite pCb hydrogeologic unit which occurs in the highest altitudes of the Santa Rita and Empire Mountains (Figure 7). A decrease in hydraulic conductivity of this parameter substantially raises groundwater levels west from the pit, resulting in a 175 percent increase in the residual standard deviation (Figure 100). Other than corehole 1445 observation well which produced inconclusive results during the 30-day pumping test, no hydraulic testing was conducted in the pCb unit. The unit is simulated as having low hydraulic conductivity ranging from 0.0001 to 1 ft/day in model layer 1 and from 0.0001 to 0.0008 ft/d in model layers 2 through 10.

Other sensitive parameters include the hydraulic conductivity of the upper cretaceous intrusives KTi and paleozoics Pz hydrogeologic units. The KTi unit occurs in the Santa Rita and Empire Mountains west and north from the pit area (Figure 7). Decrease in hydraulic conductivity of KTi changes groundwater levels through Davidson Canyon, resulting in a 175 percent increase in the residual standard deviation (Figure 100). Estimates for this parameter rely on model calibration to observed groundwater levels as no hydraulic testing was conducted in the KTi unit. The Pz unit occurs in the west pit area and the Empire Mountains (Figure 7). Variation in hydraulic conductivity of Pz changes groundwater levels in the area of the pit and downgradient from the pit, resulting in a 57 to 70 percent increase in the residual standard deviation (Figure 100). Hydraulic testing in the Pz unit was predominantly in the Backbone Fault area.

The decrease in hydraulic conductivity of the Kv hydrogeologic unit resulted in higher groundwater levels east from the Kv formation. The residual standard deviation was increased by 52 percent (Figure 100). The Kv unit is located approximately 2 to 3 miles east from the pit (Figure 7).
Reducing simulated hydraulic conductivity for the Davidson Canyon Fault to that of surrounding bedrock resulted in a 71 percent increase in the residual standard deviation. Reduction of the hydraulic conductivity results in higher water levels south from the simulated fault.

The model calibration was not sensitive to changes in basin fill hydraulic conductivities (Figure 101) and results show the model calibration is reasonably optimized for these parameters.

Variations in recharge for the bedrock areas increased the residual standard deviation more than varying recharge for the basin fill and the Backbone Fault, which are insensitive to variations in recharge (Figure 102). However, variation of the bedrock recharge resulted in only a 12 to 22 percent change to the residual standard deviation which is not significant given how well the base simulation is calibrated. Results show the model calibration is well optimized for simulated recharge.

### 7.7.3 Steady-State Model Groundwater Balance

The simulated steady-state groundwater balance is as follows:

**Simulated Groundwater Inflow**

- Recharge from precipitation – 6,500 AF/yr
  - upper Cienega Creek basin – 3,156 AF/yr
  - lower Cienega Creek basin – 1,642 AF/yr
  - Tucson basin (portion) – 1,702 AF/yr
- Stream Base Flow Losses (net) – 0 AF/yr
  - (net) upper Cienega Creek basin – 0 AF/yr
  - (net) lower Cienega Creek basin – 0 AF/yr
    - (net) including 0 AF/yr in Davidson Canyon
Simulated Groundwater Outflow
- Evapotranspiration – 5,007 AF/yr
  - upper Cienega Creek basin – 3,050 AF/yr
  - lower Cienega Creek basin – 1,957 AF/yr
    - including 171 AF/yr from Davidson Canyon
- Stream Base Flow Gains (net) – 1,715 AF/yr
  - (net) upper Cienega Creek basin – 1,223 AF/yr
  - (net) lower Cienega Creek basin – 492 AF/yr
    - including 152 AF/yr (net) in Davidson Canyon

GHB and Constant Head Boundary Flow (Net)
- (Net) boundary flow – 227 AF/yr (inflow)
  - (net) upper Cienega Creek basin – 1,497 AF/yr (inflow)
  - (net) lower Cienega Creek basin – 1,012 AF/yr (inflow)
    - including 1,714 AF/yr Cienega Creek surface flow out northern model boundary.
  - (net) Tucson basin – 2,282 AF/yr (outflow)

Inflows - Outflows
6,500 AF/yr + 0 AF/yr - 5,007 AF/yr - 1,715 AF/yr + 227 AF/yr = 5 AF/yr
Error = (5 AF/yr / 6,500 AF/yr) x 100 = 0.08 percent

7.8 MODEL CALIBRATION TO LONG-TERM MULTI-WELL PUMPING TEST

The model is calibrated to measured groundwater level drawdown and recovery response observed during the multi-well 30-day pumping test conducted at wells PC-5, RP-6, HC-1B, HC-5A, and RP-3B during the period November 2008 through January 2009. Pumping occurred for durations of 12 to 30 days through December 19, 2008. Groundwater level changes were measured at pumping wells and nearby observation wells and piezometers. After pumping stopped, groundwater level conditions were monitored for 30-
day recovery period extending to January 18, 2009. Locations of the tested wells and observation wells and piezometers are shown on Figure 29.

7.8.1 Calibration to Multi-Well Pumping Test

The primary mechanism for improving the correspondence between simulated and observed drawdown and recovery response for the multi-well pumping test was to adjust model hydraulic conductivity and storage. The model calibration to the observed drawdown is qualitative. Model parameters were adjusted to improve match of the magnitude and slope of the simulated drawdown and recovery to observed data. Hydrographs of simulated and observed drawdown and recovery response for the 5 pumping wells and 46 observation wells and multi-depth completion piezometers are shown on Figures 32 through 79. Drawdown response observed in the wells is described extensively in Section 5.1.3. The comparisons are shown on semi-log plots. Description of calibration results are grouped by pumping well.

CALIBRATION FOR PUMPED WELL PC-5

Calibration hydrographs are shown on Figures 32 through 54 for pumped well PC-5 and associated observation wells and piezometers, including: PZ-5, PC-1, PC-2, PC-6, PC-3, PZ-7, PC-7, HC-3A, HC-3B, HC-3C, PC-4, PC-8, and PZ-8. Well PC-5 was pumped for 30 days at 43.1 gpm. Well PC-5 is completed in the Willow Canyon Formation (included in Ksd) and underlying Paleozoic rocks, including the Flat Fault (Figure 5). Observed response to PC-5 pumping is complex and substantially influenced by occurrence of the intersecting Flat Fault and the Backbone Fault east from PC-5. Hydraulic parameters of these faults were adjusted to improve match of simulated to observed response. Response in other directions to PC-5 pumping is generally not observed. Results of the calibration of simulated response to observed are summarized below:
<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</th>
<th>COMMENTS</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC-5</td>
<td>Ksd and Pz (including Flat Fault)</td>
<td>Moderate</td>
<td>PC-5 is a pumping well; simulated drawdown is substantially less than observed. Simulated drawdown and recovery trends are steeper than observed.</td>
<td>32</td>
</tr>
<tr>
<td>PZ-5 (600)</td>
<td>Ksd</td>
<td>Poor</td>
<td>Simulated drawdown is less than observed; simulated drawdown and recovery trends are steeper than observed.</td>
<td>33</td>
</tr>
<tr>
<td>PZ-5 (1150)</td>
<td>Pz (including Flat Fault)</td>
<td>Poor</td>
<td>Simulated drawdown is substantially more than observed; simulated drawdown and recovery trends are steeper than observed. Connection with the Flat Fault believed to account for the smaller drawdown response.</td>
<td>34</td>
</tr>
<tr>
<td>PZ-5 (1800)</td>
<td>Pz</td>
<td>High</td>
<td>Simulated drawdown and recovery match observed.</td>
<td>35</td>
</tr>
<tr>
<td>PC-1</td>
<td>Ksd</td>
<td>Poor</td>
<td>Simulated drawdown is substantially more than observed; simulated drawdown and recovery trends are steeper than observed.</td>
<td>36</td>
</tr>
<tr>
<td>PC-2</td>
<td>Ksd and Pz (including Flat Fault)</td>
<td>Poor</td>
<td>Simulated drawdown is substantially more than observed; simulated drawdown and recovery trends are steeper than observed. Connection with the Flat Fault believed to account for the smaller drawdown response.</td>
<td>37</td>
</tr>
<tr>
<td>PC-6</td>
<td>Pz (including Flat Fault and Backbone Fault)</td>
<td>Poor</td>
<td>Simulated drawdown is substantially more than observed; simulated drawdown and recovery trends are steeper than observed. Connection with the Flat and Backbone Faults believed to account for the smaller drawdown response.</td>
<td>38</td>
</tr>
<tr>
<td>PC-3</td>
<td>QTg2 and Ksd</td>
<td>Moderate</td>
<td>No drawdown observed in well; simulated drawdown is 1.25 feet</td>
<td>39</td>
</tr>
<tr>
<td>PZ-7 (485)</td>
<td>Pz (including Flat Fault and Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown trend matches observed; simulated drawdown is slightly more than observed; simulated recovery trend is flatter than observed.</td>
<td>40</td>
</tr>
<tr>
<td>WELL IDENTIFIER</td>
<td>PRINCIPAL HYDROGEOLOGIC UNITS</td>
<td>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</td>
<td>COMMENTS</td>
<td>SHOWN ON FIGURE NUMBER</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------</td>
<td>-----------------------------------------------</td>
<td>----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>PZ-7 (790)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown trend is slightly steeper than observed; simulated drawdown is slightly more than observed; simulated recovery trend matches observed.</td>
<td>41</td>
</tr>
<tr>
<td>PZ-7 (1245)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown is slightly more than observed; simulated drawdown is more than observed; simulated recovery trend is slightly flatter than observed.</td>
<td>42</td>
</tr>
<tr>
<td>PZ-7 (1680)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown is slightly more than observed; simulated drawdown is more than observed; simulated recovery trend is slightly flatter than observed.</td>
<td>43</td>
</tr>
<tr>
<td>PZ-7 (1800)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown trend is slightly steeper than observed; simulated drawdown is slightly more than observed; simulated recovery trend matches observed.</td>
<td>44</td>
</tr>
<tr>
<td>PC-7</td>
<td>Ksd and Pz (including Flat Fault and Backbone Fault)</td>
<td>Moderate</td>
<td>Simulated drawdown trend is slightly steeper than observed; simulated drawdown is more than observed; simulated recovery trend matches observed.</td>
<td>45</td>
</tr>
<tr>
<td>HC-3A</td>
<td>Qal</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>46</td>
</tr>
<tr>
<td>HC-3B</td>
<td>Ksd</td>
<td>Undetermined</td>
<td>No drawdown simulated; unclear if observed drawdown associated with pumping test.</td>
<td>47</td>
</tr>
<tr>
<td>HC-3C</td>
<td>Ksd</td>
<td>Undetermined</td>
<td>No drawdown simulated; unclear if observed drawdown associated with pumping test.</td>
<td>48</td>
</tr>
<tr>
<td>PC-4</td>
<td>QTg2 and Ksd</td>
<td>Moderate</td>
<td>No drawdown observed; small drawdown simulated.</td>
<td>49</td>
</tr>
<tr>
<td>PC-8</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>No drawdown observed; small drawdown simulated.</td>
<td>50</td>
</tr>
<tr>
<td>PZ-8 (450)</td>
<td>Pz (including Backbone Fault)</td>
<td>Poor</td>
<td>Small drawdown observed; no drawdown simulated.</td>
<td>51</td>
</tr>
<tr>
<td>PZ-8 (1150)</td>
<td>Pz (including Backbone Fault)</td>
<td>High</td>
<td>Simulated drawdown and recovery match well with observed.</td>
<td>52</td>
</tr>
<tr>
<td>PZ-8 (1650)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>No drawdown observed; small drawdown simulated.</td>
<td>53</td>
</tr>
<tr>
<td>PZ-8 (1925)</td>
<td>Pz (including Backbone Fault)</td>
<td>Moderate</td>
<td>No drawdown observed; small drawdown simulated.</td>
<td>54</td>
</tr>
</tbody>
</table>
CALIBRATION FOR PUMPED WELL HC-1B

Calibration hydrographs are shown on Figures 55 through 58 for pumped well PC-5 and associated observation wells, including: HC-1A, RP-5, and corehole 1445. Well HC-1B was pumped for 25 days at 43.0 gpm. Well HC-1B is completed in the Ksd hydrogeologic unit and the south end of the Backbone Fault. Observed response to HC-1B pumping is limited to the adjacent HC-1A well. A potential response was measured in the shallow corehole 1440, but interpretation of this data is difficult and hydraulic conductivity values derived from this observation well response are inconsistent with the steep hydraulic gradients and low permeability of the granodiorite. Results of the calibration of simulated response to observed are summarized as follows:

<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</th>
<th>COMMENTS</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-1B</td>
<td>Ksd (including Backbone Fault)</td>
<td>High</td>
<td>HC-1B is a pumping well; simulated drawdown is substantially less than observed. Simulated drawdown and recovery trends match well with observed.</td>
<td>55</td>
</tr>
<tr>
<td>HC-1A</td>
<td>Ksd (including Backbone Fault)</td>
<td>High</td>
<td>HC-1A is adjacent to HC-1B and screened deeper than HC-1B, but both are screened in the Backbone Fault.</td>
<td>56</td>
</tr>
<tr>
<td>RP-5</td>
<td>Qtg1</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>57</td>
</tr>
<tr>
<td>1445</td>
<td>pCc</td>
<td>Poor</td>
<td>Interpretation of drawdown from raw data is difficult; simulated as no drawdown.</td>
<td>58</td>
</tr>
</tbody>
</table>

CALIBRATION FOR PUMPED WELL HC-5A

Calibration hydrographs are shown on Figures 59 through 62 for pumped well HC-5A and associated observation wells, including: HC-5B, HC-4A, and HC-4B. Well HC-5A was pumped for 23 days at 39.7 gpm. Well HC-5A is completed in the Ksd hydrogeologic unit. Observed response to HC-5A pumping is limited to the adjacent HC-5B well. Results of the calibration of simulated response to observed are summarized as follows:
<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</th>
<th>COMMENTS</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-5A</td>
<td>Ksd</td>
<td>High</td>
<td>HC-5A is a pumping well; simulated drawdown is substantially less than observed. Simulated drawdown and recovery trends match well with observed.</td>
<td>59</td>
</tr>
<tr>
<td>HC-5B</td>
<td>Ksd</td>
<td>Moderate</td>
<td>Simulated drawdown trend is more than observed in later time; recovery trends match well.</td>
<td>60</td>
</tr>
<tr>
<td>HC-4A</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>61</td>
</tr>
<tr>
<td>HC-4B</td>
<td>Kv</td>
<td>Undetermined</td>
<td>No drawdown simulated; background trends obscure observed water level response, if any.</td>
<td>62</td>
</tr>
</tbody>
</table>

**CALIBRATION FOR PUMPED WELL RP-3B**

Calibration hydrographs are shown on **Figures 63 through 74** for pumped well RP-3B and associated observation wells, including: RP-3A, G-35, RP-4A, RP-4B, Gayler, RP-2A, RP-2B, RP-2C, HC-2A, HC-2B, and RP-9. Well RP-3B was pumped for 12 days at 27.8 gpm; pumping was terminated due to large drawdown and inability to maintain a constant pumping rate. Well RP-3B is completed in the Kv hydrogeologic unit. Response to RP-3B pumping was not observed, with the possible exception of a slight drawdown measured in adjacent well RP-3A screened above RP-3B. Vertical hydraulic conductivity is simulated at 1/10 of horizontal for the Kv unit to account for this lack of response in RP-3A. Results of the calibration of simulated response to observed are summarized below:
<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</th>
<th>COMMENTS</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP-3B</td>
<td>Kv</td>
<td>Moderate</td>
<td>RP-3B is a pumping well; simulated drawdown is substantially less than observed. Simulated drawdown and recovery trends are steeper than observed.</td>
<td>63</td>
</tr>
<tr>
<td>RP-3A</td>
<td>QTg1 and Kv</td>
<td>Poor</td>
<td>No response observed in well; simulated drawdown is more than 33 feet.</td>
<td>64</td>
</tr>
<tr>
<td>G-35</td>
<td>Ksd (possibly some Qal)</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>65</td>
</tr>
<tr>
<td>RP-4A</td>
<td>QTg1</td>
<td>High</td>
<td>No drawdown observed or simulated; observed trends are not believed to be associated with pumping.</td>
<td>66</td>
</tr>
<tr>
<td>RP-4B</td>
<td>Ksd</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>67</td>
</tr>
<tr>
<td>Gayler</td>
<td>Ksd (possibly some Qal)</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>68</td>
</tr>
<tr>
<td>RP-2A</td>
<td>Qal</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>69</td>
</tr>
<tr>
<td>RP-2B</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>70</td>
</tr>
<tr>
<td>RP-2C</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>71</td>
</tr>
<tr>
<td>HC-2A</td>
<td>Qtg1</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>72</td>
</tr>
<tr>
<td>HC-2B</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>73</td>
</tr>
<tr>
<td>RP-9</td>
<td>Qtg1, Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>74</td>
</tr>
</tbody>
</table>

**CALIBRATION FOR PUMPED WELL RP-6**

Calibration hydrographs are shown on **Figures 75 through 79** for pumped well RP-6 and associated observation wells, including: Mulberry, RP-7, HV-2, and RP-8. Well RP-6 was pumped for 28 days at 47.2 gpm. Well RP-6 is completed in the Kv hydrogeologic unit. Response to RP-6 pumping was not observed. Results of the calibration of simulated response to observed are summarized below:
<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>PRINCIPAL HYDROGEOLOGIC UNITS</th>
<th>QUALITY OF SIMULATED FIT TO OBSERVED RESPONSE</th>
<th>COMMENTS</th>
<th>SHOWN ON FIGURE NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>RP-6</td>
<td>Kv</td>
<td>High</td>
<td>RP-6 is a pumping well; simulated drawdown is substantially less than observed. Simulated drawdown and recovery trends match well with observed.</td>
<td>75</td>
</tr>
<tr>
<td>Mulberry Stock</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>76</td>
</tr>
<tr>
<td>RP-7</td>
<td>Kv</td>
<td>High</td>
<td>No drawdown observed or simulated.</td>
<td>77</td>
</tr>
<tr>
<td>HV-2</td>
<td>Ksd (possibly some Qal)</td>
<td>High</td>
<td>No drawdown observed or simulated; observed water level changes believed to reflect influence of Qal.</td>
<td>78</td>
</tr>
<tr>
<td>RP-8</td>
<td>Ksd</td>
<td>High</td>
<td>No drawdown observed or simulated; apparent observed declines are associated with background changes.</td>
<td>79</td>
</tr>
</tbody>
</table>

### 7.9 PIT DEWATERING

Groundwater discharge to the pit during mining operations is simulated using the MODFLOW drain package. To simulate the temporal advance of the open pit, drain locations and altitudes are set to correspond to the projected shell of the advancing open pit. During the dewatering simulation, as the pit advances downward and outward through time, groundwater discharge to the pit increases. The mining period is simulated with 13 three-month stress periods followed by 19 one-year stress periods, as defined by mine-plan pit shells provided by Rosemont Copper. Drain configurations are constant during a stress period and drain cell altitudes at the pit bottom are set approximately equal to the bottom of the mine pit projected to exist at the end of the stress period.

The drain package is a head-dependent flux boundary condition that simulates discharge as long as the simulated groundwater level in the adjacent rock formation is above
the specified drain altitude. The simulated discharge rate is proportional to the difference between simulated head in the adjacent rock formation and the specified drain altitude, multiplied by the conductance term. In concept, the drain cells are specified at locations internal to the pit shell in the void space of the open pit. Drain cell altitudes are specified 10 feet below the pit bottoms, resulting in complete dewatering of the simulated pit void. Figure 103 shows the lateral extent of drain cells drains after 11 and 22 years of mining activity, along a section through the pit center on a west to east alignment. A conceptual depiction of drain cells specified in the model is shown on Figure 104.

The conductance of the drains must be set high enough to ensure groundwater discharge inflow into the pit void is controlled by the surrounding rock formation rather than being artificially constrained by the drain conductance. Drain cell conductances were varied between 100 to 400 feet squared per day (ft²/d), with the intent to determine the threshold at which drain cell conductances do not constrain pit inflows. Simulated results of total pit inflows for the 22-year excavation period, for each conductance, are presented in the following table:

<table>
<thead>
<tr>
<th>Drain Conductance (ft²/d)</th>
<th>Cumulative Volume (acre-feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>26,802</td>
</tr>
<tr>
<td>200</td>
<td>26,932</td>
</tr>
<tr>
<td>300</td>
<td>26,982</td>
</tr>
<tr>
<td>400</td>
<td>27,010</td>
</tr>
</tbody>
</table>

The increase in total pit inflow flow for each conductance increase was negligible. The 300 ft²/d conductance was selected as appropriate for the pit-dewatering simulations and does not constrain pit inflows.
7.10 POST-CLOSURE PIT LAKE FORMATION

Following cessation of mining and pit dewatering, groundwater levels will begin to recover, and groundwater inflow will form a lake at the bottom of the pit. To simulate hydrogeologic conditions during this period, the MODFLOW Lake Package, LAK2 (Council, 1999) is used. As formulated, the LAK2 package accounts for storage in the lake, evaporation from the lake surface, precipitation that falls in the lake catchment area, and surface runoff from the surrounding watershed. The lake package is developed as a head-dependent boundary condition. Groundwater flows into the lake as long as the calculated lake level is lower in altitude than groundwater levels in the formation surrounding the pit. For the post-closure simulation, the drains cells utilized for the final configuration of pit dewatering are inactivated. These inactive cells effectively lie within the area of the simulated pit lake.

Use of the LAK2 package requires functional relationships between lake altitude (stage), lake volume, and lake surface area. These relationships are derived from the final pit configuration for the current mine plan. A digital terrain model of the open pit is constructed and used to define the bottom of the lake in the numerical model. A feature of the LAK2 package that allows the user to subdivide individual lake cells independently of the model grid is utilized to increase resolution in the vertical direction. This allows a closer match of the model representation of the proposed mine plan for the stage-area-volume relationship. The relationships between lake surface altitude, lake surface area, and lake volume are shown on Figure 105.

Precipitation

Direct precipitation falling on the lake surface is assigned a value of 100 percent of estimated precipitation for the pit area, approximately 22.19 inches per year, or $5.06 \times 10^{-3}$ ft/d. This value represents the long-term average precipitation estimated to fall on the Rosemont Project area, as derived from review of meteorological records collected at
weather stations within 30 miles of the Rosemont Project area (Tetra Tech, 2009; Tetra Tech, written communication, 2009).

**Evaporation**

Evaporation is only simulated from the lake surface and is assigned a value of 50.06 inches per year (1.14 x 10^{-2} ft/d). This rate is approximately 70 percent of the average pan evaporation projected for the Rosemont Project area (Tetra Tech, 2009). A pan coefficient of 0.70 is commonly used to adjust the pan evaporation rate to a lake evaporation rate (Farnsworth and others, 1982).

**Runoff**

Thirty percent of the precipitation that falls in the pit catchment area surrounding the lake (i.e. above the lake stage) is simulated as runoff into the lake. Therefore, runoff is approximately 1.52 x 10^{-3} ft/d. The remaining 70 percent of the precipitation is assumed to be lost to evaporation from the wetted pit walls, which will be benched and will tend to catch and hold precipitation. The LAK2 package internally calculates the portion of precipitation that enters the lake as runoff, depending on the simulated lake size and the resulting size of the pit catchment area not covered by the lake.

**Lake Cell Conductance**

Lake cell conductance terms are computed externally to the LAK2 package. Lake cell conductance terms were adjusted so that the initial inflow rate to the lake approximately matched final outflow simulated in the dewatering model (approximately 106,200 ft^3/d). Lake cell bottom conductance was specified as 8.00 ft^2/d; lake cell side conductance was specified as 4.00 ft^2/d.
7.11 PREDICTIVE FLOW MODEL RESULTS

Two consecutive predictive groundwater flow model simulations were conducted to predict pit dewatering rates due to mining operations, post-closure pit lake formation, and associated groundwater level impacts. The first simulation represents dewatering and groundwater level drawdown for the approximate 22-year mining period. The second simulation incorporates the LAK2 package and represents the 1,000-year post-closure recovery and pit lake development period.

7.11.1 Mine Dewatering Simulation

Projected average inflow rate for each stress period was calculated and is shown on Figure 106 and summarized in Table 6. Predicted average inflow rates for the stress periods rapidly increase to 500 gpm in year 2 of proposed mining operations and range between 500 and 600 gpm for the duration of mining. Early pit inflows are elevated in part due to storage release of groundwater from the simulated Backbone Fault and Flat Fault, as the pit excavation intersects these features.

Maximum simulated groundwater level drawdown is at the end of mining operations and occurs at the center of the pit. Due to the low hydraulic conductivity in the mine area, the magnitude of drawdown decreases substantially with distance from the pit, resulting in a hydraulic sink with steep gradients in the area of the pit. Contours of simulated groundwater level altitude in vicinity of the pit at the end of mining operations are shown on Figure 107. Simulated groundwater levels shown on Figure 107 are used as initial head conditions for the pit lake formation simulation.
7.11.2 Pit Lake Formation Simulation

Projected pit lake water balance for the 1,000-year post-closure period is shown on Figure 108. The groundwater inflows reduce to approximately 104 gpm after 1,000 years. Based on the trend of the decline the inflow rate will approximately reach 100 gpm inflow rate sometime beyond 1,000 years after end of mining. At 1,000 years post-closure, the pit lake water balance has nearly reached equilibrium; however, the reduction and subsequent cessation of tailings seepage 500 years after end of mining has prevented the lake from reaching absolute equilibrium at the end of the simulation. Review of Figure 108 demonstrates these slight changes are on the order of a few feet occurring in the lake stage over the final 400 years of the simulation. For purposes of this evaluation the pit lake is considered to be in equilibrium at the end of the simulation. After 1,000 years, projected pit lake evaporation is 410 gpm, direct precipitation is 182 gpm, and runoff inflow is 122 gpm. The groundwater model projects a lake stage of about 4,097 feet msl, which corresponds to a lake depth of approximately 1,047 feet, 1,000 years after mining ceases. Projected surface area of the pit lake at 1,000 years is approximately 159 acres.

Results indicate the pit is a hydraulic sink 1,000 years after mine closure with no water discharging from the pit lake to the groundwater system. Projected groundwater level altitudes around the perimeter of the pit 1,000 years after mine closure range from 4,200 feet to 4,850 feet msl, as shown on Figure 109. The capture zone depicting the area of groundwater which moves towards the pit is shown on Figure 109. The minimum difference between lake stage and projected groundwater level along the delineated capture zone is approximately 350 feet, as shown on Figure 109.

7.11.3 Projected Impacts

Projected groundwater level drawdown at the end of mine life (2032), 20 years after mine closure (2052), 150 years after mine closure (2202), and 1,000 years after mine closure
(3032), are shown on Figures 110 through 113, respectively. Projected drawdown contours are shown for 100, 10, and 5 feet. The 5-foot contour is considered the extent of substantive impact.

Hydrographs of projected drawdown at the observed perennial stream reaches nearest the pit, in upper Cienega Creek and Davidson Canyon, are shown on Figures 114 and 115, respectively. Locations of the hydrographs are shown on Figures 110 through 113.

Additional projected results for 0, 20, 150, and 1,000 years after end of mining include:

- decreases in evapotranspiration rate
- decreases in length of perennial stream reach, and streamflow rate, for upper and lower Cienega Creek and Davidson Canyon
- decrease of simulated groundwater outflow west from the Santa Rita Mountains via GHB cells
- number of identified perennial springs and seeps within the 5-foot projected drawdown contour

**End of Mining**

The end of mining corresponds to the maximum projected drawdown in the pit area prior to start of pit lake filling. Maximum projected drawdown occurs at the pit bottom altitude of 3,050 feet msl, which is approximately 2,056 feet below initial simulated groundwater level at the center of the pit. Projected maximum extent of the 5-foot groundwater level drawdown contour is approximately 3.2 miles east-northeast from the proposed pit along Barrel Canyon (Figure 110). Projected drawdowns at the simulated perennial stream reaches nearest the pit in upper Cienega Creek and Davidson Canyon are 0 feet (Figures 114 and 115).
Projected decreases from pre-mining conditions for evapotranspiration, streamflow and west boundary outflow are summarized as follows:

- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate - 0 AF/yr
  - decreased length of perennial reach - 0 miles
  - decreased perennial base flow rate - 0 cfs
- Projections for Davidson Canyon
  - decreased evapotranspiration rate - 0 AF/yr
  - decreased length of perennial reach - 0 miles
  - decreased perennial base flow rate - 0 cfs
- Projected decrease in groundwater outflow from the west boundary - 0 AF/yr
- Three identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, and Rosemont

Results of predictive impact projections are summarized in Table 7.

20 Years After Mine Closure

Twenty years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 3,618 ft msl, which is approximately 1,488 feet below initial simulated groundwater level at the center of the pit. Projected maximum extent of the 5-foot groundwater level drawdown contour is approximately 4.2 miles east-northeast from the proposed pit along Barrel Canyon (Figure 111). Projected drawdown at the simulated perennial stream reaches nearest the pit in upper Cienega Creek and Davidson Canyon are 0 and 0.01 feet, respectively (Figures 114 and 115). Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.

Projected decreases from pre-mining conditions for evapotranspiration, streamflow and west boundary outflow are summarized as follows:
- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate - 0 AF/yr
  - decreased length of perennial reach - 0 miles
  - decreased base flow rate - 0 cfs
- Projections for Davidson Canyon
  - decreased evapotranspiration rate - 0 AF/yr
  - decreased length of perennial reach - 0 miles
  - decreased base flow rate – 0.01 cfs
- Projected decrease in groundwater outflow from the west boundary – 0 AF/yr
- Three identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, and Rosemont

Results of predictive impact projections are summarized in Table 7.

**150 Years After Mine Closure**

One hundred and fifty years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 3,977 ft msl, which is approximately 1,129 feet below initial simulated groundwater level at the center of the pit. Projected maximum extent of the 5-foot groundwater level drawdown contour is approximately 9.6 miles northeast from the proposed pit along Davidson Canyon (Figure 112). Projected drawdown at the simulated perennial stream reaches nearest the pit in upper Cienega Creek and Davidson Canyon are 0 and 0.31 feet, respectively (Figures 114 and 115). Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.

Projected decreases from pre-mining conditions for evapotranspiration, streamflow and west boundary outflow are summarized as follows:

- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate – 0 AF/yr
One thousand years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 4,097 feet msl, which is approximately 1,009 feet below initial simulated groundwater level at the center of the pit. Projected maximum extent of the 5-foot groundwater level drawdown contour is approximately 11.5 miles to the northeast from the proposed pit along Davidson Canyon (Figure 113). A small isolated area of drawdown is projected at the north end of the simulated Davidson Canyon perennial reach, reflecting the small decrease in streamflow and the resulting decrease in recharge from the north end of the reach. Projected drawdown at the simulated perennial stream reaches nearest the pit in upper Cienega Creek and Davidson Canyon are 0.01 and 0.98 feet, respectively (Figures 114 and 115). Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.

Projected decreases from pre-mining conditions for evapotranspiration, streamflow and west boundary outflow are summarized as follows:

- Decreased evapotranspiration rate – 8 AF/yr
- Decreased length of perennial reach – 0 miles
- Decreased base flow rate – 0.02 cfs
- Projected decrease in groundwater outflow from the west boundary – 11 AF/yr
- Five identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, Rosemont, Questa, and Helvetia

Results of predictive impact projections are summarized in Table 7.
• Projections for upper Cienega Creek and the Cienega Creek narrows
  o decreased evapotranspiration rate – 51 AF/yr (1.6 percent of the 3,100 AF/yr estimated ET)
  o decreased length of perennial reach – 0.16 miles (2.1 percent of the 7.6 mile observed length)
  o decreased base flow rate – 0.02 cfs (1 percent of the estimated 2 cfs rate)
• Projections for Davidson Canyon
  o decreased evapotranspiration rate – 22 AF/yr (19 percent of the 115 AF/yr estimated ET)
  o decreased length of perennial reach – 0.29 miles (41 percent of the 0.7 mile observed length)
  o decreased base flow rate – 0.04 cfs
• Projected decrease in groundwater outflow from the west boundary – 42 AF/yr
• Five identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, Rosemont, Questa, and Helvetia

Results of predictive impact projections are summarized in Table 7.

7.11.4 Predictive Results Summary

Model projections shown on Figures 110 through 113 indicate substantial dewatering of the fractured bedrock in the immediate vicinity of the pit over the simulation period, which is consistent with the expected groundwater response based on hydraulic testing in the area. More distant from the pit, extent of the projected 5-foot groundwater level drawdown at 20, 150, and 1,000 years after end of mining is less reliable due to the unknown degree of hydraulic connection, heterogeneities, and discrete features inherent in the fracture rock system which may cause drawdown response to differ from that projected by the model.
Over the 1,000-year post-mining period, projected evapotranspiration and streamflow decreases are slight, reflecting the relatively small long-term groundwater inflows to the pit. Riparian plant root systems will adjust to small change in the depth to water. Long-term equilibrium streamflow conditions will be controlled by the riparian evapotranspiration along the channel.

Model projections of groundwater drawdown west from the pit through the Santa Rita Mountains, resulting in capture of groundwater flowing west, is speculative due to the poor understanding of a groundwater connection across this boundary. The occurrence and magnitude of these projected impacts may not extend as far as projected if the rock along the topographic divide is less permeable than represented in the model; the granodiorite may act as a barrier to groundwater movement.

Model projections indicate no appreciable groundwater level drawdown will occur at Cienega Creek. Springs and seeps occurring within the projected area of drawdown may be impacted; however, hydraulic connection of individual springs and seeps to the groundwater system is uncertain and poorly defined. Springs with perennial or intermittent flow obtain their base flow from groundwater and are therefore more susceptible to impacts than the ephemeral springs and seeps where flow is typically dependent on rainfall/runoff events. Depending on the degree of hydraulic connection of the perennial or intermittent springs to drawdown-impacted areas of the bedrock flow system, flows at these springs could be adversely affected.

7.11.5 Predictive Sensitivity Simulations

Predictive sensitivity simulations were conducted to assess the effect of varying lake input parameters on projected pit lake stage, as well as whether the pit lake will be a hydrologic sink or a flow-through pit lake. The predictive sensitivity simulations were run for 1,000 years after end of mining. Lake parameters varied for the analysis include:
Precipitation to the lake catchment area
Evaporation from the pit lake surface
Percent of precipitation runoff to the pit lake

Results of the individual sensitivity simulations are described as follows:

**Precipitation to Lake Catchment Area**

Precipitation rate to the lake catchment area was decreased to 17.75 in/yr and increased to 26.63 in/yr, compared to the base simulation precipitation rate of 22.19 in/yr (an approximate 20 percent decrease and increase from the base). Precipitation runoff to the lake also varies as a result of varying precipitation. Projected lake stages over time for the lake precipitation sensitivity simulations are shown on Figure 116, along with the corresponding base simulation results.

- Projected final lake stage is 3,980 feet msl, approximately 117 feet below the base simulation for the decreased precipitation.
- Projected final lake stage is 4,208 feet msl, approximately 111 feet above the base simulation for the increased precipitation.

The results indicate the lake stage is moderately sensitive to variations in precipitation to the lake catchment area. Given the 350-foot minimum gradient towards the pit for the base simulation projected hydraulic sink capture zone (Section 7.11.2, Figure 109), the 111-foot increase in lake stage for the increased precipitation simulation will not compromise the hydraulic sink.

**Lake Evaporation**

Lake evaporation was decreased to 40.05 in/yr and increased to 60.07 in/yr, compared to the base simulation evaporation rate of 50.06 in/yr (an approximate 20 percent decrease
and increase from the base). Projected lake stages over time for the evaporation sensitivity simulations are shown on Figure 116, along with the corresponding base simulation results.

- Projected final lake stage is 4,264 feet msl, approximately 167 feet above the base simulation for the decreased evaporation.
- Projected final lake stage is 3,945 feet msl, approximately 152 feet below the base simulation for the increased evaporation.

The results indicate the lake stage is moderately sensitive to variations in evaporation. Given the 350-foot minimum gradient towards the pit for the base simulation projected hydraulic sink capture zone (Section 7.11.2, Figure 109), the 167-foot increase in lake stage for the decreased evaporation simulation will not compromise the hydraulic sink.

**Percentage of Precipitation Runoff**

Percentage of precipitation runoff was decreased to 20 percent and increased to 40 percent, compared to the base simulation 30 percent rate. Projected lake stages over time for the percentage of precipitation runoff sensitivity simulations are shown on Figure 116, along with the corresponding base simulation results.

- Projected final lake stage is 4,018 feet msl, approximately 79 feet below the base simulation, for the decreased runoff percentage.
- Projected final lake stage is 4,156 feet msl, approximately 59 feet above the base simulation, for the increased runoff percentage.

The results indicate the lake stage is moderately sensitive to variations in runoff. Given the 350-foot minimum gradient towards the pit for the base simulation projected hydraulic sink capture zone (Section 7.11.2, Figure 109), the 59-foot increase in lake stage for the increased precipitation runoff percentage simulation will not compromise the hydraulic sink.
Lake input variations for the sensitivity analysis are presented in Table 8 and results for the lake stage variations are presented in Table 9.

7.11.6 Drawdown Impact Sensitivity Simulations

Predictive sensitivity simulations were conducted to assess the effect of varying aquifer hydraulic parameters on extent of the projected 5-foot drawdown contour, including reduction in evapotranspiration and streamflow. Lake stage variation was also evaluated. The predictive sensitivity simulations were run for the steady-state, dewatering, and 1,000-year post-mining periods. Parameter variations are consistent with the minimum and maximum variations simulated for the steady-state sensitivity analysis, which indicated the steady-state model calibration was adversely affected for hydraulic conductivity variations of the Ksd, KTı, and pGb hydrogeologic units. Consideration was given to reducing the range of hydraulic conductivity variations for these 3 parameters for the predictive sensitivity analysis, due to a concern the model was poorly calibrated and results of the predictive sensitivity simulations would be invalid. However, the predictive sensitivity results are insensitive to the poor calibration of the model for these parameters and the range of variation of these 3 parameters was not constrained. The sensitivity simulations are summarized in Table 10.

For the predictive sensitivity analysis, hydraulic conductivities were varied for 9 of the 10 hydrogeologic units, and for the Backbone Fault, the Flat Fault, and the Davidson Canyon Fault. The simulated Backbone and Flat Fault zones were excluded from variations of the 9 hydrogeologic units. Basin fill units QTg and QTg1 were varied together. The Tsp sedimentary and volcanics unit was not evaluated for the analysis as it occurs only in the northernmost extent of the model domain, beyond projected drawdown impacts.

Specific yield was varied separately for the combined bedrock area (including QTg2), and for the combined basin fill area (excluding QTg2). Specific storage was varied
separately for the combined bedrock area (including QTg2). Parameter variation ranges include:

- Simulated hydraulic conductivity is increased and decreased 1 magnitude for bedrock hydrogeologic units KTi, Kv, Ksd, and Pz, and the low-permeability basin fill unit QTg2.
- Simulated hydraulic conductivity is decreased 1 magnitude for bedrock hydrogeologic unit pEb, essentially simulating a no-flow boundary west from the pit, resulting in conservatively larger drawdown impacts east from the pit.
- Simulated hydraulic conductivity is increased and decreased 30 percent for basin hydrogeologic units Qal, and for the combined QTg and QTg1 units.
- Simulated Kx horizontal hydraulic conductivity (east-west alignment) was increased 1 magnitude for the Backbone Fault, resulting in isotropic hydraulic conductivity for the Backbone Fault zone.
- Simulated Kz vertical hydraulic conductivity and Ky horizontal hydraulic conductivity (north-south alignment) is decreased 1 magnitude for the Backbone Fault, resulting in isotropic hydraulic conductivity for the Backbone Fault zone.
- Simulated hydraulic conductivity is increased 1 magnitude in the east side of the Flat Fault and decreased 1 magnitude in the west side of the Flat Fault.
- Simulated hydraulic conductivity is decreased in the Davidson Canyon Fault to approximately match the surrounding rock formations.
- Simulated specific yield is increased by 100 percent and decreased by 50 percent for the combined bedrock area (including QTg2).
- Simulated specific yield is increased and decreased by 50 percent for the combined basin fill area (excluding QTg2).
- Simulated specific storage is increased and decreased by 1 magnitude for the combined bedrock area (including QTg2).
Variations in the extent of the projected 100-foot and 5-foot drawdown contours at end of mining, and 150 and 1,000 years post-mining, are shown on Figures 117 through 119.

End of Mining

At end of mining the projected 5-foot drawdown contours are generally grouped together, with the exception of the 1-magnitude increase in paleozoics Pz hydrogeologic unit which results in a substantial deviation from the range of other sensitivity results (Figure 117). The Pz unit extends north south along the east side of the Santa Rita Mountains, within the area of the pit (Figures 7 and 81 through 90). The projected drawdown for the Pz unit extended north consistent with the occurrence of this formation in the model. Projected drawdown for the other parameter variations are combined into a maximum and minimum extent of the 5-foot drawdown contour, demonstrating a potential range for the 5-foot drawdown contour at end of mining.

150 Years after End of Mining

At 150 years after the end of mining, the projected 5-foot drawdown contours for all parameter variations are grouped together east from the pit but spread across a substantial distance along Davidson Canyon. Maximum extent of the projected 5-foot drawdown contour down Davidson Canyon is associated with two simulations: the one-magnitude increase in hydraulic conductivity for the Ksd; and the one-magnitude increase in hydraulic conductivity for the Kv hydrogeologic unit (Figure 118). The Ksd is the predominant bedrock hydrogeologic unit in the model area and the Kv unit occurs east from the pit (Figures 7 and 81 through 90). An increase of the hydraulic conductivity in either of these units increases the projected 5-foot drawdown extent.
Minimum extent of the projected 5-foot drawdown contour down Davidson Canyon is associated with two simulations: the one-magnitude decrease in hydraulic conductivity for the Kv hydrogeologic unit; and the 50 percent decrease in Sy for the combined bedrock units (Figure 118). An increased Sy reduces the rate of diffusion of the drawdown impacts from the pit.

1,000 Years after End of Mining

At 1,000 years after end of mining the projected 5-foot drawdown contours are grouped closely together (Figure 119). Projected drawdown for the parameter variations are combined into a maximum and minimum extent of the 5-foot drawdown contour, demonstrating a potential range for the 5-foot drawdown contour at 1,000 year after end of mining.

The simulated ET zones along Cienega Creek and Davidson Canyon mitigate propagation of the projected drawdown resulting in the close grouping of the sensitivity results. Drawdown reaching the ET zones causes a reduction in ET which limits the extent of drawdown beyond the ET zones. At 1,000 years after end of mining, variations in the projected decreases in ET and streamflow rates and extent, and projections of lake stage for the sensitivity simulations are presented in Table 10.

- Range of projected ET decrease for upper Cienega Creek and the narrows is from 28 to 86 AF/yr, compared to the base simulation projection of 51 AF/yr.
- Range of projected ET decrease for Davidson Canyon is from 12 to 40 AF/yr, compared to the base simulation projection of 22 AF/yr.
- Range of projected streamflow decrease for upper Cienega Creek and the narrows is from 0.01 to 0.04 cfs, compared to the base simulation projection of 0.02 cfs; range of projected decrease of streamflow is from 0.00 to 0.18 miles, compared to the base simulation projection of 0.16 miles.
• Range of projected streamflow decrease for Davidson Canyon is from 0.02 to 0.05 cfs, compared to the base simulation projection of 0.04 cfs; range of projected decrease of streamflow is from 0.0 to 0.29 miles, compared to the base simulation projection of 0.29 miles.

• Range of projected lake stage is from 4,061 to 4,123 feet amsl, compared to the base simulation projection of 4,097 feet amsl.

7.11.7 Summary

Results of the predictive sensitivity simulations indicate the simulated groundwater system is robust and variation of a wide range of hydraulic parameters resulted in a range of projections which were not substantially different from results of the base simulation. Notable results include:

• A 1-magnitude increase and decrease in hydraulic conductivity of the lower Cretaceous Ksd hydrogeologic unit, which is the predominant bedrock unit simulated in the model east from the pit, did not substantially change projections.

• A 1-magnitude decrease in hydraulic conductivity of the Precambrian granodiorite pCb hydrogeologic unit did not force the projected drawdown substantially farther east compared to the base simulation. Simulated decrease in outflow from the west model boundary 1,000 years after end of mining is 33 AF/yr compared to the 42 AF/yr projected for the base simulation.

• Decrease of the high hydraulic conductivity simulated for the Davidson Canyon fault zone to low hydraulic conductivities of the surrounding rocks did not substantially impede propagation of the projected drawdown.

• Reduction of higher hydraulic conductivity and storage simulated for the Backbone and Flat Faults did not result in a substantial change in the long-term drawdown impacts.
8.0 MODELING SUMMARY AND CONCLUSIONS

Extensive site investigations, collection of data, and data analyses were conducted for development of the Rosemont groundwater flow model. Focus of the site investigations was the bedrock groundwater system in the Rosemont Project area. The model study area was expanded to encompass the larger Cienega Creek basin, based on data from previous regional investigations. Results of the investigations indicate the groundwater system in the area of the proposed mine is complex and structural features such as the Backbone Fault and the Flat Fault have some control over the local flow system in the pit area. Based on geologic investigation and results of hydraulic testing, the flow model incorporates these structural features and the heterogeneity of hydraulic properties of the bedrock and basin fill hydrogeologic units.

Projected pit inflows, pit lake development, and impacts to the groundwater system are consistent with behavior observed in similar open pit mines in fractured-rock flow systems in arid climates, although projected pit inflows in the early years of excavation are potentially larger than realistic. Although pit inflows will be variable, the overall long-term inflow will be controlled by the average storage and permeability of the fractured-rock system, as represented in the model. Groundwater inflows to the pit represent a very small change to the overall groundwater flow system of Cienega Creek basin, as summarized below:

- Average projected pit inflow over the 1,022-year mining and post-mining simulation period is approximately 133 gpm (215 AF/yr). Over the 1,022-year period, the average 215 AF/yr pit inflow, or loss from the groundwater system, represents capture of approximately 4.5 percent of the 4,798 AF/yr simulated groundwater recharge to Cienega Creek basin, which would have otherwise moved downgradient through the flow system.
• Final projected pit groundwater inflow 1,022 years after start of mining is 104 gpm (168 AF/yr). The 168 AF/yr pit inflow represents capture of approximately 3.5 percent of 4,798 AF/yr simulated groundwater recharge to Cienega Creek basin.

Although long-term groundwater inflows are small, they are projected to be sufficient to sustain the pit lake as a perpetual hydraulic sink. Results of pit lake sensitivity analyses support the conclusion that the pit will remain a hydraulic sink.

Projected groundwater drawdown extent is limited, due to the low hydraulic conductivity of the fractured bedrock system and the small long-term projected groundwater inflow rate to the pit.

• Extent of the 100-foot drawdown contour does not substantially change during the period from 150 to 1,000 years after end of mining; location of the 100-foot drawdown is expected to remain similar beyond 1,000 years (Figure 113).
• The projected 5-foot drawdown contour does not reach Cienega Creek and projected drawdown at the nearest Cienega Creek perennial reach is substantially less than 0.01 feet during the 1,000 years after end of mining (Figure 114).
• The projected 5-foot drawdown contour does not reach the area where perennial flow was historically observed in Davidson Canyon. Projected drawdown at this location is still declining 1,000 years after end of mining, but drawdown is asymptotically approaching a maximum and it can be conservatively estimated that it will not exceed 1.5 feet (Figure 115).
• Perennial springs and seeps within the projected 5-foot drawdown contour would likely experience a decrease in discharge if they are in direct communication with the groundwater flow system.
• Maximum extent of drawdown is mitigated due to the capture (reduction) of ET discharge from simulated riparian area.
Projected Cienega Creek basin ET reduction is very small throughout the model simulation period. Projected 73 AF/yr reduction of ET discharge at 1,000 years after end of mining is approximately 1.7 percent of the estimated 4,245 AF/yr ET for the simulated Cienega Creek basin. The 73 AF/yr ET reduction is comprised of a 51 AF/yr reduction for Cienega Creek and a 22 AF/yr reduction Davidson Canyon. The 51 AF/yr reduction is approximately 1 percent of the estimated ET for Cienega Creek; the 22 AF/yr reduction is approximately 19 percent of the 115 AF/yr estimated ET rate for Davidson Canyon (Table 7).

Projected reduction in volume and extent of perennial streamflow along Cienega Creek at 1,000 years after end of mining is very small (Table 7), due to the buffering effect of the ET zones stabilizing groundwater levels in the vicinity of the stream channel. Simulated decrease in Davidson Canyon streamflow for what is currently an intermittent reach is 0.04 cfs (Table 7).

Results indicate impacts to the groundwater system will be limited by the low conductivity of the bedrock formation where the pit will be excavated. The predictive sensitivity analysis indicates the extent of long-term drawdown impacts in the area of Cienega Creek and lower Davidson Canyon behave similarly for the different parameter variations, lending confidence to the model projections in these areas. Based on results of the predictive sensitivity analysis, the higher conductivity and higher storage parameters simulated in the Backbone and Flat Faults do not substantially affect long-term drawdown impacts. Results of geologic investigations and aquifer testing investigations do not indicate potential for substantial conductive fault features that could short-circuit the flow system and transmit drawdown impacts more distant than the maximum extent projected in this study.

Groundwater model updates incorporating future data such as dewatering rates, precipitation and evaporation, discrete preferential groundwater flow patterns encountered
during excavation, and regional groundwater response will provide the basis for improvement of the predictive capabilities of the model.
9.0 REFERENCES CITED


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Oppenheimer, J.M., and Sumner, J.S., 1980, *Depth to bedrock map, basin and range province, Arizona*: University of Arizona, Laboratory of Geophysics, Scale 1:1,000,000.


____, 2000b, *GIS coverage of perennial streams, intermittent streams, and areas with shallow groundwater, Sonoran Desert Conservation Plan*: Final Project Report, prepared for Pima County.


Tetra Tech, 2009, **Rosemont Copper Project Design Storm and Precipitation Data/Design Criteria**: Technical Memorandum, April 2009.


# Table 1. Summary of construction details for wells and piezometers constructed in 2007 and 2008

**Rosemont Project, Pima County, Arizona**

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<td>523,745.1</td>
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<td>40 - 1,900</td>
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### TABLE 1. SUMMARY OF CONSTRUCTION DETAILS FOR WELLS AND PIEZOMETERS CONSTRUCTED IN 2007 AND 2008

**ROSEMONT PROJECT, PIMA COUNTY, ARIZONA**

<table>
<thead>
<tr>
<th>WELL IDENTIFIER</th>
<th>CADASTRAL LOCATION</th>
<th>ADWR REGISTRATION NUMBER</th>
<th>UTM* NORTHING (meters)</th>
<th>UTM EASTING (meters)</th>
<th>LAND SURFACE ALTITUDE (ft, msl)*</th>
<th>DATE COMPLETED</th>
<th>TOTAL DEPTH DRILLED (ft, bls)*</th>
<th>DIAMETER (inches)</th>
<th>DEPTH (feet)</th>
<th>DIAMETER (inches)</th>
<th>DEPTH (feet)</th>
<th>PERFORATED INTERVAL (feet)</th>
<th>SURFACE SEAL (feet)</th>
<th>DEPTH OF GROUTED PRESSURE TRANSDUCER*</th>
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<td>9-7/8</td>
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<td>0 - 60</td>
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--- = Not applicable

* UTM = Universal Transverse Mercator projection Zone 12 (NAD83)
* ft, msl = feet above mean sea level
* ft, bls = feet below land surface
* PC wells are screened with 5½-inch slotted steel pipe; slots are ⅛ by 3 inches, 20 slots per foot
* PZ wells are cased with 2½-inch BQ steel pipe with transducers attached to outside of pipe and pressure grouted in hole

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<th>CADASTRAL LOCATION</th>
<th>DATABASE ID</th>
<th>WELL IDENTIFIER</th>
<th>OWNER</th>
<th>UTM* NORTING (metres)</th>
<th>UTM EASTING (metres)</th>
<th>DATE COMPLETED</th>
<th>DEPTH DRILLED (ft, s.f.)</th>
<th>DIAMETER (inches)</th>
<th>DEPTH (feet)</th>
<th>PERFORATED INTERVAL (ft, m.s.l.)</th>
<th>CASING USE</th>
<th>ALTIITUDE OF LAND SURFACE (ft, m.s.l.)</th>
<th>NON-PUMPING WATER LEVEL ALTIITUDE (ft, m.s.l.)</th>
<th>NON-PUMPING WATER LEVEL MEASURED DATE</th>
<th>PUMPING RATE (gpm)</th>
<th>WEB UST</th>
<th>DATA SOURCE</th>
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TABLE 2. INVENTORY OF WELL RECORDS, CONSTRUCTION INFORMATION, AND GROUNDWATER LEVEL TARGETS USED FOR MODEL CALIBRATION
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

1232/237/Tbl1_WellConstruction_55GWSI_Rev déjà2Aug2010 Page 3 of 6
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<td>716516511003001</td>
<td>---</td>
<td>MALA BURRO DISTRICT</td>
<td>3514219</td>
<td>991959</td>
<td>12/1/1938</td>
<td>637.9  2.10</td>
<td>0  308.9</td>
<td>380.9</td>
<td>240.9-200</td>
<td>240.9-200</td>
<td>4650  13700</td>
<td>14130</td>
<td>1/21/1940</td>
<td></td>
<td>4650  13700</td>
<td>14130</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-19-15-133a</td>
<td>716514011003001</td>
<td>---</td>
<td>MALA BURRO DISTRICT</td>
<td>3514219</td>
<td>991959</td>
<td>12/1/1938</td>
<td>637.9  2.10</td>
<td>0  308.9</td>
<td>380.9</td>
<td>240.9-200</td>
<td>240.9-200</td>
<td>4650  13700</td>
<td>14130</td>
<td>1/21/1940</td>
<td></td>
<td>4650  13700</td>
<td>14130</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 2. INVENTORY OF WELL RECORDS, CONSTRUCTION INFORMATION, AND GROUNDWATER LEVEL TARGETS USED FOR MODEL CALIBRATION

**ROSEMONT PROJECT, PIMA COUNTY, ARIZONA**

<table>
<thead>
<tr>
<th>CADASTRAL LOCATION</th>
<th>DATABASE ID</th>
<th>WELL IDENTIFIER</th>
<th>OWNER</th>
<th>UTM* NORTHING (meters)</th>
<th>UTM EASTING (meters)</th>
<th>DATE COMPLETED</th>
<th>DEPTH DRILLED (ft, bsl)</th>
<th>DIAMETER (inches)</th>
<th>PERFORATED DEPTH INTERVAL (ft, bsl)</th>
<th>ALTIMETER OF LAND SURFACE (ft, msl)</th>
<th>NON-PUMPING WATER LEVEL</th>
<th>DEPTH (ft, bsl)</th>
<th>MEASURED DATE</th>
<th>ALTITUDE OF LAND SURFACE (ft, msl)</th>
<th>WATER USE(\text{a})</th>
<th>LOGS(\text{a})</th>
<th>DATA SOURCE(\text{b})</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-20-17-HS32</td>
<td>31438811013202</td>
<td>O-1743-1749-4</td>
<td>KAMAN MINING CO</td>
<td>3110224</td>
<td>537146</td>
<td>430-1972</td>
<td>700</td>
<td>15-10</td>
<td>0-40</td>
<td>0-700</td>
<td>705-1032</td>
<td>4652</td>
<td>45</td>
<td>3/14/2005</td>
<td>4578</td>
<td>---</td>
<td>S, D, G</td>
</tr>
<tr>
<td>D-20-33-HS32</td>
<td>31425211036202</td>
<td>O-3343-3349-4</td>
<td>KAMAN MINING CO</td>
<td>3509292</td>
<td>539675</td>
<td>---</td>
<td>750</td>
<td>12</td>
<td>---</td>
<td>---</td>
<td>4641-20</td>
<td>4641-20</td>
<td>4652</td>
<td>45</td>
<td>3/14/2005</td>
<td>4578</td>
<td>---</td>
</tr>
<tr>
<td>D-20-17-HS33</td>
<td>31438811013104</td>
<td>O-1743-1749-4</td>
<td>KAMAN MINING CO</td>
<td>3510293</td>
<td>537149</td>
<td>4/6/1972</td>
<td>700</td>
<td>16</td>
<td>0-700</td>
<td>0-700</td>
<td>4641-20</td>
<td>4641-20</td>
<td>4652</td>
<td>45</td>
<td>3/14/2005</td>
<td>4578</td>
<td>---</td>
</tr>
</tbody>
</table>

---

**Note:**

- **UTM** = Universal Transverse Mercator projection Zone 12 (NAD83)
- **LOG TYPE:**
  - G = Caliper
  - E = Electric
  - F = Fluid Conductivity
- **DATA SOURCE:**
  - S = Stock
  - J = Gamma Ray
  - D = Domestic
  - O = Observation
  - G = Geologist
  - F = Field Velocity
  - T = Temperature
  - E = Power
- **WATER USE:**
  - S = Stock
- **Date not used for model target; adjacent piezometers data was used instead.**

---

**Source:**

1232237/Trk_WellConstruction_5562108_Rev.fig02Aug2010

Page 6 of 6
TABLE 3. ESTIMATED DISTRIBUTION OF PLANT FUNCTIONAL GROUPS AND GROUNDWATER LOSS TO EVAPOTRANSPIRATION IN SELECTED RIPARIAN AREAS IN CIENEGA CREEK BASIN ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

<table>
<thead>
<tr>
<th>RIPARIAN AREA</th>
<th>SUBAREA</th>
<th>COTTONWOOD/WILLOW</th>
<th>MESQUITE</th>
<th>SACATON</th>
<th>WETLAND</th>
<th>SHALLOW-ROOTED UNDERSTORY</th>
<th>EVAPORATION</th>
<th>ESTIMATED PERCENT OF TOTAL PLANT COVER IN SUBAREA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>PLANT COVER DENSITY (percent)</th>
<th>EVAPOTRANSPIRATION RATE (ft/yr)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>ESTIMATED GROUNDWATER LOSS TO EVAPOTRANSPIRATION (AF/yr)&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Cienega Creek</td>
<td>1</td>
<td>15</td>
<td>25</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>70</td>
<td>1.00</td>
<td>1030</td>
<td>1030</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>10</td>
<td>30</td>
<td>5</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>60</td>
<td>0.74</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Davidson Canyon</td>
<td>3</td>
<td>0</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td>45</td>
<td>5</td>
<td>70</td>
<td>0.67</td>
<td>3100</td>
<td>3100</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>15</td>
<td>40</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Cienega Creek</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>70</td>
<td>0.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>15</td>
<td>30</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>80</td>
<td>1.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>45</td>
<td>5</td>
<td>10</td>
<td>10</td>
<td>80</td>
<td>0.95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Plant cover densities and distribution of plant functional groups (PFGs) were estimated using aerial photograph interpretations and vegetation mapping by Harris and others (2000).

<sup>b</sup> ft/yr = feet per year

<sup>c</sup> AF/yr = acre-feet per year
### TABLE 4. SUMMARY OF FIELD OBSERVATIONS SEEPS AND SPRINGS NEAR ROSEMONT MINE  
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

<table>
<thead>
<tr>
<th>SEEP OR SPRING IDENTIFIER</th>
<th>SEEP OR SPRING LOCATION</th>
<th>UTM COORDINATES&lt;sup&gt;a&lt;/sup&gt;</th>
<th>RANGE OF CONDITIONS OBSERVED</th>
<th>ADDITIONAL REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helvetia</td>
<td>(D-18-15)14dba</td>
<td>521,014 3,525,815</td>
<td>Flowing</td>
<td>Perennial</td>
</tr>
<tr>
<td>Peligro Adit</td>
<td>(D-18-15)24dcc</td>
<td>521,945 3,523,686</td>
<td>Flowing</td>
<td>Perennial; old mine adit; not technically a spring</td>
</tr>
<tr>
<td>MC-2</td>
<td>(D-18-16)19ccd</td>
<td>523,727 3,523,673</td>
<td>Dry to flowing</td>
<td>Intermittent to perennial</td>
</tr>
<tr>
<td>Rosemont</td>
<td>(D-18-16)32bbc</td>
<td>524,836 3,521,392</td>
<td>Flowing</td>
<td>Perennial</td>
</tr>
<tr>
<td>Deering</td>
<td>(D-19-15)01dbd</td>
<td>522,588 3,519,270</td>
<td>Flowing</td>
<td>Perennial</td>
</tr>
<tr>
<td>Mulberry</td>
<td>(D-18-16)09abc</td>
<td>527,245 3,527,984</td>
<td>Moist to low flow</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Papago Spring</td>
<td>(D-18-16)16bbba</td>
<td>526,500 3,526,783</td>
<td>Dry to low flow</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Fig Tree</td>
<td>(D-18-16)19abb</td>
<td>523,955 3,525,037</td>
<td>Dry to moist</td>
<td>Ephemeral to intermittent</td>
</tr>
<tr>
<td>Questa</td>
<td>(D-18-16)27ddd</td>
<td>529,473 3,522,056</td>
<td>Dry to low flow</td>
<td>Intermittent</td>
</tr>
<tr>
<td>MC-1</td>
<td>(D-18-16)30abc</td>
<td>524,152 3,523,207</td>
<td>Dry to low flow</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Sycamore</td>
<td>(D-18-15)12dba</td>
<td>522,558 3,527,449</td>
<td>Dry to small flow</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>SS-2</td>
<td>(D-18-15)13aab</td>
<td>522,805 3,526,562</td>
<td>Dry</td>
<td>Ephemeral; no evidence of spring or seep found</td>
</tr>
<tr>
<td>Ruelas</td>
<td>(D-18-15)35bdc</td>
<td>520,244 3,521,274</td>
<td>Dry</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>Crucero</td>
<td>(D-18-16)09cbd</td>
<td>527,332 3,527,348</td>
<td>Dry to low flow</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>Lower Mulberry</td>
<td>(D-18-16)09dbb</td>
<td>527,513 3,526,870</td>
<td>Dry to moist</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>Barrel</td>
<td>(D-18-16)14cab</td>
<td>529,752 3,525,673</td>
<td>Dry to small flow</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>Scholefield (SC-1)</td>
<td>(D-18-16)16ccc</td>
<td>526,499 3,525,220</td>
<td>Dry</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>SC-2</td>
<td>(D-18-16)17acc</td>
<td>526,052 3,526,106</td>
<td>Dry</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>SW</td>
<td>(D-19-15)01bba</td>
<td>521,547 3,520,154</td>
<td>Dry</td>
<td>Ephemeral</td>
</tr>
<tr>
<td>Locust</td>
<td>(D-19-15)01bdb</td>
<td>521,861 3,519,699</td>
<td>Dry</td>
<td>Ephemeral</td>
</tr>
</tbody>
</table>

<sup>a</sup>Universal Transverse Mercator, North American Datum, 1983, Zone 12
TABLE 5. SUMMARY OF MEASURED AND COMPUTED AQUIFER PARAMETERS AND
SIMULATED HYDRAULIC CONDUCTIVITY AT CORRESPONDING TEST WELL LOCATIONS AND DEPTHS
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

SHORT-TERM AND PACKER TESTS
HYDRAULIC
CONDUCTIVITY

(ft /d)

(ft/d)

DATE LONGTERM
TEST STARTED

5/24/2007

3,600

820

4.4

11/19/2008

530

Pz , Ksd

5/15/2007

47

1,060

0.044

11/19/2008

QTg2 , Ksd

5/31/2007

5.4

1,160

0.0046

QTg2, Ksd

5/17/2007

1.4

1,300

0.0010

Ksd, Pz

10/19/2008

670

1,892

EASTING
(m)

NORTHING
(m)

WELL
IDENTIFIER

GEOLOGIC UNIT

HYDROGEOLOGIC UNIT

DATE
SHORT-TERM
TEST STARTED

(D-18-16)30cba

55-906272

523421.7

3522530.2

PC-1

Willow Canyon (WC)

Ksd

(D-18-16)30cdc

55-214214

523516.3

3522101.0

PC-2

(D-18-16)31bbc

55-214212

523287.2

3521564.8

PC-3

(D-18-15)36daa

55-214173

522999.9

3520984.5

PC-4

(D-18-16)30cad1

55-908870

523745.1

3522450.7

PC-5 (all zones)

(D-18-16)30cad2

(D-18-16)30bcc

(D-18-15)25dbd1

55-908871

55-908872

55-908873

523758.5

523194.0

522665.8

3522437.9

3522829.9

3522436.3

(D-18-15)36abc1

(D-18-15)36abc2

55-908874

55-908875

55-908876

522681.3

522327.4

522308.4

3522439.2

3521582.5

3521548.4

a

TRANSMISSIVITY FROM
STORATIVITY
LONG-TERM TEST
FROM LONG-TERM
2
TEST
(ft /d)

AQUIFER
THICKNESS
(feet)

HYDRAULIC
CONDUCTIVITY
(ft/d)

1.6E-02

2,000

0.27

840

1.4E-03

2,000

0.42

11/19/2008

---

---

---

---

11/19/2008

---

---

---

---

0.35

11/19/2008

830

---

2,000

0.41

b

d

DATA

K RANGE
(ft/d)

Kh/Kz RATIO

M, 2009a & 2009b

0.0011

1:1

1-3

M, 2009a & 2009b

0.001 - 2

10:1 - 1:1

1-5

M, 2009a

0.001 - 0.003

1:1 - 1:10

1-5

M, 2009a

0.0007 - 0.003

1:1 - 1:10

1-5

0.001 - 2

10:1 - 1:1

1-7

SOURCE

c

M, 2009a & 2009b

e

MODEL LAYERS

PC-5 (109-901)

Willow Canyon

Ksd

10/19/2008

655

792

<= 0.02

---

---

---

---

---

M, 2009a

0.001

1:1

1-3

PC-5 (946-1447)

Concha, Scherrer

Pz

10/21/2008

13

531

1.23

---

---

---

---

---

M, 2009a

2.

1:1

4-5

PC-5 (1521-2001)

Epitaph, Colina

Pz

10/23/2008

~0

480

~0

---

---

---

---

---

M, 2009a

0.001 - 2

10:1 - 1:1

5-7

PZ-5

WC, Glance,
Scherrer, Epitaph,
Colina

Ksd, Pz

10/19/2008

520

1,892

0.28

11/19/2008

900

2.2E-03

2,000

0.45

---

---

---

PZ-5 (600)

Willow Canyon

Ksd

---

---

---

---

---

---

---

---

---

0.001

1:1

2

PZ-5 (1150)

Scherrer

Pz

---

---

---

---

---

---

---

---

---

2.

1:1

4

PZ-5 (1800)

Epitaph/Colina

Pz

---

---

---

---

---

---

---

---

---

0.001

1:0.1

6

PC-6 (all zones)

Concha, Epitaph

Pz

10/11/2008

200

1,780

0.11

11/19/2008

2,300

1.4E-03

2,000

1.14

0.01 - 2

10:1 - 1:1

1-6

PC-6 (220-485)

Concha

Pz

10/11/2008

94

265

0.35

---

---

---

---

---

M, 2009a

2.

1:1

1

PC-6 (525-969)

Epitaph

Pz

10/13/2008

40

444

0.09

---

---

---

---

---

M, 2009a

0.01 - 2

10:1 - 1:1

1-3

PC-6 (1013-1464)

Epitaph

Pz

10/14/2008

55

451

0.12

---

---

---

---

---

M, 2009a

0.01

10:1

3-5

PC-6 (1509-2000)

Epitaph

Pz

10/16/2008

12

491

0.02

---

---

---

---

---

M, 2009a

0.01

10:1

5-6

Pz

10/1/2008

130

1,877

0.071

11/19/2008

2,300

6.2E-04

2,000

1.14

M, 2009a & 2009b

0.01

10:1

1-6

PC-7 (all zones)

Glance, Concha,
Epitaph, Abrigo
Glance, Concha,
Epitaph

M, 2009a & 2009b

M, 2009a & 2009b

Pz , Ksd

10/1/2008

27

277

0.1

---

---

---

---

---

M, 2009a

0.01

10:1

1

PC-7 (613-878)

Abrigo

Pz

10/3/2008

53

265

0.2

---

---

---

---

---

M, 2009a

0.01

10:1

1-2

PC-7 (109-569)

(D-18-15)25dbd2

Willow Canyon,
Epitaph
Basin Fill, Willow
Canyon
Basin Fill, Willow
Canyon
WC, Glance,
Scherrer, Epitaph,
Colina

2

SIMULATED HYDRAULIC CONDUCTIVITY

LONG-TERM TEST

AQUIFER
THICKNESS
(feet)

ADWR
REGISTRATION
NUMBER

CADASTRAL
LOCATION

TRANSMISSIVITY
FROM SHORT-TERM
TEST

PC-7 920-1402)

Abrigo

Pz

10/4/2008

41

462

0.09

---

---

---

---

---

M, 2009a

0.01

10:1

2-4

PC-7 (1447-1986)

Abrigo

Pz

10/7/2008

12

539

0.02

---

---

---

---

---

M, 2009a

0.01

10:1

4-6

PZ-7

Concha, Abrigo

Pz

10/1/2008

150

1,877

0.078

11/19/2008

1,700

6.7E-04

2,000

0.87

---

---

---

PZ-7 (485)

Concha

Pz

---

---

---

---

---

---

---

---

---

2.

1:1

1

PZ-7 (800)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

2.

1:1

2

PZ-7 (1245)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

0.01

10:1

4

PZ-7 (1680)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

0.01

10:1

5

PZ-7 (1810)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

0.01

10:1

5

PC-8 (all zones)

Escbrosa/Martin,
Abrigo, Bolsa

Pz

9/22/2008

150

2,008

0.073

11/19/2008

---

---

---

---

M, 2009a

0.0001 - 0.01

10:1 - 1:1

1-7

M, 2009a & 2009b

PC-8 (197-794)

Escabrosa, Martin

Pz

9/22/2008

27

597

0.04

---

---

---

---

---

M, 2009a

0.01

10:1

1-2

PC-8 (860-1860)

Abrigo

Pz

9/25/2008

40

1,000

0.04

---

---

---

---

---

M, 2009a

0.01

10:1

2-6

PC-8 (1962-2205)

Bolsa, Granodiorite

Pz

9/27/2008

80

243

0.33

---

---

---

---

---

M, 2009a

0.0001 - 0.01

10:1 - 1:1

6-7

PZ-8

Escbrosa/Martin,
Abrigo

Pz

9/22/2008

270

2,008

0.13

11/19/2008

1,900

6.9E-03

2,000

0.94

---

---

---

PZ-8 (450)

Escabrosa/Martin

Pz

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0.01

10:1

1

PZ-8 (1150)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

0.01

10:1

3

PZ-8 (1650)

Abrigo

Pz

---

---

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---

---

---

---

---

---

0.01

10:1

5

PZ-8 (1925)

Abrigo

Pz

---

---

---

---

---

---

---

---

---

0.01

10:1

6

Glance

Ksd

8/19/2008

240

180

1.3

11/19/2008

120

7.1E-03

759

0.16

M, 2009a & 2009b

0.01

10:1

1

M, 2009a & 2009b

(D-19-15)01bab1

55-908879

522014.7

3520121.8

HC-1A

(D-19-15)01bab2

55-908880

522015.8

3520112.7

HC-1B

Glance

Ksd

8/15/2008

940

440

2.1

11/19/2008

150

---

759

0.19

M, 2009a & 2009b

0.01

10:1

1

(D-19-16)06aad1

55-909047

524536.7

3519925.9

HC-2A

Basin Fill

QTg1

7/3/2008

17

620

0.028

11/19/2008

---

---

---

---

M, 2009a

0.02

1:10

1-3

(D-19-16)06aad2

55-909048

524526.6

3519929.2

HC-2B

Salero (tuff)

Kv

7/8/2008

4.0

220

0.018

11/19/2008

---

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---

---

M, 2009a

0.02

1:10

3-4

HC-3A

Quaternary Alluvium,
Willow Cyn

Qal, Ksd

9/11/2008

8.0

29

0.28

11/19/2008

---

---

---

---

M, 2009a

0.05

1:1

1

(D-18-16)29ccb1

55-909043

524807.8

3522152.8

(D-18-16)29ccb2

55-908881

524814.1

3522160.3

HC-3B

Willow Canyon

Ksd

9/9/2008

16

200

0.080

11/19/2008

110

1.9E-03

2,000

0.053

M, 2009a & 2009b

0.03

1:1

2

(D-18-16)29ccb3

55-908882

524819.3

3522162.2

HC-3C

Willow Canyon

Ksd

9/2/2008

12

560

0.021

11/19/2008

80

1.6E-03

2,000

0.040

M, 2009a & 2009b

0.03

1:1

2-4

(D-18-16)20dbc1

55-909049

525545.4

3524037.9

HC-4A

Salero

Kv

7/22/2008

44

540

0.082

11/19/2008

---

---

---

---

M, 2009a

0.0008 - 0.03

1:10

1-2

(D-18-16)20dbc2

55-909050

525538.8

3524031.4

HC-4B

Salero

Kv

7/17/2008

0.27

320

0.00084

11/19/2008

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---

---

---

M, 2009a

0.0008

1:10

2-3

(D-18-16)30bab1

55-908883

523686.0

3523492.2

HC-5A

Willow Canyon

Ksd

6/18/2008

370

440

0.85

11/19/2008

40

---

485

0.083

M, 2009a & 2009b

0.07

1:1

1

(D-18-16)30bab2

55-908885

523691.2

3523484.0

HC-5B

Willow Canyon
(minor Epitaph)

Ksd

6/23/2008

0.13

380

0.00035

11/19/2008

40

1.0E-01

862

0.047

M, 2009a & 2009b

0.001

1:1

2-3

(D-18-16)28aba1

55-909051

527459.8

3523501.0

RP-2A

Quaternary Alluvium

Qal

8/28/2008

---

10

---

11/19/2008

---

---

---

---

M, 2009a

0.04

1:10

1

(D-18-16)28aba2

55-909052

527459.4

3523510.7

RP-2B

Salero (sediments)

Kv

8/26/2008

2.0

120

0.017

11/19/2008

---

---

---

---

M, 2009a

0.04

1:10

1-2

(D-18-16)28aba3

55-909053

527461.5

3523520.2

RP-2C

Salero
(tuff, sediments)

Kv

8/22/2008

4.0

260

0.015

11/19/2008

---

---

---

---

M, 2009a

0.04

1:10

2-3

(D-18-16)33bbc1

55-909054

526328.0

3521633.9

RP-3A

Basin Fill, Salero

QTg1, Kv

7/15/2008

13

340

0.039

11/19/2008

---

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---

---

M, 2009a

0.02 - 0.04

1:10

1-2

(D-18-16)33bbc2

55-909056

526332.2

3521642.8

RP-3B

Salero (tuff,
sediments)

Kv

7/12/2008

63

140

0.449

11/19/2008

7

---

505

0.013

0.02

1:10

2-3

M, 2009a & 2009b

(D-18-16)32cad1

55-908886

525485.7

3520871.2

RP-4A

Basin Fill

QTg1

7/1/2008

8.0

358

0.022

11/19/2008

---

---

---

---

M, 2009a

0.02

1:10

1-2

(D-18-16)32cad2

55-908887

525483.6

3520862.2

RP-4B

Apache Canyon

Ksd

6/26/2008

0.40

420

0.00095

11/19/2008

---

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---

---

M, 2009a

0.001 - 0.02

1:1 - 1:10

2-4

1323/27/Tbl5_SumAquiferParameters.xlsx/31Aug2010

Page 1 of 2


**TABLE 5. SUMMARY OF MEASURED AND COMPUTED AQUIFER PARAMETERS AND SIMULATED HYDRAULIC CONDUCTIVITY AT CORRESPONDING TEST WELL LOCATIONS AND DEPTHS**

**ROSEMONT PROJECT, PIMA COUNTY, ARIZONA**

<table>
<thead>
<tr>
<th>DATE</th>
<th>SHORT-TERM TEST STARTED</th>
<th>TRANSMISSIVITY FROM SHORT-TERM TEST</th>
<th>AQUIFER THICKNESS (ft)</th>
<th>HYDRAULIC CONDUCTIVITY (ft/d)</th>
<th>DATE</th>
<th>TRANSMISSIVITY FROM LONG-TERM TEST</th>
<th>AQUIFER THICKNESS (ft)</th>
<th>HYDRAULIC CONDUCTIVITY (ft/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROSEMONT PROJECT, PIMA COUNTY, ARIZONA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>SIMULATED HYDRAULIC CONDUCTIVITY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SHORT-TERM AND PACKER TESTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>LONG-TERM TEST</strong></td>
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</tr>
<tr>
<td><strong>TRANSMISSIVITY</strong></td>
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<td></td>
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<tr>
<td><strong>AQUIFER THICKNESS</strong></td>
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<tr>
<td><strong>HYDRAULIC CONDUCTIVITY</strong></td>
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<tr>
<td><strong>DATA SOURCE</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>a</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>b</strong></td>
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<td></td>
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</tr>
<tr>
<td><strong>c</strong></td>
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</tr>
</tbody>
</table>

**K** = Hydraulic Conductivity

**K** = Rate of horizontal hydraulic conductivity to vertical hydraulic conductivity

--- = not applicable or unknown

NC = No construction data available for well screened depths

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--- = No construction data available for well screened depths
<table>
<thead>
<tr>
<th>STRESS PERIOD</th>
<th>TIME ELAPSED SINCE START OF PREPRODUCTION (Years)</th>
<th>PIT INFLOW RATE (gpm)a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.75</td>
<td>0</td>
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<tr>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1.25</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1.5</td>
<td>42</td>
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<td>7</td>
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<td>8</td>
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<tr>
<td>10</td>
<td>2.5</td>
<td>489</td>
</tr>
<tr>
<td>11</td>
<td>2.75</td>
<td>509</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>511</td>
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<tr>
<td>13</td>
<td>3.25</td>
<td>503</td>
</tr>
<tr>
<td>14</td>
<td>4.25</td>
<td>450</td>
</tr>
<tr>
<td>15</td>
<td>5.25</td>
<td>443</td>
</tr>
<tr>
<td>16</td>
<td>6.25</td>
<td>509</td>
</tr>
<tr>
<td>17</td>
<td>7.25</td>
<td>497</td>
</tr>
<tr>
<td>18</td>
<td>8.25</td>
<td>532</td>
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<tr>
<td>19</td>
<td>9.25</td>
<td>533</td>
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<td>20</td>
<td>10.25</td>
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<td>11.25</td>
<td>630</td>
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<td>22</td>
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<td>599</td>
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<td>13.25</td>
<td>550</td>
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<td>24</td>
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<td>623</td>
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<tr>
<td>25</td>
<td>15.25</td>
<td>637</td>
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<tr>
<td>26</td>
<td>16.25</td>
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<td>605</td>
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<td>29</td>
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<td>30</td>
<td>20.25</td>
<td>560</td>
</tr>
<tr>
<td>31</td>
<td>21.25</td>
<td>582</td>
</tr>
<tr>
<td>32</td>
<td>22.25</td>
<td>552</td>
</tr>
</tbody>
</table>

a gpm = gallons per minute
<table>
<thead>
<tr>
<th>YEARS AFTER END OF MINING</th>
<th>PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles)</th>
<th>PROJECTED PIT LAKE STAGE (feet, amsl)</th>
<th>NUMBER OF SEEPS/SPRINGS WITHIN 5-FOOT DRAWDOWN CONTOUR</th>
<th>PROJECTED DECREASE IN GROUNDWATER OUTFLOW FROM MODEL BOUNDARY WEST FROM PIT (AF/yr)</th>
<th>PROJECTED DRAWDOWN AT PERENNIAL STREAM REACH (feet)</th>
<th>PROJECTED DECREASE IN PERENNIAL STREAM BASEFLOW (cfs)</th>
<th>PROJECTED DECREASE IN ET&lt;sup&gt;1&lt;/sup&gt; (AF/yr)</th>
<th>PROJECTED DECREASE IN STREAM BASEFLOW (cfs)</th>
<th>PROJECTED DECREASE IN ET&lt;sup&gt;2&lt;/sup&gt; (AF/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.2</td>
<td>3†</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>20</td>
<td>4.2</td>
<td>3†</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>150</td>
<td>9.6</td>
<td>5&lt;sup&gt;†&lt;/sup&gt;</td>
<td>11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.31</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>1,000</td>
<td>11.5</td>
<td>5&lt;sup&gt;†&lt;/sup&gt;</td>
<td>42</td>
<td>0.01</td>
<td>0.16</td>
<td>0.02</td>
<td>0.98</td>
<td>0.29</td>
<td>0.04</td>
</tr>
</tbody>
</table>

<sup>*</sup> Note: Extends to immediately above confluence of Davidson Canyon with Cienega Creek

<sup>a</sup> feet, amsl = feet above mean sea level
<sup>b</sup> AF/yr = acre-feet per year
<sup>c</sup> = at hydrograph locations shown on Figures 110 through 113
<sup>d</sup> = at simulated streamflow locations shown on Figure 97
<sup>e</sup> cfs = cubic feet per second
<sup>f</sup> ET = evapotranspiration
<sup>g</sup> ET zones 4 and 5 (<sup>Figures 27 and 96</sup>)
<sup>h</sup> ET zones 6, 7, and 8 (<sup>Figures 27 and 96</sup>)
<sup>i</sup> Dry Pit Bottom
<sup>j</sup> includes springs: MC-1, Deering, and Rosemont (<sup>Figures 110 and 111</sup>)
<sup>k</sup> includes springs: MC-1, Deering, Rosemont, Questa, and Helvetia (<sup>Figures 112 and 113</sup>)
### TABLE 8. LAKE SENSITIVITY ANALYSIS PARAMETERS

<table>
<thead>
<tr>
<th>VARIED INPUT PARAMETER</th>
<th>DECREASED LAKE STAGE (Low Multivariate)</th>
<th>BASE SIMULATION</th>
<th>INCREASED LAKE STAGE (High Multivariate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake surface precipitation</td>
<td>17.75 in/yr</td>
<td>22.19 in/yr</td>
<td>26.63 in/yr</td>
</tr>
<tr>
<td>Lake evaporation</td>
<td>40.05 in/yr</td>
<td>50.06 in/yr</td>
<td>60.07 in/yr</td>
</tr>
<tr>
<td>Percentage of precipitation runoff</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
</tr>
</tbody>
</table>

in/yr = inches per year
TABLE 9. SUMMARY OF FINAL PIT-LAKE STAGES FOR THE BASE AND SENSITIVITY SIMULATIONS

<table>
<thead>
<tr>
<th>SINGLE VARIABLE MODEL SENSITIVITY SIMULATION</th>
<th>FINAL PIT-LAKE STAGE (feet, msl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Simulation</td>
<td>4,097</td>
</tr>
<tr>
<td>Increased Lake Surface Precipitation</td>
<td>4,208</td>
</tr>
<tr>
<td>Decreased Lake Surface Precipitation</td>
<td>3,980</td>
</tr>
<tr>
<td>Increased Lake evaporation</td>
<td>3,945</td>
</tr>
<tr>
<td>Decreased Lake evaporation</td>
<td>4,264</td>
</tr>
<tr>
<td>Increased precipitation runoff</td>
<td>4,156</td>
</tr>
<tr>
<td>Decreased precipitation runoff</td>
<td>4,018</td>
</tr>
</tbody>
</table>

feet, msl = feet above mean sea level
### TABLE 10. PREDICTIVE SENSITIVITY ANALYSIS RESULTS AT 1,000 YEARS POST-MINING

**ROSEMONT PROJECT, PIMA COUNTY, ARIZONA**

<table>
<thead>
<tr>
<th>HYDROGEOLOGIC UNIT OR FAULT ZONE</th>
<th>SENSITIVITY ANALYSIS</th>
<th>PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles)</th>
<th>PROJECTED PIT LAKE STAGE (feet, masl)</th>
<th>UPPER CIENEGA CREEK AND THE NARROWS</th>
<th>PROJECTED CHANGE IN STREAM REACH LENGTH (miles)</th>
<th>PROJECTED CHANGE IN STREAM BASEFLOW (cfs)</th>
<th>PROJECTED CHANGE IN ET (AF/yr)</th>
<th>PROJECTED CHANGE IN STREAM REACH LENGTH (miles)</th>
<th>PROJECTED CHANGE IN STREAM BASEFLOW (cfs)</th>
<th>PROJECTED CHANGE IN ET (AF/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KT1 = Upper Cretaceous and Early Tertiary intrusive rocks</td>
<td>K * 10</td>
<td>11.5</td>
<td>4097.59</td>
<td>0.16</td>
<td>0.18</td>
<td>66</td>
<td>0.29</td>
<td>0.04</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>K = Hydraulic Conductivity</td>
<td>K * 0.1</td>
<td>11.6</td>
<td>4096.90</td>
<td>0.15</td>
<td>0.2</td>
<td>55</td>
<td>0.28</td>
<td>0.1</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>K&lt;sub&gt;d&lt;/sub&gt; = Lower Cretaceous sedimentary units</td>
<td>K * 10</td>
<td>11.5</td>
<td>4096.90</td>
<td>0.16</td>
<td>0.18</td>
<td>54</td>
<td>0.29</td>
<td>0.02</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Pz = Paleozoic sedimentary and metamorphic formations</td>
<td>K * 0.1</td>
<td>11.5</td>
<td>4097.59</td>
<td>0.16</td>
<td>0.01</td>
<td>50</td>
<td>0.29</td>
<td>0.04</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;T&lt;/sub&gt;g2</td>
<td>K * 10</td>
<td>11.5</td>
<td>4097.59</td>
<td>0.16</td>
<td>0.02</td>
<td>50</td>
<td>0.29</td>
<td>0.03</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;T&lt;/sub&gt;al</td>
<td>K * 0.1</td>
<td>11.6</td>
<td>4096.90</td>
<td>0.15</td>
<td>0.2</td>
<td>55</td>
<td>0.28</td>
<td>0.1</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Flat Fault (east)</td>
<td>K * 10</td>
<td>11.7</td>
<td>4118.30</td>
<td>0.16</td>
<td>0.18</td>
<td>66</td>
<td>0.29</td>
<td>0.04</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Flat Fault (west)</td>
<td>K * 0.1</td>
<td>11.5</td>
<td>4086.41</td>
<td>0.16</td>
<td>0.2</td>
<td>48</td>
<td>0.29</td>
<td>0.03</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Basin Fill (excluding QTg2)</td>
<td>Sy * 0.5</td>
<td>11.5</td>
<td>4087.71</td>
<td>0.16</td>
<td>0.02</td>
<td>53</td>
<td>0.29</td>
<td>0.04</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Basin Fill (excluding QTg2)</td>
<td>Sy * 0.5</td>
<td>11.5</td>
<td>4087.71</td>
<td>0.16</td>
<td>0.02</td>
<td>53</td>
<td>0.29</td>
<td>0.04</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Base Simulation</td>
<td>No Change</td>
<td>11.5</td>
<td>4097.40</td>
<td>0.16</td>
<td>0.02</td>
<td>55</td>
<td>0.29</td>
<td>0.04</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>

* Note: Extends to immediately above confluence of Davidson Canyon with Cienega Creek
6 feet, masl = feet above mean sea level
5 = at simulated streamflow locations shown on Figure 97
1 = cubic feet per second
6 ET = evapotranspiration
7 AF/yr = acre-feet per year
8 Davidson Canyon Fault hydraulic conductivity reduced to approximately match surrounding rock formations
NA = Not analyzable due to poor steady-state calibration for this parameter sensitivity variation resulting in Davidson Canyon simulated ET and streamflow being zero.

KT1 = Upper Cretaceous and Early Tertiary intrusive rocks
K = Hydraulic Conductivity
K<sub>d</sub> = Upper Cretaceous sedimentary and volcanic rocks
K<sub>d</sub> = Lower Cretaceous sedimentary units
Pz = Paleozoic sedimentary and metamorphic formations
Q<sub>T</sub>g2 = Precambrian igneous and metamorphic crystalline formations
Q<sub>T</sub>g = Late Tertiary to Early Quaternary basin-fill deposits - lowest permeability
Q<sub>T</sub>g1 = Late Tertiary to Early Quaternary basin-fill deposits - higher permeability
Q<sub>T</sub>al = Late Tertiary to Early Quaternary basin-fill deposits - lowest permeability
K<sub>x</sub> = East-west horizontal Hydraulic Conductivity
K<sub>y</sub> = North-south Hydraulic Conductivity
K<sub>z</sub> = Vertical Hydraulic Conductivity
Sy = Specific yield
S<sub>s</sub> = Specific storage
Groundwater Flow Modeling Conducted for Simulation of Proposed Rosemont Pit Dewatering and Post-Closure Volume 2: Figures
Rosemont Project, Pima County, Arizona
Prepared by:

www.elmontgomery.com  520-881-4912  1550 East Prince Road, Tucson AZ 85719
FIGURE 1. LOCATION OF STUDY AREA

EXPLANATION

- Extent of Model Domain

GIS-Tuc\1232\32\REPORT_July2010\RegionalLocMap_east.mxd;20Aug2010\UTM NAD83 Zone12N
EXPLANATION

- Ephemeral Drainage Channel
- Perennial Stream Reach
- Cienega Creek Basin Boundary
- Proposed Rosemont Open Pit
- Projected Extent of Waste Rock Area
- Projected Extent of Tailings Storage Area
- Extent of Model Domain

STUDY AREA
EXPLANATION

Powerline
Roads
Fault
Inferred fault
Thrust fault
Hydrogeologic Section Line

Well Symbols

Pit Characterization Well
Multi-Level Piezometer
Deep Characterization Well
Intermediate Characterization Well
Shallow Characterization Well
Alluvium Characterization Well
Other Water Well
Other Piezometer
Monitored Spring or Seep
Geotechnical Characterization Hole
Anaconda Core Hole
Min Adit

Hydrogeologic Units

Recent Alluvium
Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
Early to Mid Tertiary Sedimentary and Volcanic Units (Panama Formation)
Upper Cretaceous and Early Tertiary Intrusive Rocks
Upper Cretaceous Sedimentary and Volcanic Rocks
Lower Cretaceous Sedimentary Formations (Bisbee Group)
Paleozoic Sedimentary and Metamorphic Formations
Precambrian Igneous and Metamorphic Crystalline Formations

PROJECT AREA
HYDROGEOLOGIC FEATURES

FIGURE 4
EXPLANATION

Hydrogeologic Units

Qal
  Recent Alluvium
QTg
  Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
QTg1
  Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
QTg2
  Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
Tsp
  Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
KTi
  Upper Cretaceous and Early Tertiary Intrusive Rocks
Kv
  Upper Cretaceous and Early Tertiary Sedimentary and Volcanic Rocks
Ksd
  Lower Cretaceous Sedimentary Formations (Bisbee Group)
Pz
  Paleozoic Sedimentary and Metamorphic Formations
pCb
  Precambrian Igneous and Metamorphic Crystalline Formations

A-A’ Trace of Section

0 5 Miles

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HYDROGEOLOGIC UNITS
5,400 FOOT ALTITUDE

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FIGURE 9
Hydrogeologic Units:

- Qal: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- QTg2: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- Tsp: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- Pz: Upper Cretaceous and Early Tertiary Intrusive Rocks
- Kv: Upper Cretaceous Sedimentary and Volcanic Rocks
- Ksd: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

Proposed Rosemont Open Pit (at land surface)

Extent of Model Domain

Ephemeral Drainage Channel

Perennial Stream Reach

Proposed Rosemont Open Pit (at land surface)
EXPLANATION

Hydrogeologic Units

- Qal: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- QTg2: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- Tsp: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- KTi: Upper Cretaceous and Early Tertiary Intrusive Rocks
- Kv: Upper Cretaceous Sedimentary and Volcanic Rocks
- Ksd: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

Trace of Section

- A-A': Ephemeral Drainage Channel
- B-B': Perennial Stream Reach
- C-C': Extent of Model Domain
- D-D': Proposed Rosemont Open Pit (at land surface)
EXPLANATION

Hydrogeologic Units

- **Qal**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **Tsp**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KTi**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Ksd**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Kv**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **Pz**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

A A' - Trace of Section

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HYDROGEOLOGIC UNITS
4,800 FOOT ALTITUDE

MONTGOMERY & ASSOCIATES
Water Resource Consultants

FIGURE 12
EXPLANATION

Hydrogeologic Units

- Qal: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- QTg2: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
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- Ksd: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

A—A' Trace of Section

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HYDROGEOLOGIC UNITS
4,600 FOOT ALTITUDE

FIGURE 13
Hydrogeologic Units

- **Qa**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **Tsp**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KTi**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Ksd**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Pz**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **pCb**: Paleozoic Sedimentary and Metamorphic Formations
- **pEb**: Precambrian Igneous and Metamorphic Crystalline Formations

EXPLANATION

Grid north orientation

**A-A'** Trace of Section

0 5 Miles

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HYDROGEOLOGIC UNITS

4,400 FOOT ALTITUDE

FIGURE 14
EXPLANATION

Hydrogeologic Units

- Qa: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- KTg2: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- Tsp: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- KTi: Upper Cretaceous and Early Tertiary Intrusive Rocks
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- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

A--A': Trace of Section

- Ephemeral Drainage Channel
- Perennial Stream Reach
- Extent of Model Domain
- Proposed Rosemont Open Pit (at land surface)
Hydrogeologic Units

- **Qal**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
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- **Kv**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

**EXPLANATION**

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**HYDROGEOLOGIC UNITS**

4,000 FOOT ALTITUDE

GIS-Tuc1232.32REPORT_July2010HydrogeologicSurface4000July2010
Hydrogeologic Units

- Qal: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- QTg2: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- Tsp: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- KTi: Upper Cretaceous and Early Tertiary Intrusive Rocks
- Kv: Upper Cretaceous Sedimentary and Volcanic Rocks
- Ksd: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

EXPLANATION

Proposed Rosemont Open Pit
(at land surface)

Extent of Model Domain
Ephemeral Drainage Channel
Perennial Stream Reach
Trace of Section
EXPLANATION
Hydrogeologic Units

QaL  Recent Alluvium
QTg  Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
QTg1 Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
QTg2 Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
Tsp  Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
KTi  Upper Cretaceous and Early Tertiary Intrusive Rocks
Ksd  Upper Cretaceous Sedimentary and Metamorphic Formations
Kv   Paleozoic Sedimentary and Metamorphic Formations
Pz   Lower Cretaceous Sedimentary Formations (Bisbee Group)
pCb  Precambrian Igneous and Metamorphic Crystalline Formations

A-A' Trace of Section

GIS-Tuc323.23REPORT_July2010/HydrogeologicSurface3600/29July2010

HYDROGEOLOGIC UNITS
3,600 FOOT ALTITUDE

Proposed Rosemont Open Pit
(at land surface)
EXPLANATION

Hydrogeologic Units

- **Qal**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **Ts**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KTi**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Ksd**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Kv**: Paleozoic Sedimentary and Metamorphic Formations
- **Pz**: Precambrian Igneous and Metamorphic Crystalline Formations
- **pCb**: Trace of Section

**Proposed Rosemont Open Pit** (at land surface)

**Extent of Model Domain**

**Ephemeral Drainage Channel**

**Perennial Stream Reach**

**Trace of Section**

**Hydrogeologic Units**

3,400 FOOT ALTITUDE

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**HYDROGEOLOGIC UNITS**

2010

**FIGURE 19**
Hydrogeologic Units

- **Qal**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **Tsp**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KTi**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Kv**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Ksd**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **Pz**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

Trace of Section

- **A**
- **A'**
- **B**
- **B'**
- **C**
- **C'**
- **D**
- **D'**
- **E**
- **E'**

**FIGURE 20**

**HYDROGEOLOGIC UNITS**

3,200 FOOT ALTITUDE
FIGURE 21

EXPLANATION

Hydrogeologic Units

- **Qa**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **Tsp**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KTi**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **KTi**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Ksd**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **Pz**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

A\textendash}A' Trace of Section

- **Ephemeral Drainage Channel**
- **Perennial Stream Reach**
- **Extent of Model Domain**
- **Proposed Rosemont Open Pit (at land surface)**

**HYDROGEOLOGIC UNITS**

3,000 FOOT ALTITUDE

GIS-Tuc\textcopyright 32 REPORT July 2010 Hydrogeologic Surface 3000\textcopyright July 2010
Hydrogeologic Units

- **Qal**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **QTg2**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **TsP**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **KtI**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Kv**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Ksd**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **Pz**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

**EXPLANATION**

- **A A'**: Ephemeral Drainage Channel
- **B B'**: Perennial Stream Reach
- **C C'**: Extent of Model Domain
- **D D'**: Proposed Rosemont Open Pit (at land surface)

**HYDROGEOLOGIC UNITS**

**2,800 FOOT ALTITUDE**
Hydrogeologic Units

- OA: Recent Alluvium
- QTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- QTg1: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- KTg: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- Tsp: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- KT: Upper Cretaceous and Early Tertiary Intrusive Rocks
- Kv: Upper Cretaceous Sedimentary and Volcanic Rocks
- Ksd: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- Pz: Paleozoic Sedimentary and Metamorphic Formations
- pCb: Precambrian Igneous and Metamorphic Crystalline Formations

EXPLANATION

Hydrogeologic Units

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EXPLANATION

Hydrogeologic Units

- **QaL**: Recent Alluvium
- **QTg**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability
- **QTg1**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability
- **KTsp**: Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability
- **KTi**: Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation)
- **Kv**: Upper Cretaceous and Early Tertiary Intrusive Rocks
- **Ksd**: Upper Cretaceous Sedimentary and Volcanic Rocks
- **Pz**: Lower Cretaceous Sedimentary Formations (Bisbee Group)
- **pCb**: Paleozoic Sedimentary and Metamorphic Formations
- **pCb**: Precambrian Igneous and Metamorphic Crystalline Formations

**A-A'** Trace of Section

- **Ephemeral Drainage Channel**
- **Perennial Stream Reach**
- **Extent of Model Domain**
- **Proposed Rosemont Open Pit (at land surface)**

**2,400 FOOT ALTITUDE**

2010

FIGURE 24
EXPLANATION

RIPARIAN AREA ZONE AND ESTIMATED EVAPOTRANSPIRATION RATES, in acre-feet per year

Zone 1 0 AF/yr
Zone 2 755 AF/yr
Zone 3 275 AF/yr
Zone 4 80 AF/yr
Zone 5 35 AF/yr
Zone 6 480 AF/yr
Zone 7 730 AF/yr
Zone 8 1,890 AF/yr

Ephemeral Drainage Channel

Perennial Stream Reach

Approximate Boundary between Upper and Lower Cienega Creek Basins

Cienega Creek Basin Boundary

Proposed Rosemont Open Pit

Projected Extent of Waste Rock Area

Projected Extent of Tailings Storage Area

Extent of Model Domain

ESTIMATED ANNUAL EVAPOTRANSPIRATION RATES

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FIGURE 27

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FIGURE 30. CHART OF SIMULATED HYDRAULIC CONDUCTIVITY AND AQUIFER TEST RESULTS FOR EACH HYDROGEOLOGIC UNIT
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 32. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT PUMPING WELL PC-5, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA
Figure 33. Hydrograph of observed and simulated drawdown at observation well PZ-5 (600), Rosemont Project, Pima County, Arizona.

Nearest Pumping Well: PC-5

End of Multi-well Pumping Test

EXPLANATION
- • Observed Drawdown and Recovery
- • Simulated Drawdown and Recovery

S:\projects\1232\1232.32\Drawdown\Observation_Well_Hydrographs\PumpingWell_Start_Times\PZ-5_600__semi_startPC-5  27Aug2010
FIGURE 34. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-5 (1150), ROSEМONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

Nearest Pumping Well: PC-5
End of Multi-well Pumping Test
FIGURE 35. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-5 (1800), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

Nearest Pumping Well: PC-5

End of Multi-well Pumping Test

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

DRAWDOWN, IN FEET

DAYS PUMPING FOR WELL PC-5
FIGURE 36. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-1, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- • Observed Drawdown and Recovery
- ○ Simulated Drawdown and Recovery

Nearest Pumping Well: PC-5

End of Multi-well Pumping Test
FIGURE 37. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-2, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

Nearest Pumping Well: PC-5
FIGURE 38. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-6, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA
FIGURE 39. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-3, ROSEMont PROJECT, PIMA COUNTY, ARIZONA
FIGURE 40. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-7 (485), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 41. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-7 (790), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 42. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-7 (1245), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 43. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-7 (1680), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 44. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-7 (1800), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 45. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-7, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 46. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-3A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

Nearest Pumping Well: PC-5
End of Multi-well Pumping Test
FIGURE 47. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-3B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 48. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-3C, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 49. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-4, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 50. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PC-8, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 51. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-8 (450), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 52. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-8 (1150), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 53. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-8 (1650), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

Nearest Pumping Wells: PC-5, HC-1B

End of Multi-well Pumping Test
FIGURE 54. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL PZ-8 (1925), ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 55. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT PUMPING WELL HC-1B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

End of Multi-well Pumping Test

Observed Drawdown and Recovery
Simulated Drawdown and Recovery

DAYS PUMPING FOR WELL HC-1B
0.1 1 10 100
DRAWDOWN, IN FEET
0 -10

Pumping Well
FIGURE 56. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-1A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 57. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-5, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 58. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL 1445, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

Nearest Pumping Well: HC-1B

End of Multi-well Pumping Test
FIGURE 59. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT PUMPING WELL HC-5A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 60. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-5B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 61. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-4A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 6.2. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-4B, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA
FIGURE 63. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT PUMPING WELL RP-3B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 64. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION井 RP-3A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

End of Pumping Test
RP-3B Pumped for 12 Days

Nearest Pumping Wells: RP-3B

Observed Drawdown and Recovery
Simulated Drawdown and Recovery

DAYS PUMPING FOR WELL RP-3B
DRAWDOWN, IN FEET
FIGURE 65. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL G-35, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

Nearest Pumping Well: RP-3B

End of Pumping Test
RP-3B Pumped for 12 Days

Observed Drawdown and Recovery
Simulated Drawdown and Recovery
FIGURE 66. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-4A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

Nearest Pumping Well: RP-3B

End of Pumping Test
RP-3B Pumped for 12 Days

Explaination:
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery
FIGURE 67. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-4B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery

End of Pumping Test
RP-3B Pumped for 12 Days

Nearest Pumping Well: RP-3B
Observed Drawdown and Recovery
Simulated Drawdown and Recovery

Nearest Pumping Well: RP-3B

End of Pumping Test
RP-3B Pumped for 12 Days

FIGURE 68. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL GAYLER, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 69. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-2A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

Nearest Pumping Wells: RP-3B, RP-6

End of Pumping Test
RP-3B Pumped for 12 Days

EXPLANATION
- Observed Drawdown and Recovery
- Simulated Drawdown and Recovery
FIGURE 70. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-2B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 71. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-2C, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 72. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-2A, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 73. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HC-2B, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 74. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-9, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 75. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT PUMPING WELL RP-6, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 76. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL MULBERRY STOCK, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
Observed Drawdown and Recovery

Simulated Drawdown and Recovery

Nearest Pumping Well: RP-6

End of Multi-well Pumping Test

FIGURE 77. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-7, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 78. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL HV-2, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 79. HYDROGRAPH OF OBSERVED AND SIMULATED DRAWDOWN AT OBSERVATION WELL RP-8, ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA
**EXPLANATION**

- **Proposed Rosemont Open Pit** (at land surface)
- **Extent of Model Domain**
- **Ephemeral Drainage Channel**
- **Perennial Stream**
- **Trace of Hydraulic Conductivity Section**

**Simulated Hydraulic Conductivity, in feet per day**

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

**Geologic Zone Boundary**

- Backbone Fault (1:10:10)\(^a\)
- Flat Fault (1:1:1)\(^a\)
- Quaternary and Recent Alluvium (10:10:1)\(^a\)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)\(^a\)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)\(^a\)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)\(^a\)
- Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)\(^a\)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)\(^a\)
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)\(^a\)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)\(^a\)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)\(^a\)

\(^a\) t:10:10 = Ratio of Horizontal Conductivity (x): Vertical Conductivity (y): Horizontal Conductivity (z)
EXPLANATION
- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day:
- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Geologic Zone Boundary
- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)
- Quaternary and Recent Alluvium (10:10:1)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
- Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)

Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)
Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)
EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Geologic Zone Boundary

- Backbone Fault (1:1:10)ά
- Flat Fault (1:1:1)ά
- Quaternary and Recent Alluvium (10:10:1)ά
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)ά
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)ά
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)ά
- Late Quaternary to Early Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)ά
- Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)ά
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)ά
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)ά

ά 1:10:10 = Ratio of Horizontal Conductivity (x): Vertical Conductivity (y): Trace of Hydraulic Conductivity Section

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EXPLANATION

- **Proposed Rosemont Open Pit (at land surface)**
- **Extent of Model Domain**
- **Ephemeral Drainage Channel**
- **Perennial Stream**
- **Trace of Hydraulic Conductivity**

**Simulated Hydraulic Conductivity, in feet per day**

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

**Ratio of Horizontal Conductivity (x): Vertical Conductivity (z)**

**Geologic Boundary**

- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)

**Geologic Zones**

- **Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)**
- **Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)**
- **Upper Cretaceous Sedimentary and Volcanic Rocks (10:10:1)**
- **Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)**
- **Paleozoic Sedimentary and Metamorphic Formations (1:1:1)**
- **Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)**

**Legend**

- **Ksd**
- **Kv**
- **Pz**
- **QTg**
- **QTg1**
- **QTg2**
- **Qal**
- **Tsp**
- **pCb**
- **KTi**
- **Kv**
- **Ksd**
- **T. 16 S.**
- **T. 17 S.**
- **T. 18 S.**
- **T. 19 S.**
- **T. 20 S.**
- **R. 15 E.**
- **R. 16 E.**
- **R. 17 E.**
- **R. 18 E.**
- **R. 19 E.**

**FIGURE 84**

**SIMULATED HYDRAULIC CONDUCTIVITY FOR MODEL LAYER 4**
EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day

<table>
<thead>
<tr>
<th>Value</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.0001</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>0.0001 - 0.001</td>
<td></td>
<td>Low to Medium</td>
</tr>
<tr>
<td>0.001 - 0.01</td>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td>0.01 - 0.1</td>
<td></td>
<td>Medium to High</td>
</tr>
<tr>
<td>0.1 - 1.0</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>1.0 - 10</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>&gt; 10</td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

**Geologic Boundary**

- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)

**Other Geologic Units**

- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
- Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)
- Quaternary and Recent Alluvium (10:10:1)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)

**Legend**

- Tsp
- Ksd
- KTi
- KV
- Pz
- Qal
- QTg
- QTg1
- QTg2
- pCb

**Ratio of Horizontal Conductivity (x):**

\[ x = \frac{K_x}{K_y} \]
FIGURE 86

SIMULATED HYDRAULIC CONDUCTIVITY FOR MODEL LAYER 6

EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Geologic Zone Boundary

- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)

Springs (1:10:1)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
- Upper Cretaceous Sedimentary and Volcanic Rocks (10:10:1)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)

Legend:
- Tep
- KT1
- KV
- Ksd
- Pz
- pCb

Trace of Hydraulic Conductivity Section

NOTE: Trace of Hydraulic Conductivity Section is not shown on map.

Montgomery & Associates

ROSEMONT COPPER

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EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Geologic Zone Boundary

- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)

Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
Upper Cretaceous Sedimentary and Volcanic Rocks (10:10:1)
Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)
Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)

0 ≤ 10 = Ratio of Horizontal Conductivity (x): Vertical Conductivity (z)

FIGURE 88
SIMULATED HYDRAULIC CONDUCTIVITY FOR MODEL LAYER 8

2010

MONTGOMERY & ASSOCIATES
Water Resource Consultants
EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

**Simulated Hydraulic Conductivity**, in feet per day:
- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

**Geologic Zone Boundary**:
- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
- Upper Cretaceous Sedimentary and Volcanic Rocks (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lowest Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)
- Quaternary and Recent Alluvium (10:10:1)
- Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)

**a 1:10:10** = Ratio of Horizontal Conductivity (x): Vertical Conductivity (y)

**GOVERNMENT AND UNDERTAKEN UNDER THE AUTHORITY OF THE RECON CORDIA TRUST, A STATE TRUST AUTONOMOUS FROM THE STATE OF ARIZONA**

**SIMULATED HYDRAULIC CONDUCTIVITY FOR MODEL LAYER 9**

2010

**FIGURE 89**

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EXPLANATION

- Proposed Rosemont Open Pit (at land surface)
- Extent of Model Domain
- Ephemeral Drainage Channel
- Perennial Stream
- Trace of Hydraulic Conductivity Section

Simulated Hydraulic Conductivity, in feet per day

- ≤ 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Geologic Zone Boundary

- Backbone Fault (1:10:10)$^a$
- Flat Fault (1:1:1)$^a$
- Quaternary and Recent Aluvium (10:10:1)$^a$
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Higher Permeability (10:10:1)$^a$
- Late Tertiary to Early Quaternary Basin-Fill Deposits - Lower Permeability (10:10:1)$^a$

$^a$ 1:10:10 = Ratio of Horizontal Conductivity (x): Vertical Conductivity (z)

Simulated Hydraulic Conductivity, in feet per day

- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- > 10

Early to Mid Tertiary Sedimentary and Volcanic Units (Pantano Formation) (1:1:1)$^a$
Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)$^a$
Upper Cretaceous Sedimentary and Volcanic Rocks (10:10:1)$^a$
Lower Cretaceous Sedimentary Formations (Bisbee Group) (1:1:1)$^a$
Paleozoic Sedimentary and Metamorphic Formations (1:1:1)$^a$
Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)$^a$

FIGURE 90

SIMULATED HYDRAULIC CONDUCTIVITY FOR MODEL LAYER 10

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Simulated Hydraulic Conductivity
(in feet per day)
- <0.001
- 0.001 - 0.001
- 0.01 - 0.1
- 0.1 - 1.0
- 1.0 - 10
- >10

Geologic Zone Boundary
- Backbone Fault (1:10:10)
- Flat Fault (1:1:1)
- Quaternary and Recent Alluvium (1:10:1)
- Late Tertiary to Early Quaternary Basal Fill Deposits - Higher Permeability (1:10:10)
- Late Tertiary to Early Quaternary Basal Fill Deposits - Lower Permeability (1:10:10)
- Late Tertiary to Early Quaternary Basal Fill Deposits - Lowest Permeability (1:10:10)
- Triassic Early to Mid Tertiary Sedimentary and Volcanic Rocks (Permian Formation) (1:1:1)
- Upper Cretaceous and Early Tertiary Intrusive Rocks (1:1:1)
- Upper Cretaceous and Early Tertiary Sedimentary and Volcanic Rocks (1:1:1)
- Lower Cretaceous Sedimentary and Metamorphic Formations (1:1:1)
- Paleozoic Sedimentary and Metamorphic Formations (1:1:1)
- Precambrian Igneous and Metamorphic Crystalline Formations (1:1:1)

Ratio of Horizontal Conductivity (k): Vertical Conductivity (v)
Simulated Recharge for Pre-Mining and 22-Year Mining Period, inches per year:

- 0.09 - 0.20
- 0.21 - 0.27
- 0.28 - 0.43
- 0.44 - 0.67
- 0.68 - 1.44
- 1.45 - 2.05

Note: Recharge in the pit area decreases over time due to expansion of pit. The pit is a location of groundwater discharge.
Total recharge from tailings seepage = 13.6 AF/yr (8.4 gpm); decreasing to 0 after 500 years.

Total recharge from drain infiltration = 7.5 AF/yr (4.7 gpm).

EXPLANATION

Post-Mining Flow-Through Drains
(Location of drains provided by TetraTech, 2010)

FIGURE 94. SIMULATED RECHARGE FOR MINING FACILITIES FOR 1,000-YEAR POST-MINING PERIOD
FIGURE 95. POST-MINING TAILINGS IMPOUNDMENT CLOSURE SEEPAGE RATES
EXPLANATION

RIPARIAN AREA ZONES WITH SIMULATED EVAPOTRANSPIRATION RATES AND EXTINCTION DEPTHS

- Zone 1: 0 AF/yr, 0 feet
- Zone 2: 0 AF/yr, 14.5 feet
- Zone 3: 226 AF/yr, 15.6 feet
- Zone 4: 18 AF/yr, 9.1 feet
- Zone 5: 102 AF/yr, 5.7 feet
- Zone 6: 790 AF/yr, 10.0 feet
- Zone 7: 1,107 AF/yr, 17.3 feet
- Zone 8: 1,695 AF/yr, 10.9 feet

- Ephemeral Drainage Channel
- Perennial Stream Reach
- Approximate Boundary between Upper and Lower Cienega Creek Basins
- Cienega Creek Basin Boundary
- Proposed Rosemont Open Pit
- Projected Extent of Waste Rock
- Projected Extent of Tailings Storage Areas
- Extent of Model Domain

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FIGURE 96
**Cienega Creek Basin Boundary**

**Projected Extent of Tailings Storage Areas**

**Projected Extent of Waste Rock**

**Ephemeral Drainage Channel**

**Observed Perennial Stream Reach**

**Approximate Boundary between Upper and Lower Cienega Creek Basins**

**Lower Cienega Creek Basin**

**Upper Cienega Creek Basin**

**Simulated Flow = 2.04 cfs**

**Simulated Flow = 0.24 cfs**

**Lower Cienega Creek Basin**

**Upper Cienega Creek Basin**

**Simulated Perennial Stream Reach**

**Cienega Creek Basin Boundary**

**Proposed Rosemont Open Pit**

**Projected Extent of Tailings Storage Areas**

**Extent of Model Domain**

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**FIGURE 97**

**EXPLANATION**

**Simulated Streamflow Extent of Model Domain**

**Miles**
FIGURE 99. GRAPH OF SIMULATED VERSUS OBSERVED GROUNDWATER LEVEL ALTITUDES FOR STEADY-STATE CALIBRATION, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 100. SENSITIVITY OF BASE SIMULATION RESIDUAL STANDARD DEVIATION DUE TO VARYING HYDRAULIC CONDUCTIVITY IN BEDROCK (INCLUDING QTg2), STEADY-STATE SIMULATION
FIGURE 101. SENSITIVITY OF BASE SIMULATION RESIDUAL STANDARD DEVIATION DUE TO VARYING HYDRAULIC CONDUCTIVITY IN BASIN-FILL DEPOSITS (EXCLUDING QTg2), STEADY-STATE SIMULATION
FIGURE 102. SENSITIVITY OF BASE SIMULATION RESIDUAL STANDARD DEVIATION DUE TO VARYING RECHARGE, STEADY-STATE SIMULATION
EXPLANATION
- Simulated Extent Drain Cells, 11 years after start of mining
- Simulated Extent Drain Cells, 22 years after start of mining

FIGURE 103. SECTION PROFILE OF SIMULATED DRAINS IN GROUNDWATER FLOW MODEL CELLS FOR 11 AND 22 YEARS AFTER START OF MINING
EXPLANATION

- Formation
- Pit Shell
- Dry Cell
- Simulated Groundwater Discharge Into Pit Void Via Drains
- Drain Cell*

* Drain elevation is specified 10 feet below the cell bottom.

FIGURE 104. CONCEPTUAL VERTICAL SECTION DIAGRAM OF MODEL DRAIN CELLS
FIGURE 105. PROJECTED PIT LAKE SURFACE AREA AND LAKE VOLUME VERSUS LAKE SURFACE ALTITUDE, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Projected Lake Surface Area
- Projected Lake Volume

4,097.4 Feet Above Mean Sea Level
Pit Lake Elevation 1,000 Years After End of Mining
FIGURE 106. GRAPH OF SIMULATED PIT INFLOW RATES DURING MINING OPERATIONS
ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 107

EXPLANATION

- Contour of Projected Groundwater Level Altitude, in feet above mean sea level, 100 foot contour intervals

- Proposed Rosemont Open Pit
- Tailings Impoundment
- Waste Rock Impoundment

Footnotes

1 Bottom of Simulated Pit (Dry)
FIGURE 108. GRAPH OF SIMULATED PIT INFLOW AND OUTFLOW RATES, AND LAKE STAGE AFTER CESSION OF MINING OPERATIONS ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
LOCAL PIT-AREA PROJECTED GROUNDWATER LEVEL ALTITUDES 1,000 YEARS AFTER END OF MINING

EXPLANATION
Contour of Projected Groundwater Level Altitude, in feet above mean sea level
- Projected Pit Lake Extent
- Proposed Rosemont Open Pit
- Tailings Impoundment
- Waste Rock Impoundment

Footnotes
1. Projected Pit Lake Stage, in feet above mean sea level

FIGURE 109
4,097 feet

Hydraulic Sink
Capture Zone Outline

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2010
MONTGOMERY & ASSOCIATES
West Reservoir Consultants
FIGURE 110

PROJECTED GROUNDWATER LEVEL DRAWDOWN AT END OF 22-YEAR MINING OPERATIONS

EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment

Footnotes

1 Maximum Projected Drawdown (at Dry Pit Bottom) from simulated pre-mining groundwater level of 5,106 feet above mean sea level

2010

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Waste Resource Consultants

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Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.
EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment

Footnotes

Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.
Lower Cienega Creek
Canyon
Davidson Creek
Upper Cienega Canyon
Gardner
Santa Rita Mountains
Whetstone Mountains
Greaterville Road
Empire Mountains
Mustang Mountains
1,009 feet
1
10
5
5
10
100
5
10
1
27Aug2010
PROJECTED GROUNDWATER LEVEL DRAWDOWN 1,000 YEARS AFTER THE END OF MINING OPERATIONS

EXPLANATION

Hydrograph Location

Contour of Projected Drawdown, in feet

Ephemeral Drainage Channel

Perennial Stream Reach

Perennial Spring or Seep

Cienega Creek Watershed

Proposed Rosemont Open Pit

Extent of Model Domain

Tailings Impoundment

Waste Rock Impoundment

Footnotes

Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.

FIGURE 113

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FIGURE 114. HYDROGRAPH OF SIMULATED DRAWDOWN AT UPPER CIENEGA CREEK PERENNIAL REACH NEAREST TO ROSEMONT PIT, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 115. HYDROGRAPH OF SIMULATED DRAWDOWN AT DAVIDSON CANYON PERENNIAL REACH NEAREST TO ROSEMONT PIT, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 116. GRAPH OF PROJECTED LAKE STAGE SENSITIVITY AFTER CESSATION OF MINING OPERATIONS
ROSEMONT PROJECT, PIMA COUNTY ARIZONA
EXPLANATION

- Hydrograph Location
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment
- Contour of 5-foot Projected Drawdown, Base Simulation, in feet
- Range of Projected 5-foot Drawdown Contours (excluding Pz increased K simulation)
- Contour of Projected Drawdown for Pz Hydraulic Conductivity increased by 1 magnitude

PROJECTED 5-FOOT GROUNDWATER LEVEL DRAWDOWN AT END OF 22-YEAR MINING OPERATIONS FOR SENSITIVITY SIMULATIONS
PROJECTED GROUNDWATER LEVEL DRAWDOWN 150 YEARS AFTER THE END OF MINING OPERATIONS FOR SENSITIVITY SIMULATIONS

FIGURE 118

EXPLANATION

- Hydrograph Location
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment
- Contour of 5-foot Projected Drawdown, Base Simulation, in feet
- Range of Projected 5-foot Drawdown Contours

Contour of Projected Drawdown for Ksd Hydraulic Conductivity increased by 1 magnitude
Contour of Projected Drawdown for Kv Hydraulic Conductivity increased by 1 magnitude
Contour of Projected Drawdown for Kv Hydraulic Conductivity decreased by 1 magnitude
Contour of Projected Drawdown for Sy (including QTg2) increased by 50 percent

PROJECTED GROUNDWATER LEVEL DRAWDOWN 150 YEARS AFTER THE END OF MINING OPERATIONS FOR SENSITIVITY SIMULATIONS

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Contour of 5-foot Projected Drawdown, Base Simulation, in feet

Lower Cienega Creek

Upper Cienega Canyon

Davidson Creek

Canyon

Cienega Creek

Gardner Creek

Santa Rita Mountains

Whetstone Mountains

Greaterville Road

Empire Mountains

Mustang Mountains

MC-1

Spring 10

Spring 83

Spring 82

Spring 83

Santa Rita Road

Sahuarita Road

Houghton Road

Vail

Elgin

Sonoita

Corona Del Tucson

Helvetia Spring

Questa Spring

Kane Spring

Rosemont Spring

Greaterville Road

Helvetia Springs

Cienega Creek Watershed

Perennial Spring or Seep

Ephemeral Drainage Channel

Perennial Stream Reach

Hydrograph Location

Extent of Model Domain

Tailings Impoundment

Waste Rock Impoundment

Contour of 5-foot Projected Drawdown, Base Simulation, in feet

Range of Projected 5-foot Drawdown Contours

FIGURE 119

EXPLANATION

0 1 2 3 4
Miles

Miles

PROJECTED 5-FOOT GROUNDWATER LEVEL DRAWDOWN 1,000 YEARS AFTER THE END OF MINING OPERATIONS FOR SENSITIVITY SIMULATIONS

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