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1.0 INTRODUCTION

The Rosemont Copper Project (Project) site is located in the Santa Rita Mountains southeast of Tucson. Peaks in the Santa Rita Mountains are over 6,000 feet above mean sea level (amsl) and the topography drops into the Cienega Creek and Davidson Canyon watersheds to the east and northeast. The elevation at the confluence of Davidson Canyon and Cienega Creek is 3,325 feet amsl. The proposed Rosemont Open Pit and the other main Project facilities are located in the upper Davidson Canyon watershed (Figure 1). The western flank of the Empire Mountains also drains into Davidson Canyon.

A reach of lower Davidson Canyon from an unnamed spring (referred to here as the Reach 2 Spring) to the confluence with Cienega Creek has been designated as an Outstanding Arizona Water (OAW; Figure 1). This designation provides a level of protection to assure the outstanding waters will not be degraded (PAG, 2005). Mining and other development activities, including the Rosemont Project, have been proposed or are currently in operation within the Davidson Canyon Watershed. Agriculture, ranching, domestic homes, and recreation are currently active land uses within the watershed. The current and future land uses may alter the groundwater quantity and quality in Davidson Canyon.

2.0 PURPOSE AND SCOPE

The purpose of this Davidson Canyon Conceptual Groundwater Monitoring Plan (Plan) is to recommend additional monitoring locations and data collection that can be used to assist in predicting and evaluating potential future groundwater quantity and quality changes to Davidson Canyon. Potential impacts include water-quality and water-level changes that could alter riparian vegetation and spring flow. This Plan recommends data collection that is intended to confirm and increase the current understanding of the natural hydrogeologic processes that contribute to groundwater and surface water interactions and watershed health.

Davidson Canyon’s overall watershed health may depend to some degree on groundwater conditions. Riparian vegetation is important for several reasons, including maintaining bank stability and erosion control during storm-water runoff events. Storm-water infiltration into alluvial channel deposits is a source of water for vegetation. However, vegetation may also be supported to some degree by shallow groundwater. Interactions and changes in these water sources could potentially impact vegetation, spring flow, duration of ephemeral surface-water flows, and watershed health.

Baseline groundwater-level and groundwater-quality data are currently being collected by Rosemont in the Project area and by other entities (e.g. Pima Association of Governments (PAG) and Arizona Department of Environmental Quality (ADEQ)) in lower Davidson Canyon and in the Cienega Creek Natural Preserve. As required by the Aquifer Protection Permit (APP) program managed by the ADEQ, groundwater data will also be collected at point of compliance (POC) wells located along the periphery of project facilities.
The scope of this Plan is to provide additional, complementary hydrogeologic data in the Davidson Canyon watershed. Meteorological data are currently being collected by Rosemont near the proposed pit area and by various weather stations in the region. Additional meteorological data will not be collected as part of this Plan.

3.0 HYDROGEOLOGY

The bedrock forming the Santa Rita Mountains consists of a metamorphic core flanked by a metamorphic shell of Paleozoic and Mesozoic-aged sedimentary rock including carbonates, shales, and limestones (Wardrop, 2005). These and similar rocks across the watershed are collectively termed bedrock. Permeability in the bedrock is primarily due to secondary fractures since the bulk rock is typically metamorphosed or highly consolidated with minimal storage and permeability. This bedrock is typically covered by basin-fill deposits, recent alluvium, and unconsolidated deposits in the low lying storm-water drainage channels. These surficial deposits typically have higher storage and permeability with the capacity to transmit more water than the underlying bedrock (Tetra Tech, 2010a).

The bedrock topographic highs define the watershed boundary for Davidson Canyon (Figure 1). Due to the generally low permeability of the bedrock, and the focusing of water toward the interior of the watershed, it is assumed that the groundwater sub-basin follows the watershed boundary. Although groundwater inflows to the sub-basin are not believed to be occurring in significant amounts, there could be inflows in the upper-most reaches where the divides are less pronounced. Groundwater observed in Davidson Canyon is predominately the result of recharge occurring within the watershed (Tetra Tech, 2010a).

The configuration and properties of the bedrock and basin-fill deposits leads to a groundwater system with two (2) primary flow components. The bedrock forms a deeper flow system with limited storage and groundwater flows primarily through fractures. The basin-fill deposits form spatially limited, shallow flow systems with greater storage (per unit volume), and groundwater flow is primarily occurring through the unconsolidated sediments.

The Davidson Canyon fault zone consists of a western fault that is concealed by alluvium and an eastern fault that is partially exposed in the northern piedmont of the Empire Mountains (Ferguson and others, 2001). These faults are poorly understood (Ferguson and others, 2001), but their importance to groundwater flow has been demonstrated from groundwater flow modeling (Tetra Tech, 2010b; M&A, 2010). Water-level contours indicate that groundwater flow is focused toward the Davidson Canyon surface water drainage (M&A, 2010). The orientation of the Davidson Canyon fault zone is likely to be roughly parallel to the groundwater flow direction, suggesting that there is some degree of enhanced flow in the fault zone. The width of an enhanced flow zone due to faulting cannot be accurately determined based on the available information. Observed water levels suggest that the fault zone is permeable, is near the alluvial stream channel, and extends from near the confluence of Barrel and Davidson Canyons to the
confluence of Davidson Canyon and Cienega Creek. A permeable fault zone would tend to focus bedrock groundwater flow towards the Davidson Canyon alluvial stream channel area.

Numerous quartz-porphyry dikes have formed in the Empire Mountains (Ferguson, 2009) and Mount Fagan areas (Ferguson et. al., 2001). There is the potential that these dikes may create barriers to groundwater flow due to their low permeability, relatively young geologic age that bisects older rocks, orientation transverse to flow, and the tendency to seal fractures in the surrounding bedrock. One of the longest, thickest, and most continuous dikes perpendicularly intersects Davidson Canyon downstream of the confluence with Barrel Canyon (Figure 1).

The regional groundwater flow system has been numerically modeled by Tetra Tech (2010b) and by Montgomery & Associates (2010). These groundwater flow models incorporated different conceptual models for Davidson Canyon. Tetra Tech (2010b) simulated the low-permeability dike and did not simulate a high-permeability fault zone. M&A (2010) did not simulate the dike, but did simulate the fault as a higher permeability zone. These different conceptual and numerical models demonstrated the influence of the dike and fault on the groundwater flow and predicted drawdown. These models predict that the leading edge of drawdown in Davidson Canyon will become focused near the dike in the alluvial stream channel. A low permeability dike would impede drawdown propagation into the lower reaches of Davidson Canyon, while a higher permeability fault zone would tend to allow drawdown propagation into the lower reaches.

4.0 CONCEPTUAL MODEL

Monitoring locations and data collection in this recommended Plan are guided by the conceptual model of groundwater recharge, occurrence, and flow in Davidson Canyon. Implementation of this Plan will confirm and update the conceptual model and the understanding of the groundwater flow system.

Nearly the entire length of Davidson Canyon consists of a variable width, alluvium-filled channel bounded by bedrock. In the OAW reach, steeply dipping geologic units, faulting, and other structures control the alluvium-bedrock channel geometry. Shallow depth to bedrock, infiltrating storm water, and narrowing of the channel likely causes groundwater levels to rise in the vicinity of the Reach 2 Spring. When the groundwater levels rise high enough to intersect the land surface, spring discharge results. In relatively wet periods and after storm-water runoff, flow may be occurring in the alluvium when no spring discharge and no surface flow are evident. This flow may be shallow groundwater, storm-water infiltration, water perched in the alluvium, or a mix of all. The subsurface bedrock geometry and topography largely determines where groundwater discharges, how far surface water flow is maintained, and the water volume stored in the alluvium. A schematic of how ephemeral and perennial springs occur due to storm-water infiltration and deep groundwater flow paths is presented in Figure 2.
In the upper reaches of Davidson Canyon, near the Rosemont Project area, the regional groundwater table is typically 20 feet to over 100 feet below the ground surface (bgs). The shallowest depth-to-water (DTW) tends to occur in the alluvial drainages. Water levels in the Project area typically, but not always, indicate downward gradients, which suggest that this is a recharge area. Recharge can occur due to precipitation infiltrating through the fractured bedrock to the saturated zone and also due to storm-water flow infiltrating into the stream channel deposits and ultimately reaching the underlying bedrock groundwater system. Stream-channel recharge is likely occurring through the alluvium that is present along the entire Davidson Canyon reach and its tributaries.

4.1 Hydraulic Connection

It is commonly understood and accepted that the bedrock permeability and storage in the Project area and in most of the region is due to fractures. A point of contention, however, is the degree of hydraulic connection between these fractures and the spatial extent of this connection. This is an important issue since the degree of hydraulic connection between the proposed Open Pit and down-gradient ecologically sensitive areas will determine the long-term groundwater inflow to the pit, the magnitude and timing of groundwater drawdown, and the hydrogeology related environmental impacts. Drawdown will preferentially propagate to areas with higher fracture permeability when there is a hydraulic connection over long distances. Conversely, if the hydraulic connection is limited in spatial extent, drawdown propagation will be limited, regardless of the permeability in disconnected fractures.

Large hydraulic gradients occur in areas with low permeability and gradients tend to decrease in areas with higher permeability. Measured water levels in the region are highest in the high elevation Project area and water levels decrease with decreasing elevation. Consistent with these water-level conditions is the presence of large hydraulic gradients in the Project area. Conversely, gradients in the lower reaches of Davidson Canyon are much smaller and indicate higher permeability.

Numerous 12- and 24-hour single well tests and a 30-day hydraulic test with five (5) pumping wells have been conducted by Montgomery & Associates (2009). The results indicated that there are zones within select wells that are permeable and capable of producing water. A 2-foot Water-level drawdown response to pumping was observed between wells PC-5 and PC-7, which are 3,541 feet apart in the proposed pit area. This was the greatest distance between a pumped well and an observed response in the 30-day test. The Flat Fault is a low angle fault that has been observed in several wells in the proposed pit area. This fault was interpreted as being the structure responsible for the hydraulic connection between PC-5 and PC-7 (M&A, 2010).

The permeability in several wells was quite low resulting in minimal groundwater flow to the well. This suggests that a limited set of fractures are hydraulically connected and this connection does not extend over large distances due to these low permeability zones. Groundwater flow to
wells and the Open Pit will be predominately from fracture storage. As long-term pumping depletes the water stored in the fractures, flow to wells and the Open Pit will be controlled by the matrix material.

Hydraulic connection in the Project area is therefore considered to exist at a scale of less than 5,000 feet. At a scale of 10 to 100’s of feet, it is possible to have hydraulic connections between permeable fractures. Poor hydraulic connection over 1,000’s to 10,000’s of feet would result in limited drawdown propagation away from Project area.

The hydraulic gradients within Davidson Canyon suggest that the fault zone has enhanced permeability. Numerical groundwater flow modeling by M&A (2010) achieved good water-level matches below the Barrel Canyon confluence with Davidson Canyon, simulating the fault is a higher-permeability zone. The question is whether this higher-permeability zone is hydraulically connected to the Project area. The high water levels and large hydraulic gradients suggest that the hydraulic connection is limited. Hydraulically connected fractures that allow groundwater flow over long distances would result in high discharge springs in lower Davidson Canyon. This hydraulic connection would tend to drain water from the Project area. The absence of large perennial springs in Davidson Canyon suggests that there is a limited hydraulic connection with the Project area. Additionally, low precipitation and low recharge rates in the Project area would not be able to sustain the high observed water levels if a good hydraulic connection existed.

The Davidson Canyon Dike (DC Dike) is an extensive, cross-cutting geologic feature with low permeability that may be limiting the hydraulic connection between Davidson Canyon and the Project area. The Tetra Tech (2010b) groundwater flow model simulated the low-permeability dike, while the M&A (2010) model did not. These different conceptual and numerical models demonstrated the influence of the dike on the groundwater flow. Even though there are insufficient water-level and hydraulic-test data in close proximity to the DC Dike to conclusively support or disprove its hydraulic properties and its impact on the flow system, the DC Dike’s low permeability, relatively young geologic age (i.e. it bisects older rocks), orientation transverse to flow, thickness, and its tendency to seal fractures in the surrounding bedrock suggest that it restricts groundwater flow to some degree.

Based on the above evidence, the current conceptual model concludes that fractures are not hydraulically connected over large distances in the Project area. If there was a good hydraulic connection between the pit area and the confluence of Barrel and Davidson Canyons, water levels would be lower, gradients smaller, and significant spring flows would be observed in the lower reaches.

4.2 Groundwater Flow Paths

Conceptually there are three primary flow paths (deep, shallow, and alluvial stream channel) in the Davidson Canyon groundwater flow system (Figure 2). Deep flow paths likely originate in high-elevation, bedrock recharge areas in the Santa Rita Mountains. Infiltrating precipitation that
reaches the saturated bedrock flows through fractures and fault zones. These waters tend to obtain geochemical characteristics that reflect water-rock interactions, long resident times, and long flow paths. Water being recharged at high elevation and in mineralized rocks also tends to obtain unique isotopic signatures compared to water recharged at low elevations and in non-mineralized rocks. Groundwater that circulates at greater depths also tends to be at higher temperature due to natural geothermal gradients.

Shallow groundwater flow paths tend to be shorter and can occur at any elevation. Precipitation infiltrating through bedrock or alluvium can reach the water table and then flows down gradient. If these waters stay near the water table they are considered to have shallow flow paths. These shallow flow paths can result in groundwater discharging at the ground surface, particularly in areas with steep topography (Figure 2). The water may also intersect alluvial filled stream channels that are incised into the bedrock, where the water may or may not discharge at the surface. Shorter flow paths, less residence time, and less water-rock interaction can result in different chemical constituent concentrations than water with deep flow paths.

Stream channel flow paths occur when storm-water runoff infiltrates into the alluvium. The magnitude, intensity, and duration of precipitation and runoff determine how deep the water infiltrates. The water may completely or partially saturate the alluvium and it will flow down gradient in the subsurface or discharge at the surface in the form of a spring. Low permeability bedrock obstructions and constrictions in the alluvium can contribute to forcing the groundwater to the surface (Figure 2). This water would tend to have the shortest residence time and shortest flow paths.

The deep, shallow, and stream-channel flow paths can have distinct geochemical properties. However, in practice these flow paths likely mix, which may reduce the distinction between the flow paths and water sources. A high degree of mixing can complicate the data interpretation. Deep and shallow groundwater that have mixed, however, are still likely to have different geochemical signatures than storm-water infiltration.

4.3 Groundwater and Surface-Water Interactions

Groundwater and surface-water interactions occur in alluvial stream channels where groundwater comes in contact with surface water, which in Davidson Canyon is the result of storm-water runoff. Streams either gain water from inflow of groundwater (gaining stream; Figure 3A) or lose water by outflow to groundwater (losing stream; Figure 3B). Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure 3B) or can be disconnected from the groundwater system by an unsaturated zone (Figure 3C). An important feature of streams that are disconnected from groundwater is that groundwater pumping does not affect the flow of the stream (Winter and others, 1998). The connection between storm-water runoff and groundwater can also vary on a seasonal or annual basis depending on the overall climatic conditions.
At lower elevations in Davidson Canyon, the DTW in the alluvial stream channels is relatively shallow and larger magnitude storm-water flow is possible due to the majority of the watershed being up gradient. These conditions are the most favorable for groundwater and surface-water interactions. DTW has been persistently 7 to 15 feet below the stream channel in the OAW Reach (Figure 4) based on the Pima County well ((D-16-17)31dcb, Figure 8). Persistent DTW below the stream channel bottom, combined with ephemeral, short duration, low discharge, and limited surface-length expression of spring flow, indicates that the groundwater system is usually disconnected from the surface-water system.

A temporary connection between the groundwater and surface-water systems is possible during wet periods and long duration storm-water runoff events. Large volumes of infiltrating storm-water runoff can saturate the alluvium and connect to the shallow groundwater. Groundwater-levels that ultimately rise to the surface are expressed as spring discharge after the storm-water flow event has ended. Bedrock constrictions in the alluvial channels create the most favorable conditions for forcing this shallow, alluvial channel groundwater to the surface (Figure 2). The Reach 2 Spring and Escondido Spring in lower Davidson Canyon are examples of this type of disconnected groundwater and surface-water interaction with an occasional, temporary connection.

The Project area will result in a reduction in the Davidson Canyon watershed that contributes storm-water flow the OAW Reach. This decrease in watershed area is expected to reduce peak storm-water runoff to some degree. Infiltration estimates in Rillito Creek, a broad ephemeral alluvial channel in nearby Tucson, Arizona, indicated that the majority of infiltration occurred during long-duration, multiple day storm-water runoff events (Hoffmann and others, 2007). Infiltration in Davidson Canyon is also expected to depend largely on the duration of storm-water runoff and not the peak flow.

### 4.4 Potential Impacts

The Rosemont Project’s potential groundwater impacts to Davidson Canyon’s watershed health are largely related to water-level declines impacting vegetation and spring flow. These impacts depend on the hydraulic connection in the fractured rock, flow paths, and groundwater and surface-water interactions.

Existing geologic, groundwater-level, water-quality, and spring-flow data indicate that potential impacts to the OAW Reach will be limited. The hydraulic connection between the Open Pit and Davidson Canyon is limited by low permeability bedrock, disconnected fractures, and the DC Dike. Groundwater is disconnected from the alluvial stream channel and short-duration, temporary connections between groundwater and storm-water runoff may occur during infrequent, extended wet periods.

Vegetation and spring flow are most dependent on storm-water infiltration and groundwater storage within the alluvial channel sediments. The limited groundwater-level drawdown due to
the Project and a reduction in peak storm-water runoff due to the decrease in contributing watershed area are not expected to significantly impact the volume of water stored in the alluvium. Project impacts will likely be indistinguishable from groundwater level and storm-water runoff variation due to natural climate changes.

5.0 CONCEPTUAL GROUNDWATER MONITORING PLAN

This recommended Conceptual Groundwater Monitoring Plan has been developed based on the observed hydrogeologic conditions and the resulting Davidson Canyon conceptual model. The data collected will validate, disprove, or result in modifications to the conceptual model. Prediction of impacts to the watershed health and mitigation measures will be improved as data are collected and analyzed.

Land ownership within the Davidson Canyon watershed consists of Arizona State Trust, Bureau of Land Management (BLM), Pima County, U.S. Forest Service, and private. All proposed field activities are on public land (State Trust, Pima County, and U.S. Forest Service). No privately owned land will be accessed during implementation of this recommended Plan. Existing roads and stream channels can be used to access the proposed monitoring locations.

5.1 Groundwater Monitoring Approach

The monitoring approach is designed to define groundwater flow paths, the nature of groundwater and surface-water interactions, and infiltration from storm-water runoff into the stream-channel alluvium. Groundwater conditions in the alluvial stream channel and the underlying bedrock, which are the two main groundwater system components (bedrock and alluvium) are recommended for monitoring. Distinguishing flow paths and natural processes, including groundwater mixing between the various flow paths, are anticipated to require multiple data types and several locations. Water levels, water quality, environmental isotopes, and subsurface temperature data are recommended to provide multiple lines of evidence to support conclusions.

Water-quality parameters proposed in this Plan are consistent with those currently used for storm-water monitoring (Water and Earth, 2012) and also for the draft APP program, with the exception of total concentrations being obtained for storm water. Environmental tracers (stable isotopes) will be analyzed to provide information on the source and age of the groundwater.

5.2 Monitoring Locations

Desirable monitoring locations provide data that are representative of flow paths, mixing zones, or aid in understanding natural features that will influence impacts and mitigation measures. Monitoring locations have therefore been selected along the following groundwater flow paths (Figure 5):

- Barrel Canyon down gradient of Project area
• Upper Davidson Canyon (above the confluence with Barrel Canyon)
• Davidson Canyon below confluence with Barrel Canyon
• Near the Reach 2 Spring
• Near the Davidson Canyon and Cienega Creek confluence

Important hydrogeologic features being monitored include the following:

• Davidson Canyon Dike
• Davidson Canyon Fault Zone
• Deep bedrock flow paths
• Shallow bedrock flow paths
• Alluvial stream-channel infiltration
• Groundwater conditions at surface-water monitoring locations

Co-locating groundwater and surface-water monitoring locations allows direct comparison of water quality and correlation of storm-water flows with groundwater levels, subsurface temperature profiles, and infiltration. Alluvial wells and temperature sensors are anticipated to be located in the active stream channel with bedrock wells located nearby, but out of the active channel. The wells and surface-water monitoring locations will be in close enough proximity so they can share instrumentation enclosures, data loggers, solar panels, data transmission, etc.

The following subsections describe each recommended monitoring location. Specific data collected at each location are discussed in subsequent sections. A summary of monitoring locations is provided in Table 1 and illustrated on Figure 6, Figure 7, and Figure 8.
Table 1. Summary of Recommended Monitoring Locations for the Davidson Canyon Conceptual Groundwater Monitoring Plan

<table>
<thead>
<tr>
<th>Location</th>
<th>Well Name</th>
<th>Monitored Condition</th>
<th>Well Depth (feet)</th>
<th>Status</th>
<th>Land Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemont Weather Station</td>
<td>--</td>
<td>Precipitation</td>
<td>--</td>
<td>--</td>
<td>Rosemont</td>
</tr>
<tr>
<td>Barrel Canyon</td>
<td>RP-2A¹</td>
<td>Recent alluvium: Groundwater</td>
<td>30</td>
<td>Existing</td>
<td>U.S. Forest Service</td>
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<td></td>
<td>RP-2B¹</td>
<td>Bedrock: Shallow groundwater</td>
<td>200</td>
<td>Existing</td>
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<td>Existing</td>
<td>U.S. Forest Service</td>
</tr>
<tr>
<td></td>
<td>BC-1A-GW¹,²</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>&lt;50</td>
<td>New</td>
<td>U.S. Forest Service</td>
</tr>
<tr>
<td></td>
<td>BC-1B-GW¹,²</td>
<td>Bedrock: Shallow groundwater</td>
<td>100-150</td>
<td>New</td>
<td>U.S. Forest Service</td>
</tr>
<tr>
<td>Upper Davidson Canyon</td>
<td>DC-1A-GW¹,²</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>&lt;50</td>
<td>New</td>
<td>AZ State Land Dept.</td>
</tr>
<tr>
<td></td>
<td>DC-1B-GW¹,²</td>
<td>Bedrock: Shallow groundwater</td>
<td>100-150</td>
<td>New</td>
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<tr>
<td></td>
<td>RP-9</td>
<td>Bedrock: Deep groundwater</td>
<td>250</td>
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<tr>
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<td>New</td>
<td>AZ State Land Dept.</td>
</tr>
<tr>
<td></td>
<td>DC-2B-GW¹,²</td>
<td>Bedrock: Shallow groundwater</td>
<td>100-150</td>
<td>New</td>
<td>AZ State Land Dept.</td>
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<tr>
<td>Davidson Canyon Dike (DC Dike)</td>
<td>DC-Dike-A-GW²</td>
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</tr>
<tr>
<td></td>
<td>DC-Dike-B-GW²</td>
<td>Bedrock: Shallow groundwater</td>
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</tr>
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<td>OAW Reach</td>
<td>DC-3A-GW¹,²</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
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<td>New</td>
<td>Pima County</td>
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<tr>
<td></td>
<td>DC-3B-GW¹,²</td>
<td>Bedrock: Shallow groundwater</td>
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<td>New</td>
<td>Pima County</td>
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<td></td>
<td>DC-4A-GW¹,²</td>
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<td>New</td>
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<td></td>
<td>DC-4B-GW¹,²</td>
<td>Bedrock: Shallow groundwater</td>
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<td>(D-16-17)31dcb²</td>
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<td>Bedrock: Deep groundwater</td>
<td>495</td>
<td>Existing</td>
<td>Pima County</td>
</tr>
</tbody>
</table>
Table 1. Summary of Recommended Monitoring Locations for the Davidson Canyon Conceptual Groundwater Monitoring Plan - CONTINUED

<table>
<thead>
<tr>
<th>Location</th>
<th>Well Name</th>
<th>Monitored Condition</th>
<th>Well Depth (feet)</th>
<th>Status</th>
<th>Land Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAW Reach</td>
<td>CC-1A- GW&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>&lt;50</td>
<td>New</td>
<td>Pima County</td>
</tr>
<tr>
<td></td>
<td>CC-1B- GW&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>Bedrock: Shallow groundwater</td>
<td>100-150</td>
<td>New</td>
<td>Pima County</td>
</tr>
<tr>
<td></td>
<td>CC-2A- GW&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>&lt;50</td>
<td>New</td>
<td>Pima County</td>
</tr>
<tr>
<td></td>
<td>CC-2B- GW&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>Bedrock: Shallow groundwater</td>
<td>100-150</td>
<td>New</td>
<td>Pima County</td>
</tr>
</tbody>
</table>

<sup>1</sup>This well is co-located or in close proximity to a proposed surface-water monitoring location (Water and Earth, 2012)

<sup>2</sup>Use and installation of this well requires permission from the land owner
5.2.1 Barrel Canyon

Existing wells RP-2A, RP-2B, and RP-2C are located in Barrel Canyon near the proposed Project facilities (Figure 6). RP-2A monitors the recent stream-channel alluvium and RP-2B and RP-2C monitor the bedrock at different depths. The three depth levels in RP-2A, RP-2B, and RP-2C allow characterization of alluvial groundwater, shallow bedrock water, and deeper bedrock water in the Project area. These groundwater sources may or may not be reaching the Reach 2 Spring and lower Davidson Canyon. Recharge in the upper most part of the groundwater system is likely represented by these waters. Similarities and differences in water quality and stable isotopes will provide information on groundwater mixing and the nature of groundwater flow paths from the Project area to the lower reaches of Davidson Canyon.

The existing RP-2 well cluster is currently being monitored for water levels and water quality in Rosemont’s routine monitoring network. Additional water quality and environmental isotope data are recommended to be collected in these wells as part of this plan.

An alluvial channel well (BC-1A-GW) and a shallow bedrock groundwater (BC-1B-GW) well are recommended for installation in the stream channel in close proximity to surface-water monitoring location BC-1-SW (Figure 6) as proposed in the surface-water monitoring plan (Water and Earth, 2012). These wells will allow direct correlation with the storm-water monitoring data.

The Barrel Canyon monitoring locations provide data immediately below the Project facilities and represents Barrel Canyon’s groundwater contribution to Davidson Canyon so that flow paths to down-gradient areas can be determined. Groundwater and surface-water interactions can also be monitored at this higher elevation.

5.2.2 Upper Davidson Canyon

The contribution of upper Davidson Canyon to the lower reaches can be determined by monitoring water levels, water quality, and isotopes up gradient of the confluence with Barrel Canyon. The recommended groundwater monitoring locations, DC-1A-GW and DC-1B-GW, are co-located with surface-water monitoring location DC-1-SW (Figure 7). A shallow, alluvial well and a well completed in bedrock are recommended near DC-1-SW. The exact location of DC-1-SW is not yet decided. Two locations are proposed in the surface-water monitoring plan (Water and Earth, 2012) (DC-1-SW and DC-1-SW alt, Figure 7). It is also recommended that deep groundwater conditions in upper Davidson Canyon be monitored in existing well RP-9 (Figure 1).

Existing well (D-18-16)14ddd is a potential location for shallow groundwater monitoring (Figure 7). This well is 115 feet deep, likely completed in bedrock, and potentially monitors shallow groundwater conditions. Well (D-18-16)14ddd is located on land controlled by the Arizona State Land Department and use of this well would require cooperation from this agency.
5.2.3 **Davidson Canyon Dike**

The recommended monitoring locations in the DC Dike area are illustrated on Figure 7. An alluvial well and a bedrock well are proposed immediately upstream of the mapped dike. The intent of this monitoring location is to determine the hydraulic significance of the DC Dike and the chemical characteristics of the groundwater. The dike is expected to limit groundwater flow and there is the potential for it to limit drawdown propagation into lower Davidson Canyon. Conversely, if this is a zone of higher permeability due to the fault zone then there is the potential for drawdown to be focused in this area. Since this location is potentially important as an early indicator of drawdown propagation, collecting background water-level data will define the range of natural fluctuations under the observed climate and storm-water runoff conditions.

Horizontal hydraulic gradients between the DC Dike area and recommended up gradient monitoring wells DC-2A and DC-2B will also provide information on whether the dike is a barrier to groundwater flow. A decrease in hydraulic gradient would occur up gradient from the dike if it restricts groundwater flow.

This location is down gradient of the confluence of Barrel and Davidson Canyons and groundwater represents a mixture of these flow paths. This may also be a potential mixing zone for storm-water infiltration with shallow and deep groundwater. Water chemistry and isotopic contributions to the lower reaches are recommended to be monitored at this location.

5.2.4 **OAW Reach**

The recommended monitoring well locations in the OAW Reach are illustrated on Figure 8. One shallow alluvial well and one bedrock well are recommended at both the upstream (DC-3A-GW and DC-3B-GW) and downstream (DC-4A-GW and DC-4B-GW) ends of the Davidson Canyon Wash OAW reach. One shallow alluvial well and one bedrock well are recommended upstream (CC-1A-GW and CC-1B-GW) and downstream (CC-2A-GW and CC-2B-GW) of the confluence of Cienega Creek and Davidson Canyon Wash. Locations of the wells within or in close proximity to the channel will be determined in the field and in consultation with PAG.

In Davidson Canyon Wash, the recommended upstream wells will be in close proximity to the Reach 2 Spring, which is surface-water monitoring location DC-3-SW (Water and Earth, 2012). Storm-water runoff and Reach 2 Spring interactions with alluvial and shallow groundwater will be monitored. The recommended downstream wells will assist in determining the groundwater flow and water-chemistry contribution of Davidson Canyon to Cienega Creek.

Existing bedrock well (D-17-17)06bdc is located within the PAG OAW designated parcel and is reported to be 495 feet deep. This well likely monitors the deep groundwater conditions in lower Davidson Canyon (Figure 8). The monitored depth interval in (D-17-17)06bdc is comparable to RP-2C. If a deep groundwater flow path exists between the Project area and the lower reaches it can potentially be identified using these two (2) well sites. The functionality of well (D-17-17)06bdc and access permission needs to be determined.
Existing alluvial well (D-16-17)31dcf is located within the OAW Reach (Figure 8). This well monitors the shallow alluvial groundwater conditions in lower Davidson Canyon and historical water level data are available. Continued and more frequent monitoring at this location will be beneficial. Permission to access this well site will need to be obtained.

In Cienega Creek, the recommended wells upstream of the confluence with Davidson Canyon Wash will be in close proximity to surface-water monitoring location CC-1-SW (Figure 8); the recommended wells downstream of the confluence will be in close proximity to surface-water monitoring location CC-2-SW (Water and Earth, 2012). The purpose of these wells is to determine the contribution of Cienega Creek and Davidson Canyon Wash to the combined channel downstream of the confluence.

5.3 Water-level Monitoring

Water levels will be monitored in wells completed in the stream-channel alluvium and in wells completed in the underlying bedrock. These data will provide information on the vertical and horizontal hydraulic gradients, hydraulic connection between the alluvium and bedrock, stream-channel recharge, and groundwater and surface-water interactions. These wells will also provide a baseline for the natural water-level fluctuations that are presently occurring under pre-mining conditions.

Rosemont has been monitoring wells and springs in the Project area since 2007 (M&A, 2009). Point of Compliance (POC) wells have been proposed by Rosemont in their Draft Aquifer Protection Permit (APP) application (NO. P-106100; ADEQ, 2012). The POC wells will monitor water levels and water quality near the Project facilities. Additional wells are proposed herein to augment existing wells, the proposed POC wells, and to monitor specific conditions within Davidson Canyon.

New wells installed in the Davidson Canyon stream channel alluvium are intended to monitor the short-term water-level fluctuations due to storm-water runoff events. Capturing groundwater and surface-water interactions and fluctuations will require wells equipped with pressure transducers. Transducers can measure water levels at high frequencies, but an hourly frequency is initially anticipated. When the timing of groundwater responses to storm-water events is adequately understood, the monitoring frequency at these wells could then be modified.

New bedrock wells are recommended in close proximity to the stream channel alluvial wells. The bedrock wells are intended to monitor the shallow groundwater that may be in contact, persistently or intermittently, with the stream-channel alluvium and storm-water flow. Consistent water-levels and fluctuations between the bedrock and alluvial wells will indicate a hydraulic connection. Transducers are recommended for monitoring water levels in the bedrock wells.

Existing, deeper bedrock wells are also recommended for monitoring. These wells are intended to provide information on the deeper flow paths and the vertical and horizontal hydraulic
gradients. Upward gradients indicate that deeper groundwater is potentially a source for shallow groundwater, spring discharge, and surface-water flow. Downward gradients may suggest that the storm-water runoff is recharging the groundwater system.

Alluvial, stream-channel wells are likely to be less than 50 feet deep and bedrock wells will likely be 100 to 150 feet deep depending on their location (Figure 9). Depth-to-bedrock, however, is likely highly variable and exact well depths will be determined in the field. Alluvial wells will be completed with screens immediately above the bedrock contact. Bedrock wells will penetrate into competent bedrock until groundwater producing fractures are encountered. A schematic cross-sectional diagram of the well completions within the stream channel is provided in Figure 9. Bedrock wells are recommended to be 4-inch diameter PVC to allow for future aquifer testing if needed (Figure 9). Alluvial monitoring wells are recommended to be 4-inch diameter PVC, but deeper water levels may require larger diameters to facilitate water-quality sampling (Figure 11).

Monitoring well locations are illustrated on Figure 1, Figure 6, Figure 7, and Figure 8, and summarized in Table 1. Existing wells and recommended new wells on land owned by the Arizona State Land Department, Pima County, and the U.S. Forest Service will require access permission. Submersible pressure transducers measured at an hourly frequency are the recommended monitoring method for water level and water temperature. If water levels in the deeper wells do not respond to seasonal changes and have minimal variation then monthly monitoring with manual methods should be evaluated.

Groundwater monitoring will share shelters and instrumentation with the surface-water monitoring plan locations (Water and Earth, 2012). An example structure for the combined surface and groundwater monitoring instrumentation is illustrated on Figure 12.
5.4 Water-Quality Monitoring

Water quality is recommended to be monitored in the wells identified in Table 2. These data will provide information on the water source, flow paths, hydraulic connection between the alluvium and bedrock, stream-channel recharge, and groundwater and surface-water interactions. Generally, waters with similar solute concentrations and ratios of concentrations likely originated in the same area and/or travel along similar flow paths. Conversely, waters with different solute concentrations likely did not originate in the same area, travel along the same flow paths, or have mixed with other waters. In this way, water-quality analyses can be used to identify similar waters and flow paths.

Water-quality monitoring parameters and detection limits in the proposed wells are recommended to be consistent with the full-suite of APP monitoring. This list of constituents is consistent with the surface-water monitoring plan with the exception of total recoverable concentrations are included in the surface-water suite (Water and Earth, 2012). Based on the initial water-quality results, the frequency of analysis and number of constituents may be reduced. Analytical tests, detection limits, and methods provided in Table 2 are subject to change if regulatory, water-quality, or laboratory conditions change.

APP parameters are provided in Table 3 for comparison. PAG monitoring in Davidson Canyon and Cienega Creek includes a very similar list of parameters. A complete analysis of samples should be performed in the initial stages of monitoring to provide a complete picture of background conditions.

Samples will be collected and analyzed quarterly for two years. The purpose of the quarterly sampling is to determine background conditions, and to determine which constituents are changing with time. It may also be advantageous to simultaneously collect groundwater and surface-water samples during longer duration storm-water flow events. The logistics and feasibility of simultaneous sampling can be further evaluated when sampling locations and instrumentation are finalized.

The water-quality constituents in Table 2 go beyond the APP constituent list and are consistent with the Davidson Canyon Surface-Water Monitoring Plan (Water and Earth, 2012). Non-detect and low concentration constituents may be removed from the analytical list after the initial sampling results have been evaluated. After the two year background period, the list of constituents will again be reviewed to determine if some constituents can be removed from the list, including a review of the monitoring frequency.
Table 2. Proposed Constituent List for Groundwater Measurement and Analysis

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Detection Limit Required</th>
<th>EPA Method for Analysis accepted by ADEQ (2004, appendix C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Measurements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth-to-Water</td>
<td>0.01 feet</td>
<td>--</td>
</tr>
<tr>
<td>Water-level Elevation</td>
<td>0.1 feet amsl</td>
<td>--</td>
</tr>
<tr>
<td>Field Water Temperature</td>
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<td>--</td>
</tr>
<tr>
<td>Field Specific Conductance</td>
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<td>--</td>
</tr>
<tr>
<td>Field pH</td>
<td>0.1 units</td>
<td>--</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>0.1 mg/L</td>
<td>--</td>
</tr>
<tr>
<td>Oxidation-Reduction Potential (ORP or Eh)</td>
<td>1 mV</td>
<td>--</td>
</tr>
<tr>
<td><strong>Laboratory Analysis</strong></td>
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<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.1 units</td>
<td>--</td>
</tr>
<tr>
<td>Specific conductance at 25 C</td>
<td>1 uS/cm</td>
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<tr>
<td>Hardness as CaCO₃</td>
<td>1 mg/L</td>
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<td>Total Alkalinity</td>
<td>1 mg/L</td>
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<td>Alkalinity Bicarbonate</td>
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<tr>
<td>Alkalinity Carbonate</td>
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<td>--</td>
</tr>
<tr>
<td>Alkalinity Hydroxide</td>
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<td>--</td>
</tr>
<tr>
<td>Calcium</td>
<td>4 mg/L</td>
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<tr>
<td>Carbon Disulfide</td>
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<td>--</td>
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<tr>
<td>Chloride</td>
<td>2.5 mg/L</td>
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<tr>
<td>Fluoride</td>
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<td>EPA 340.2</td>
</tr>
<tr>
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<tr>
<td>Silica</td>
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<td>--</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.5 mg/L</td>
<td>EPA 200.7/273.1</td>
</tr>
<tr>
<td>Sulfate</td>
<td>3 mg/L</td>
<td>EPA 375.3</td>
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<td>Sulfide</td>
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<td>Total Dissolved Solids</td>
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</tr>
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<td>Total Kjeldahl Nitrogen</td>
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<tr>
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<td>EPA 353.2</td>
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<td>Nitrate (as N)</td>
<td>0.1 mg/L</td>
<td>EPA 353.2T</td>
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<tr>
<td>Nitrogen Ammonia (as N)</td>
<td>0.1 mg/L</td>
<td>EPA 350.3</td>
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Table 2  Proposed Constituent List for Groundwater Measurement and Analysis - CONTINUED

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Detection Limit Required</th>
<th>EPA Method for Analysis accepted by ADEQ (2004, appendix C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.1 mg/L</td>
<td>EPA 202.1</td>
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<tr>
<td>Antimony</td>
<td>1 µg/L</td>
<td>EPA 204.2</td>
</tr>
<tr>
<td>Arsenic</td>
<td>10 µg/L</td>
<td>EPA 206.2</td>
</tr>
<tr>
<td>Barium</td>
<td>0.1 mg/L</td>
<td>EPA 200.7/208.1</td>
</tr>
<tr>
<td>Beryllium</td>
<td>1 µg/L</td>
<td>EPA 210.2</td>
</tr>
<tr>
<td>Boron</td>
<td>50 µg/L</td>
<td>EPA 200.7/213.3</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.25 µg/L</td>
<td>EPA 213.2</td>
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<tr>
<td>Chromium</td>
<td>10 µg/L</td>
<td>EPA 218.2</td>
</tr>
<tr>
<td>Cobalt</td>
<td>10 µg/L</td>
<td>EPA 219.2</td>
</tr>
<tr>
<td>Copper</td>
<td>1 µg/L</td>
<td>EPA 220.1</td>
</tr>
<tr>
<td>Iron</td>
<td>0.1 mg/L</td>
<td>EPA 200.7/236.1</td>
</tr>
<tr>
<td>Iron (Total)</td>
<td>1 mg/L</td>
<td>EPA 200.7/236.1</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5 µg/L</td>
<td>EPA 239.2</td>
</tr>
<tr>
<td>Magnesium</td>
<td>10 µg/L</td>
<td>EPA 200.7/242.1</td>
</tr>
<tr>
<td>Manganese</td>
<td>10 µg/L</td>
<td>EPA 200.7/243.1</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.01 µg/L</td>
<td>EPA 245.1</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.01 µg/L</td>
<td>EPA 246.2</td>
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<tr>
<td>Nickel</td>
<td>10 µg/L</td>
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</tr>
<tr>
<td>Silver</td>
<td>0.5 µg/L</td>
<td>EPA 272.2</td>
</tr>
<tr>
<td>Strontium</td>
<td>0.5 mg/L</td>
<td>--</td>
</tr>
<tr>
<td>Selenium</td>
<td>1 µg/L</td>
<td>EPA 200.9</td>
</tr>
<tr>
<td>Thallium</td>
<td>0.5 µg/L</td>
<td>EPA 279.2</td>
</tr>
<tr>
<td>Titanium</td>
<td>20 µg/L</td>
<td>--</td>
</tr>
<tr>
<td>Vanadium</td>
<td>10 µg/L</td>
<td>EPA 289.1</td>
</tr>
<tr>
<td>Zinc</td>
<td>30 µg/L</td>
<td>EPA 289.1</td>
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Table 2  Proposed Constituent List for Groundwater Measurement and Analysis - CONTINUED

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Detection Limit Required</th>
<th>EPA Method for Analysis accepted by ADEQ (2004, appendix C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radiological Constituents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Alpha Particle Activity (pCi/L)²</td>
<td>1 pCi/L</td>
<td>600-00 02</td>
</tr>
<tr>
<td>Radium 226 (pCi/L)</td>
<td>0.3 pCi/L</td>
<td>903.1</td>
</tr>
<tr>
<td>Radium 228 (pCi/L)</td>
<td>0.3 pCi/L</td>
<td>904</td>
</tr>
<tr>
<td>Uranium (total)¹</td>
<td>1 µg/L</td>
<td>00-07</td>
</tr>
<tr>
<td>Uranium-isotopes (pCi/L)³</td>
<td>0.03 pCi/L</td>
<td>--</td>
</tr>
<tr>
<td><strong>Isotopic Constituents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (¹⁵N)</td>
<td>1 mg/L</td>
<td>Continuous-flow gas-ratio mass spectrometer</td>
</tr>
<tr>
<td>Oxygen (δ¹⁸O)</td>
<td>N/A</td>
<td>Gas-source isotope ratio mass spectrometer</td>
</tr>
<tr>
<td>Deuterium (²H or D)</td>
<td>N/A</td>
<td>Gas-source isotope ratio mass spectrometer</td>
</tr>
<tr>
<td>Carbon (¹³C and ¹⁴C)</td>
<td>10 mg/L</td>
<td>Liquid scintillation spectrophotometer</td>
</tr>
<tr>
<td>Sulfur (³⁴S)</td>
<td>100 mg/L</td>
<td>Continuous-flow gas-ratio mass spectrometer</td>
</tr>
</tbody>
</table>

¹ Metals must be analyzed as dissolved metals, unless otherwise specified.
² The adjusted gross alpha particle activity is the gross alpha particle activity, including radium 226, and any other alpha emitters, if present in the water sample, minus radon and total uranium (the sum of uranium 238, uranium 235 and uranium 234 isotopes). The gross alpha analytical procedure (evaporation technique: EPA Method 900.0) drives off radon gas in the water samples. Therefore, the Adjusted Gross Alpha should be calculated using the following formula: (Laboratory Reported Gross Alpha MINUS Sum of the Uranium Isotopes).
³ Uranium Isotope activity results must be used for calculating Adjusted Gross Alpha.

Filtered water samples will be provided and analyzed by the laboratory for dissolved concentrations. Unfiltered water samples will also be provided and analyzed by the laboratory for total recoverable concentrations of iron and uranium. The same constituents, as dissolved and total concentrations, are analyzed in surface-water samples at co-located monitoring sites (Water and Earth, 2012). Samples will be preserved as required by analysis.
### Table 3. Draft Aquifer Protection Permit Parameters for Ambient Groundwater Monitoring for POC Wells (APP NO. P-106100)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analyte 1</th>
<th>Analyte 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth to Water (feet)</td>
<td>Potassium</td>
<td>Nickel</td>
</tr>
<tr>
<td>Water Level Elevation (feet amsl)</td>
<td>Sodium</td>
<td>Selenium</td>
</tr>
<tr>
<td>Temperature – field (°F)</td>
<td>Magnesium</td>
<td>Thallium</td>
</tr>
<tr>
<td>pH – Field &amp; Lab (S.U.)</td>
<td>Aluminum</td>
<td>Zinc</td>
</tr>
<tr>
<td>Field Specific Conductance (µmhos/cm)</td>
<td>Antimony</td>
<td>Molybdenum</td>
</tr>
<tr>
<td>Total Dissolved Solids – Lab</td>
<td>Arsenic</td>
<td>Gross Alpha Particle Activity (pCi/L)</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>Barium</td>
<td>Radium 226 (pCi/L)</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>Beryllium</td>
<td>Radium 228 (pCi/L)</td>
</tr>
<tr>
<td>Carbonate</td>
<td>Cadmium</td>
<td>Uranium-Isotopes (pCi/L)</td>
</tr>
<tr>
<td>Hydroxide</td>
<td>Chromium</td>
<td>Carbon Disulfide</td>
</tr>
<tr>
<td>Sulfate</td>
<td>Cobalt</td>
<td>Calcium</td>
</tr>
<tr>
<td>Chloride</td>
<td>Copper</td>
<td>Mercury</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Lead</td>
<td>Uranium (total)</td>
</tr>
<tr>
<td>Nitrate + Nitrite</td>
<td>Manganese</td>
<td>Iron (total)</td>
</tr>
</tbody>
</table>

1 Metals must be analyzed as dissolved metals, unless otherwise specified.
2 The adjusted gross alpha particle activity is the gross alpha particle activity, including radium 226, and any other alpha emitters, if present in the water sample, minus radon and total uranium (the sum of uranium 238, uranium 235 and uranium 234 isotopes). The gross alpha analytical procedure (evaporation technique: EPA Method 900.0) drives off radon gas in the water samples. Therefore, the Adjusted Gross Alpha should be calculated using the following formula: (Laboratory Reported Gross Alpha minus Sum of the Uranium isotopes).
3 Uranium isotope activity results must be used for calculating Adjusted Gross Alpha.
4 Draft Rosemont Aquifer Protection Permit P-106100, ADEQ, 2012

### 5.5 Environmental Isotope Monitoring

Environmental isotope monitoring is recommended in the wells identified in Figure 1 and Table 1 and in springs monitored as part of the surface-water monitoring plan (Water and Earth, 2012). Stable isotopes have the potential to provide information on many processes that include recharge area, flow paths, groundwater age, hydraulic connection between the alluvium and bedrock, stream-channel recharge, and groundwater and surface-water interactions. In simplistic terms, waters with similar isotopic ratios and relationships with solute concentrations likely originated in the same area and/or travel along similar flow paths. In this way, isotope analyses can be used to identify similar waters, recharge areas, flow paths, and mixing of different water sources.

Nitrogen isotopes (\(^{15}\text{N}\)) are potentially important due to the wide range of water uses and development within Davidson Canyon. Sources of nitrogen from septic systems, manure, fertilizers, and explosives can be constrained with nitrogen isotopic analyses. In addition, stable
isotopes of oxygen ($\delta^{18}O$), deuterium ($^2H$ or D), carbon ($^{13}C$ and $^{14}C$), and sulfur ($^{34}S$) are also recommended for analyses (Table 2).

It is difficult to determine in advance which isotopes will be most useful in distinguishing the various water sources, flow paths, and mixing ratios. Several isotopes are recommended for screening until the most useful isotopes are identified. Previous oxygen and deuterium isotope analyses in the region have indicated that groundwater mixing is occurring and these isotopes alone have resulted in somewhat inconclusive findings (M&A, 2009). This is likely due to the mixture of high-altitude and low-altitude precipitation contributing to groundwater recharge. Additional isotopes in combination with water-quality solute concentrations provide other alternatives that may result in more conclusive results. For example, in Sonoita Creek, to the south of the Project area (Figure 1), sulfur isotopes and sulfate concentrations have been used to identify groundwater sources of base flow (Gu and others, 2008). Geologic and climate similarities between the Project area and Sonoita Creek suggest that sulfur isotopes may be helpful in distinguishing water sources in Davidson Canyon.

It is recommended that oxygen and deuterium isotopes be measured at the high-elevation (5,350 feet) Rosemont weather station (Figure 6). Precipitation isotopes from lower elevations in Davidson Canyon would also be helpful, but it is anticipated that existing isotope data from Tucson will be sufficient to distinguish the altitude effect on oxygen isotopes. These isotope data will provide site specific conditions that will aid interpretation of groundwater recharge sources and flow paths.

Background isotope analyses are most useful when they are obtained over a range of climate, seasons, elevations, depths, and distance from the Project area. Data from the recommended wells and springs will provide this variability. Quarterly monitoring is initially recommended and it may then be adjusted based on the results. Isotopes that are not useful or provide inconclusive results can be discontinued as appropriate.

5.6 Subsurface Temperature Monitoring

Infiltration rates and the infiltrating water’s interaction with groundwater can potentially be determined with temperature data collected at various depths and under a variety of hydrologic conditions. Subsurface temperature monitoring is recommended in the stream-channel alluvium at three water-level monitoring locations (Table 4). Temperature sensors installed over a range of depths (Figure 13) will provide information on groundwater and surface-water interactions and stream-channel recharge. Infiltrating storm water will likely have a different temperature than perched water, unsaturated sediments, and shallow groundwater. Water temperature will also be measured in wells equipped with pressure transducers (Table 4). A schematic diagram of temperature sensor placement in the alluvial channel is illustrated in Figure 13. If temperature data provide inconclusive results, additional measurement techniques can be recommended for evaluation.
Table 4. Summary of Recommended Data Collection for the Davidson Canyon Conceptual Groundwater Monitoring Plan

<table>
<thead>
<tr>
<th>Location</th>
<th>Well Name</th>
<th>Monitored Condition</th>
<th>Water Level and Temperature</th>
<th>Water Quality</th>
<th>Isotopes</th>
<th>Subsurface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemont Weather Station</td>
<td>--</td>
<td>Precipitation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barrel Canyon</td>
<td>RP-2A²</td>
<td>Recent alluvium: Groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP-2B²</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP-2C²</td>
<td>Bedrock: Deep groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BC-1A-GW²,³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>BC-1B-GW²,³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Upper Davidson Canyon</td>
<td>DC-1A-GW²,³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>DC-1B-GW²,³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RP-9</td>
<td>Bedrock: Deep groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Davidson-Barrel Confluence</td>
<td>DC-2A-GW²,³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>DC-2B-GW²,³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Davidson Canyon Dike (DC Dike)</td>
<td>DC-Dike-A-GW³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DC-Dike-B-GW³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>OAW Reach</td>
<td>DC-3A-GW²,³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DC-3B-GW²,³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>DC-4A-GW²,³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>DC-4B-GW²,³</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>(D-16-17)31deb³</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>(D-17-17)06bde³</td>
<td>Bedrock: Deep groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Table 4. Summary of Recommended Data Collection for the Davidson Canyon Conceptual Groundwater Monitoring Plan - CONTINUED

<table>
<thead>
<tr>
<th>Location</th>
<th>Well Name</th>
<th>Monitored Condition</th>
<th>Water Level and Temperature(^1)</th>
<th>Water Quality</th>
<th>Isotopes</th>
<th>Subsurface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAW Reach</td>
<td>CC-1A- GW(^2,3)</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CC-1B- GW(^2,3)</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CC-2A- GW(^2,3)</td>
<td>Alluvium: Groundwater and surface-water interactions</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CC-2B- GW(^2,3)</td>
<td>Bedrock: Shallow groundwater</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

\(^1\)Water level and temperature measured with submersible pressure transducers

\(^2\)This well is co-located or in close proximity to a proposed surface-water monitoring location (Water and Earth, 2012)

\(^3\)Use and installation of this well requires permission from the land owner (see Table 1)
6.0 POSSIBLE FUTURE CHARACTERIZATION ACTIVITIES

As discussed in the hydrogeology and conceptual model sections, the characteristics of the hydraulic connection between the Project area and Davidson Canyon, the DC Dike, and the DC fault zone will influence the impacts observed in Davidson Canyon. The recommended water-level, water-quality, isotope, and subsurface temperature data collection described in previous sections are designed to assist in further characterizing these features. It is possible, however, that the recommended data collection and subsequent analysis may need to be augmented.

It is recommended that this Plan be implemented for an appropriate period and then if necessary, other characterization methods can be evaluated. Potential future characterization could include the following:

- Hydraulic testing using high-capacity pumps in the proposed Open Pit area to assist in determining the degree of hydraulic connection of the Project area to lower Davidson Canyon
- Installing additional wells down gradient of the DC Dike and conducting hydraulic tests to provide direct information on the degree to which the dike restricts groundwater flow
- Hydraulic testing within the Davidson Canyon fault zone to explicitly determine its permeability and area of influence
- Geophysical surveys to locate and characterize the Davidson Canyon Dike, fault zone, and alluvial stream channel
- Additional subsurface temperature profiles and/or other methods for estimating storm-water infiltration rates and groundwater and surface-water interactions
- Refined grid and refined temporal discretization of groundwater flow models for predicting impacts in Davidson Canyon

Analysis and interpretation of data collected for this recommended Plan will provide additional insight into Davidson Canyon and the potential for Rosemont Project impacts. Additional characterization beyond that recommended in the Plan can be evaluated as needed.

7.0 DATA QUALITY

Detailed field-data collection and analysis activity notes will be maintained. Well locations and measuring point elevations will be determined by GPS or other adequately accurate method. Water-level data, water-quality samples, stable isotope samples, and temperature data will be collected and analyzed using standard operating procedures that are currently in-place or will be developed upon approval of this Plan. All field measurement, sampling procedures, and laboratory analytical procedures will comply with ADEQ requirements to ensure the collection of reliable and credible data. Consistent labeling, documentation, and chain-of-custody
procedures for sample shipping will be followed. The inclusion of sample duplicates and blanks is anticipated to comply with all QA/QC requirements.

Following completion and approval of a final Davidson Canyon Monitoring Plan, a formalized Quality Assurance Plan (QAP) and Sampling Analysis Plan (SAP) that follow current ADEQ guidelines (ADEQ, 2004) may be required. The SAP will describe the overall sampling plan design and description of the environmental measurements. Details of equipment used for monitoring is also typically specified in a SAP.

The QAP discusses the details of the sampling and measurement protocols for field collection and laboratory analysis. The analytical laboratory QAPs will also be included into the Rosemont QAP. Sample analyses will meet the acceptable criteria outlined by ADEQ. An analytical laboratory list is presented in Appendix F of ADEQ (2004).
REFERENCES

ADEQ, 2004, Surface Water Data Submittal Guidance Document, Prepared by Arizona Department of Environmental Quality, Water Quality Division and Waste Programs Division, Hydrologic Support and Assessment Section, May 2004


Figure 1
Recommended Rosemont Monitoring Locations and Detailed Map Areas

Explanation
- Detailed Map Area
- Extent of Ultimate Pit
- Davidson Canyon Dike
- Proposed Tailings and Waste Rock Facilities
- Proposed Surface-water Monitoring Location (Water and Earth, 2012)
- Proposed Stormwater Sampling Location (Water and Earth, 2012)
- Proposed New Monitoring Well
- Existing Well Location

Monitor Locations
- RP-9

- Davidson Canyon Watershed Boundary
- Ephemeral Streams

See Figure 6
See Figure 7
See Figure 8

Recommended Rosemont Monitoring Locations and Detailed Map Areas

File: T:\GIS\Projects\110195\Figures\Monitoring_Basemap.mxd UTM NAD 83 Zone 12 N
March 30, 2012
Precipitation

Ephemeral springs supported by shallow flow paths and storm-water infiltration

Perennial springs and flowing wells supported by deep flow paths

Fractured Bedrock

Shallow Bedrock Flow Paths

Deep Bedrock Flow Path

Alluvial stream-channel deposits

Recharge and infiltrating storm-water runoff

FIGURE 2
CONCEPTUAL MODEL OF GROUNDWATER FLOW PATHS, EPHEMERAL SPRINGS, AND PERENNIAL SPRINGS
FIGURE 3
INTERACTIONS OF STREAMS AND GROUNDWATER
(MODIFIED FROM WINTER AND OTHERS, 1998)
Channel Elevation (3452.1 feet amsl) surveyed by Tetra Tech in the middle of the channel, adjacent to the USGS gauging station

± 7 feet below channel bottom

Data suggest consistent hydraulic disconnection for Davidson Canyon near the USGS gauge - ephemeral flow.

± 15 feet below channel bottom

Pima County Well ((D-16-17)31dcb)


Project No. 110195

Note: Data was compiled from the Davidson Canyon Unique Waters Nomination (PAG, 2005).

(from Tetra Tech, 2010b)

March 2012

FIGURE 4

GROUNDWATER DISCONNECTED FROM THE STREAM CHANNEL BOTTOM IN THE OAW REACH
Figure 5
Overview of Recommended Rosemont Groundwater Monitoring Locations

Explanation
- **DC-1A-GW**: Proposed New Alluvial and Bedrock Monitoring Well
- **Ephemeral Streams**: Streams with intermittent flow
- **Proposed Tailings and Waste Rock Facilities**: Areas designated for tailings and waste rock storage
- **Outstanding Arizona Water Reach**: Reaches of the stream designated as outstanding Arizona water resources

Extent of Proposed Pit

File: T:\GIS\Projects\110195\Figures\DCMonitoring_Overview.mxd  UTM NAD 83 Zone 12N
March 30, 2012
Figure 6
Barrel Canyon Monitoring Locations
Figure 7
Upper Davidson Canyon Monitoring Locations

Explanation

- Existing Well Location and Identifier
- Proposed Surface-water Monitoring Location (Water and Earth, 2012)
- Proposed Bedrock and Alluvial Monitoring Wells

Legend

- Davidson Canyon Dike
- Ephemeral Streams
- Road
- Private Land
- State Trust Land

File: T:\GIS\Projects\110195\Figures\Monitoring_UpperDavidsonCanyon.mxd  UTM NAD 83 Zone 12 N
March 20, 2012
Figure 8
Outstanding Arizona Water Reach
Monitoring Locations

Explanation
(D-16-17)31bad
- Existing Well Location and Identifier
(D-17-17)08bdc
- Existing Well Location Proposed for Monitoring
DC-4-SW
- Proposed Surface-water Monitoring Location (Water and Earth, 2012)
DC-4A-GW
- Proposed Bedrock and Alluvial Monitoring Wells

Land Ownership
- Pima County Land
- State Trust Land
- Approximate Boundary of Cienega Creek Natural Preserve

Davidson Canyon Watershed
- OAW Reach
- Ephemeral Stream
- Road

Reach 2 Spring
Escondido Spring
Cienega Creek
DC-3-SW
DC-3A-GW
DC-3B-GW
DC-3-SW
CC-2-SW
CC-2A-GW
CC-2B-GW
CC-1-SW
CC-1A-GW
CC-1B-GW
DC-4-SW
DC-4A-GW
DC-4B-GW

(T16S R16E) 0
(T16S R17E) 2,000
(T17S R16E) 2,000
(T17S R17E) 0

Figure 8
Outstanding Arizona Water Reach
Monitoring Locations

File: T:\GIS\Projects\110195\Figures\Monitoring_OAW.mxd  UTM NAD 83 Zone 12 N
March 20, 2012
FIGURE 9
CONCEPTUAL CONFIGURATION OF BEDROCK AND ALLUVIAL MONITORING WELLS
ALL DEPTHS BELOW GROUND SURFACE.
NOT TO SCALE

FIGURE 10
EXAMPLE BEDROCK WELL DESIGN
ALL DEPTHS BELOW GROUND SURFACE.
NOT TO SCALE
FIGURE 12
TYPICAL STAGE AND RAIN MONITORING GAGE

(from Water & Earth, 2012)
FIGURE 13
CONCEPTUAL CONFIGURATION OF
SUBSURFACE TEMPERATURE MONITORING