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TECHNICAL MEMORANDUM

DATE: & May 1, 2013 PROJECT: 605.76

TO: & Greg Ghidotti
RESOLUTION COPPER MINING, LLC

FROM: & Janis Blainer-Fleming, Jeff Meyer, and Mark Cross, P.G.
MONTGOMERY ASSOCIATES

SUBJECT:& PHASE I HYDROGEOLOGIC FIELD INVESTIGATIONS, NEAR WEST TAILINGS SITE, PINAL COUNTY, ARIZONA

In accordance with arrangements with Mr. Greg Ghidotti, Resolution Copper Mining, LLC (RCM), this technical memorandum has been prepared to summarize results of the Phase I hydrogeologic assessment of the Near West site, conducted by Montgomery & Associates (M&A) in support of RCM's ongoing prefeasibility studies for storage of RCM mine tailings. The Near West site encompasses an area of approximately 12 square miles west-northwest from the Town of Superior and is shown on **Figure 1**. The site includes two areas, one centered on Happy Camp Canyon, and the other located between Roblas Canyon on the west and Potts Canyon on the east.

The purpose of the Phase I assessment was to conduct non-invasive field investigations to supplement information obtained previously from published data, and to plan Phase III investigations involving subsurface exploration drilling and hydrologic testing. Phase II investigations were conducted concurrently with Phase I investigations and involved electrical resistivity surveys conducted by HydroGeophysics, Inc. to further characterize the subsurface in support of planning for Phase III investigations. Results of Phase II investigations are summarized in a separate technical memorandum.

SUMMARY

- **Background:** A preliminary hydrogeologic assessment was conducted in 2012 and involved compiling, reviewing, and summarizing published hydrogeologic data, and assessing hydrogeologic conditions and water uses in the vicinity of the Near West site (M&A, 2012b). The initial investigation was focused in the vicinity of Silver King, Whitford, and Happy Camp Canyons. The area of the preliminary hydrogeologic assessment is shown on **Figure 2**. Following submittal of the hydrologic data summary, the Silver King and Whitford Canyon areas were removed from consideration, and the area to the west of Happy Camp Canyon, including parts of Bear Tank, Benson Spring, and Roblas Canyons, was added to area of investigation (**Figure 1**). Results of the initial assessment and subsequent investigations in the expanded area indicated the following hydrogeologic features:

- The site is underlain by unconsolidated to weakly consolidated Quaternary alluvial deposits on the floors of and immediately adjacent to canyons and washes, widespread weakly to well lithified Tertiary conglomerate and sandstone, weakly to well lithified extrusive Tertiary volcanic rocks, well lithified Paleozoic sedimentary rocks, well lithified younger Precambrian sedimentary and igneous rocks, and well lithified older Precambrian schist. The Quaternary alluvial deposits are relatively thin and confined to the drainages. The Tertiary sedimentary and volcanic rocks crop out across most of the site, while Paleozoic and Precambrian rock units crop out along the northern, western, and southern margins of the site.

- Depth to groundwater level at selected wells in the vicinity of the Near West site ranged from 3.2 to 16.7 meters (m) below land surface (bls) (10.5 to 54.7 feet [ft] bls) in September 2012 (Montgomery & Associates, 2013). Direction of groundwater movement is generally from northeast to southwest.

- **Objectives:** The Phase I hydrogeologic assessment was designed to supplement information from the 2012 preliminary hydrogeologic assessment using non-invasive field investigations. The Phase I program included confirmatory geologic mapping along selected traverses, documenting four reported springs, collecting water samples at two of the springs, and testing methods for conducting infiltration tests on bedrock surfaces.

- **Conclusions:** The following conclusions are based on results of the Phase I Hydrogeologic Assessment of the Near West site:

  - Geologic mapping by Arizona Geological Survey (AZGS) appears to be generally accurate with some relatively minor exceptions at a local scale. Small-scale features were not always mapped locally, and small inconsistencies were noted along some of the traverses. Near the southwest corner of the proposed tailing impoundment, faulting was observed to be more complex than shown on the published geologic map.

  - With the exception of Quaternary alluvium along ephemeral stream channels, permeability for all geologic units at the site would be very small except where fractured. Fracturing of rock units was most evident along and adjacent to mapped faults in the northern part of the proposed tailings impoundment. However, some evidence of fracturing was also observed in rock units in the western and southwestern parts of the proposed tailings impoundment.

- Three springs occur in the vicinity of the Near West site, including Happy Camp, Benson, and Bear Tank Canyon Springs. Discharge was observed at Happy Camp and Bear Tank Canyon Springs, but not at Benson Spring. Happy Camp and Bear Tank Canyon Springs occur within the Tertiary conglomerate. Benson Spring occurs near the contact between the Tertiary conglomerate and the Pinal Schist. A feature mapped as Perlite Spring was inspected. Three apparent surface water impoundments occur in the vicinity of the perlite quarries in the northern part of the site, but are not believed to be springs. Samples were collected for laboratory chemical analyses from Happy Camp and Bear Tank Canyon Springs.

- Results of pilot infiltration testing indicate that the "bottomless bucket" method provided an appropriate means for measuring infiltration rates and field-saturated hydraulic conductivity (Ksat) of exposed bedrock surfaces. The generally very small Ksat values determined by these pilot tests are consistent with the general magnitude of Ksat values that would be expected for these bedrock units.

BACKGROUND

The Near West site encompasses an area of approximately 12 square miles west-northwest from Superior, Arizona. The site is shown on **Figure 1** and includes all or parts of sec. 22, 23, 24, 25, 26, 27, 34, 35, and 36, T. 1 S., R. 11 E., all or parts of sec. 19, 21, 27, 28, 29, 30, 31, 32, 33, and 34, T. 1 S., R. 12 E., part of sec. 1, T. 2 S., R. 11 E., and parts of sec. 5 and 6, T. 2 S., R. 12 E., in Pinal County, Arizona. The Near West site is located on land managed by the U.S. Forest Service, Tonto National Forest (TNF).

A preliminary hydrogeologic assessment was conducted by M&A in 2012, and involved compiling, reviewing, and summarizing published hydrogeologic data, and assessing hydrogeologic conditions and water uses in the vicinity of Silver King, Whitford, and Happy Camp Canyons. The principal sources of data were the Arizona Department of Water Resources (ADWR), AZGS, and United States Geological Survey (USGS). The results of the preliminary assessment were reported in an October 23, 2012 technical memorandum from M&A to Greg Ghidotti and Sergio Gonzalez of RCM.

Based on results of the preliminary hydrogeologic assessment, the following hydrogeologic units (in descending order) were inferred to occur in the subsurface at the Near West site:

- A thin veneer of unconsolidated active Quaternary alluvium and weakly consolidated older Quaternary alluvium on and adjacent to the floors of canyons and washes

- Tertiary conglomerate, sandstone, and volcanic rocks of relatively low permeability, except where fractured, which are exposed across most of the site

- Paleozoic sedimentary rocks including carbonates, siltstone, shale, and quartzite of relatively low permeability, except along bedding planes and where fractured, which are exposed in the western part of the site and underlies younger units in the remainder of the site

- Younger Precambrian sedimentary and igneous rocks including quartzite, shale, limestone, and diabase of low permeability, except along bedding planes and where fractured, which are exposed in the northeastern, western and southwestern parts of the site and underlies younger units in the remainder of the site

- Older Precambrian crystalline metamorphic rocks (Pinal Schist) of low permeability, except along relict bedding surfaces and where fractured, which is exposed in the northern, southern, and southwestern parts of the site and underlies younger units in the remainder of the site

Hydraulic properties for these units in the at the Near West site are not available. However, based on data collected at the RCM West Plant site, hydraulic conductivities were estimated to be:

- Alluvium – 3.4 x 10^{-5} centimeters per second (cm/sec)
- Tertiary conglomerate – 6 x 10^{-9} to 1.1 x 10^{-5} cm/sec
- Mudstone unit within the Tertiary conglomerate – 1.3 x 10^{-9} cm/sec
- Volcanic units interbedded with the Tertiary conglomerate – 1 x 10^{-5} cm/sec
- Younger Precambrian sedimentary rocks and diabase – 4 x 10^{-6} cm/sec

Data collected for Precambrian sedimentary rocks, diabase, and schist located in the Cross Canyon area southeast of Superior, yielded an estimated hydraulic conductivity of 1 x 10^{-6} cm/sec. Data collected for the Tertiary Apache Leap Tuff in the Oak Flat area east of Superior yielded estimated hydraulic conductivities ranging from 2 x 10^{-7} to 6 x 10^{-3} cm/sec.

As part of the Queen Creek corridor survey, groundwater levels were measured in selected wells in the Superior basin during the period May to September 2012. For wells in the vicinity of the Near West site, depth to groundwater level was in the range of 3.2 to 16.7 m bls (10.5 to 54.7 ft bls. Groundwater is believed to be moving generally from northeast to southwest (M&A, 2013).

Wells in the vicinity of the Near West site are reported to be for domestic, stock, or industrial uses. No groundwater quality data were available for the area of Near West site.

PHASE I HYDROGEOLOGIC INVESTIGATIONS

The objective of the Phase I hydrogeologic investigations was to supplement information from the preliminary hydrogeologic assessment by conducting surface investigations using non invasive techniques, which would be within the scope of activities allowed by TNF without notice or permit. The Phase I investigations included geologic mapping, spring survey and sampling, and developing methods for infiltration testing on bedrock surfaces. The results of the Phase I investigations will be used for planning of Phase III investigations. Field investigations were conducted on 8 days during the period from February 11 through March 5, 2013.

CONFIRMATORY GEOLOGIC MAPPING

The purpose of the confirmatory geologic mapping was to:

- Investigate site geology and determine the accuracy of the AZGS and USGS geologic maps of the Near West site
- Investigate selected exposures of principal geologic units at the site
- Investigate selected exposures of principal geologic structures at the site

Principal Geologic Units

The principal geologic units at the Near West site, in order of increasing age, include Quaternary alluvial deposits, Tertiary sedimentary and volcanic rocks, Paleozoic sedimentary rocks, younger Precambrian sedimentary and igneous rocks, and older Precambrian Pinal Schist. Selected traverses were walked to inspect outcrops of these units and to document the accuracy of the 1:24,000 scale geologic mapping of the Picketpost Mountain Quadrangle by AZGS (Spencer and Richard, 1995), and the Superior quadrangle by USGS (Peterson, 1969). **Figure 1** is a geologic map of portions of the Superior and Picketpost Mountain Quadrangles. The Quaternary and Tertiary surficial geology shown in the southwest part of the Superior Quadrangle was modified using the Mesa 1:100,000 scale geologic map by AZGS (Spencer and others, 1998).

Quaternary alluvial deposits

The Quaternary alluvial deposits occur chiefly along Happy Camp Canyon, Potts Canyon, Whitford Canyon, Roblas Canyon, and Hewitt Canyon Washes, and along Queen Creek. Pockets of Quaternary alluvial deposits also occur in the unnamed drainages northwest from Barnett Camp in sec. 18, 19, 20, and 29, T. 1 S., R. 12 E., and in the tributaries of Roblas Canyon. Mapping by Spencer and Richard (1995) appears to be generally accurate; however, many of the smaller drainages, such as Bear Tank Canyon, contain a thin veneer of unmapped active alluvium on bedrock surfaces as shown on **Photograph 1** (NE1/4 sec. 35, T. 1 S., R. 11 E.). The Quaternary alluvial deposits likely have moderate to high hydraulic conductivity.

Mapping by Spencer and others (1998) at a scale of 1:100,000 shows a smaller area of outcrop for the Quaternary units, but more detail for the alluvial deposits along Queen Creek. For the purposes of this report, the classification from the more detailed mapping (Spencer and Richard, 1995) will be used. Ages shown for each of the units are based on equivalent units from Spencer and others (1998).

Photograph 1. Unmapped Quaternary active alluvium (Qal) in Bear Tank Canyon

The Quaternary alluvial deposits constitute a relatively small percentage of the overall outcrop at the Near West site with the most common deposits comprising undivided surficial deposits (Qs), unconsolidated alluvium (Qal), and old alluvium (Qoa). Small localized deposits of talus and colluvium (Qtc) and older alluvium (QTs) are present to a smaller degree.

Qs – Undivided Surficial Deposits (Quaternary)

The undivided surficial deposits (Qs) include undifferentiated modern and older sediments that comprise slightly to moderately consolidated alluvial deposits forming dissected and undissected surfaces, and unconsolidated sand and gravel in washes and streambeds. The Qs is exposed in Silver King Wash, Happy Camp Canyon, lower Bear Tank Canyon, Queen Creek and some of its unnamed tributaries, the unnamed drainage northwest of Barnett Camp in the SW1/4 sec. 20, T. 1 N., R. 12 E. (**Photograph 2**), Roblas Canyon and its tributaries, and Hewitt Canyon (**Figure 1**).

Photograph 2. Surficial deposits (Qs) northwest of Barnett Camp

Qal – Unconsolidated Alluvium (Holocene)

The active alluvium (Qal) consists of unconsolidated sand and gravel in unvegetated or sparsely vegetated active stream channels, and along vegetated flats up to 2 meters above stream channels. The Qal is exposed in Silver King Wash, Potts Canyon, Queen Creek, lower Roblas Canyon, and lower Hewitt Canyon (**Figure 1**). As noted previously, a thin veneer of Qal is present in most drainages at the site.

Qoa – Old Alluvium (late Pleistocene to early Pleistocene)

The old alluvium (Qo) consists of weakly consolidated cobble to boulder conglomerate capped by surfaces generally 2 to 5 m above active stream channels. The Qoa is generally characterized by a well preserved geomorphic surface. The Qo is exposed in Happy Camp, Rice Water, Bear Tank, Benson Spring, Roblas, and Hewitt Canyons above the confluences with Queen Creek (**Figure 1**).

Qtc – Talus and Colluvium (Quaternary)

Talus and colluvium (Qtc) consists of unconsolidated sediment on steep hillsides in the Roblas Butte vicinity and in Whitford Canyon (**Figure 1**).

QTs – Older Alluvium (early Quaternary to late Tertiary)

The older alluvium (QTs) consists of unconsolidated massive boulder conglomerate produced by landsliding. These deposits typically have scarps in the headwall of the landslide that are degraded and revegetated. The QTs is exposed in lower Roblas Canyon (**Figure 1**).

Tertiary sedimentary and volcanic rocks

The Tertiary sedimentary and volcanic rocks at Near West site are part of the greater Superstition Volcanic Field which encompasses the extent of the Apache Leap Tuff outcrop (Ferguson and Trapp, 2001). In Superior basin, the Superstition Volcanic Field includes four principal stratigraphic units which from youngest to oldest include the Gila Group, the Apache Leap Tuff, the Superstition Group, and the Whitetail Formation.

In Superior basin, the Gila Group includes the Tertiary units that range in age from 18.6 to ~15 million years old (Ma) including volcaniclastic conglomerates, sandstones, rare mudstones, locally interbedded basalt flows and unwelded tuffs, and the Picketpost Mountain Formation volcanic and volcaniclastic units. The Picketpost Mountain Formation is approximately 17 to 16 Ma (Ferguson and Trapp, 2001).

The Apache Leap Tuff, an extensive ash-flow tuff, is a regional rock-stratigraphic marker unit of the Superstition Volcanic Field that separates the older Superstition Group from the younger Gila Group. The Apache Leap Tuff is 18.58 ± 0.03 Ma (sanidine, single crystal, laser-fusion $^{40}Ar/^{39}Ar$ technique) (Ferguson and Trapp, 2001).

The Superstition Group includes volcanic rocks and minor associated sedimentary rocks that underlie the Apache Leap Tuff. The Superstition Group crops out primarily in the Superstition Mountains to the northwest of Superior basin, and is approximately 20 to 18.6 Ma (Ferguson and Trapp, 2001). The Superstition Group includes three formal units and two possible informal units as described by Ferguson and Trapp (2001). The formal units are Whitlow Canyon Formation (18.75 to 18.55 Ma), Tule Canyon Formation (19.0 to 18.7 Ma), and Government Well Formation (~20 to 19.0 Ma), and the informal units are Unit of Buzzard's Roost (18.6 Ma) and Unit of Pass Mountain (unknown age) (Ferguson and Trapp, 2001). In the northwest part of the Near West site, the Superstition Group includes felsic lavas that resemble Whitlow Canyon Formation or Unit of Buzzard's Roost. In the Superstition Mountains, Unit of Buzzard's Roost overlies Whitlow Canyon Formation, and Whitlow Canyon Formation is overlain by Apache Leap Tuff. The age relationship between Unit of Buzzard's Roost and Apache Leap Tuff is unknown, but outcrop relationships in the Superstition Mountains suggest that Unit of Buzzard's Roost is older than Apache Leap Tuff (Spencer and others, 1998, and Ferguson and Trapp, 2001).

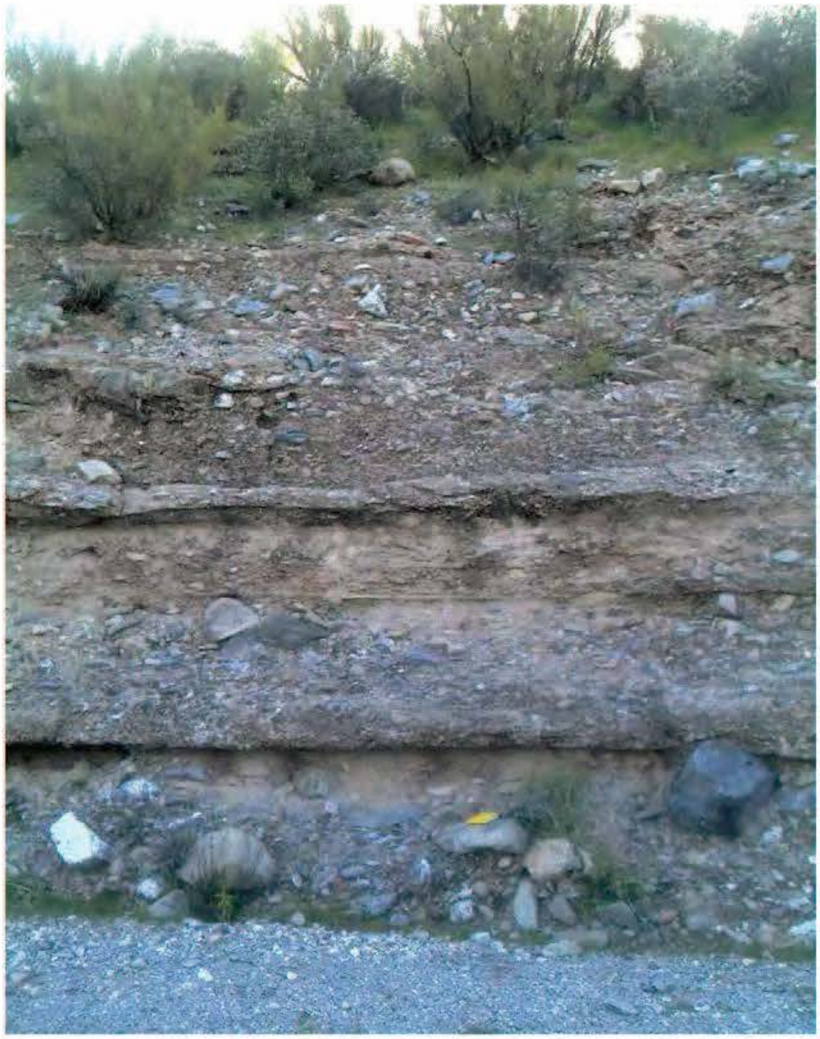
The Whitetail Formation is a dominantly non-volcaniclastic sedimentary sequence that underlies and is locally interbedded with volcanics of the Superstition Group. The sedimentary sequence includes conglomerate, sandstone, and lesser avalanche breccia and mudstone. The Whitetail Formation is approximately 22 to 18.6 Ma (Ferguson and Trapp, 2001).

Tertiary Gila Group sedimentary rocks

The Gila Group sedimentary rocks at the Near West site occur in a belt across the center of the site from the Concentrator Fault on the east to the ridge east of Roblas Canyon on the west, and from the Concentrator and Roblas Canyon Faults on the north to approximately Queen Creek on the south (**Figure 1**). At Near West site, the exposed sedimentary units include conglomerate and sandstone. These units were deposited within the present-day basin and are relatively undeformed. Deposition of the sediments began within a closed basin and later, when rate of deposition exceeded basin subsidence, spill-over points developed between adjacent basins and through-going drainage of the ancestral Gila River was established (Scarborough, 1989, and Ferguson and Trapp, 2001). The Gila Group sedimentary rocks likely have low hydraulic conductivity except where fractured which is rare. Mapping by Spencer and Richard (1995) appears to be generally accurate. Ages shown for each of the units are based on equivalent units from Spencer and others (1998).

Tcg – Conglomerate (Miocene)

The Tertiary conglomerate (Tcg), or Gila Conglomerate, is chiefly moderately to well indurated conglomerate with subrounded to subangular pebbles to boulders in a tuffaceous sandy matrix. The unit includes sparse planar sandy pebble to cobble conglomerate beds, and tuffaceous sandstone beds near the base of the unit. The matrix is commonly poorly sorted and cemented with carbonate. Some beds are clast-supported while others are matrix-supported. Some outcrops display fining upward sequences. The Tcg is typically tan to gray with multi lithologic clasts that include Pinal Schist, a variety of granitic rocks, Apache Group rocks, Paleozoic rocks, vein quartz, and Tertiary volcanic rocks. The unit formed following the main phase of mid-Tertiary volcanism; however, some later Tertiary basalt flow units and tuff layers are interbedded with the Tcg in the subsurface in the Superior basin. The Tcg crops out over the central portion of the Near West site (**Figure 1**). **Photograph 3** (center of sec. 25, T. 1 S., R. 11 E.) shows a typical exposure of Tcg. The Tcg shows sparse evidence of fracturing.



Photograph 3. Tertiary conglomerate (Tcg) in Bear Tank Canyon

The Tcg is well bedded and generally best exposed in the drainages; ridges are typically littered with boulders weathered from the deposit. The Tcg exposures on ridges have a weathered horizon with varying thickness across the site. Across the outcrop belt, strikes and dips of bedding planes are variable. Generally dip angles are 15 degrees or less, except for outcrops in the northern portion of the outcrop belt between Silver King and Happy Camp Canyons where the beds dip 10 to 30 degrees. Dip directions for the northernmost outcrops are generally south, southeast or southwest, whereas dip directions of beds near the central and southeastern edges of the outcrop belt are generally east and northeast. It is uncertain if the variability of strike and dip is primary or caused by subsequent deformation. The fact that the unit is relatively unfractured suggests that any post-depositional deformation has been very minor. Variable dips may in part reflect deposition of the unit during on-going faulting.

The Tcg was deposited in the Superior basin near the end of a period of regional extensional faulting along the west-dipping Concentrator Fault and southwest-dipping Roblas Canyon Fault (Spencer and Richard, 1995). The Tcg overlies Miocene volcanic rocks in the Picketpost and Superior Quadrangles at the Near West site, overlies the Apache Leap Tuff (Tal) and non-welded tuff (Tt) in the Haunted Canyon Quadrangle to the east and north of the Near West site (Spencer and others, 1998), and is interbedded with basaltic lava flows and unwelded tuff in the southern part of the site (Bonanza exploration holes). In the vicinity of the perlite quarries (NE1/4 sec. 30, T. 1 S., R. 12 E.) an erosional remnant of the Tcg is in depositional contact with the underlying perlitic rhyolite (Tfp) of the Picketpost Mountain Formation.

Tss – Sandstone (Miocene)

The Tertiary sandstone (Tss) is a weakly to moderately indurated, poorly sorted, medium to fine-grained sandstone with tuffaceous matrix (**Photograph 4;** east-center sec. 36, T. 1 S., R. 11 E.). The unit grades upward into Tcg. The Tss is exposed along the southern margin of the Tcg outcrop belt near Queen Creek. Bedding planes generally strike north-northwest and dip east-northeast; however local variations are common (**Figure 1**). Like the Tcg, the best exposures of Tss occur in the drainages. The Tcg shows sparse evidence of fracturing.

Photograph 4. Tertiary sandstone (Tss) in Benson Spring Canyon

Tertiary Gila Group volcanic rocks

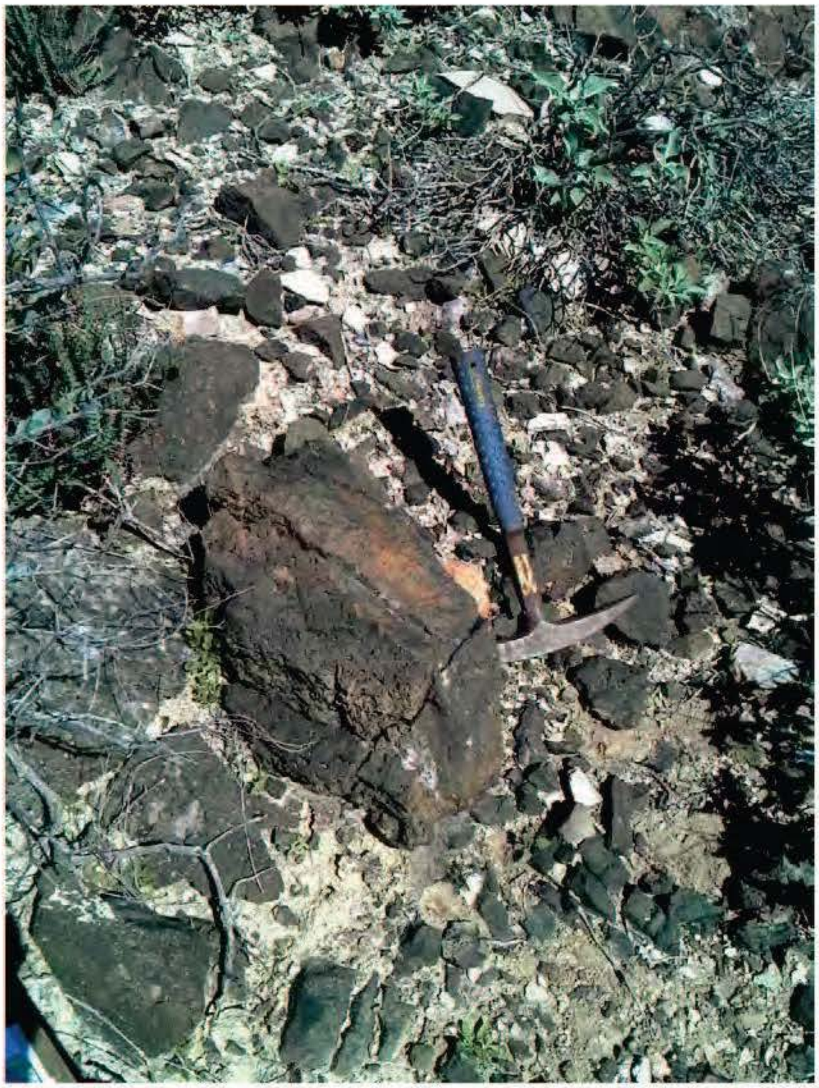
The Gila Group volcanic rocks at the Near West site include basaltic lavas, unwelded felsic tuffs, and Picketpost Mountain Formation felsic lavas and tuffs. The basaltic lavas primarily crop out near Queen Creek in the southern part of the site, with a few outcrops in the northeast part of Superior basin. The unwelded felsic tuffs crop out in the north central part of the site primarily adjacent to the Roblas Canyon Fault. The Picketpost Mountain Formation crops out in the central and southern parts of the site (**Figure 1**). Mapping by Spencer and Richard (1995) appears to be generally accurate; however, the units that were classified as undivided felsic volcanic rocks (Tf) and tuff (Tt) have been reclassified in the present report to be consistent with Spencer and others (1998) and Ferguson and Trapp (2001). The Gila Group volcanic rocks likely have low hydraulic conductivity, except where fractured or possibly along bedding planes. All of the Gila Group volcanic units display a moderate to high degree of fracturing and therefore may have higher hydraulic conductivity than many other geologic units at the Near West site.

Tb – Basalt (middle Miocene to early Miocene)

The Tertiary basalt (Tb) consists of basalt flows and flow breccias in the vicinity of Queen Creek (**Figure 1**). The basalt is dark gray, very fine-grained, and locally vesicular or amygdaloidal, with localized zones of autobreccia (Spencer and others, 1998). Outcrop exposures typically display weathered olivine and pyroxene phenocrysts in an aphyric to aphanitic groundmass. **Photograph 5** shows a Tb exposure in Bear Tank Canyon (NW1/4 sec. 36, T. 1 S., R. 11 E.). The Tb is generally weathered and poorly exposed except in the drainages. The Tb crops out near the southern part of the Near West site and is interbedded with the Tcg. Basalt interbeds within the Tcg occur in the subsurface at monitor wells DHRES-03, DHRES-04, and DHRES-05 at West Plant site to the east, and in the Bonanza explorations holes. An interbedded scoriaceous basalt flow breccia occurs in the Tcg in the drainage between Happy Camp Canyon and Silver King Canyon, upstream from proposed drill site DS-C, near the center of sec. 33, T.1 S., R. 12 E.

Photograph 5. Tertiary basalt with flow breccia (Tb) in Bear Tank Canyon

An outcrop north of Happy Camp Spring northeast of drill site DS-A was mapped by Spencer and Richard (1995) as middle Tertiary lower basalt (Tbl). This unit appears to be in the proper stratigraphic location to be the basalt unit at the top of the younger Precambrian (middle Proterozoic) Apache Group, but Spencer and Richard (1995) did not consider this to be likely. The Tbl is deeply weathered and oxidized red to dark reddish brown to black aphyric vesicular basalt. **Photograph 6** shows the Tbl northeast of proposed drill site DS-A in the SE1/4 sec. 21, T. 1 S., R. 12 E. In general, the Tb is highly fractured.



Photograph 6. Lower Tertiary basalt (Tbl) Happy Camp Canyon vicinity

Tt – Tuff (middle Tertiary)

The Tertiary tuff (Tt) is a massive and bedded, unwelded to poorly welded tuff of uncertain affinity (**Figure 1**). The unit is white to light gray and contains phenocrysts of feldspar, biotite, quartz, and hornblende and lithic fragments. Exposures of the unit are locally very weathered. The Tt underlies the Tfp in the north central part of the Near West site. It occurs in narrow outcrop bands throughout the Near West site. **Photograph 7** shows an exposure of Tt in Whitford Canyon in the north center of sec. 29, T. 1 S., R. 12 E. The Tt in the northeast part of Superior basin (north of Happy Camp) includes some Apache Leap Tuff (Tal) (Spencer and others, 1998).

Photograph 7. Poorly welded tuff (Tt) in Whitford Canyon

Picketpost Mountain Formation

The Picketpost Mountain Formation occurs mainly in the southern part of the Near West site, but also in the north central part of the site south of the Roblas Canyon Fault (**Figure 1**). Spencer and others (1998) suggest the source of the Picketpost Mountain Formation lavas and tuffs was 10 to 15 km to the south.

Tfp and Tfpt– Felsic lava flows and tuffs (middle Miocene to early Miocene): The Picketpost Mountain Formation felsic lava flows (Tfp) include quartz latite and rhyolite with associated vitrophyre, autobreccia, and perlite. The Tfp is interbedded with associated tuffs of unit Tfpt. The Tfp in the north central part of the site (unit Tp of Spencer and Richard, 1995) is a pale gray, glassy, perlitic aphyric rhyolite that is tan on weathered surfaces. The unit has spheroidal fractures that are likely related to devitrification (Spencer and Richard, 1995). The unit shows layering and parallel fracturing that likely reflect flow texture; layers strike northeast and dip 25°SE (**Photograph 8;** NE1/4 sec. 30, T. 1 S., R. 12 E.). The upper part of the unit at this location is pale tan to gray aphyric rhyolite with brecciated to flow banded texture. The glassy perlite occurs beneath the rhyolite and overlies older volcanic unit (Tt). Lithic fragments are common. In the north central part of the Near West site, the Tfp occurs south of the alignment of the Roblas Canyon Fault (**Figure 1**). Near the eastern part of this outcrop in the NW1/4 sec. 29, T. 1 S., R. 12 E., deep cracks occur in a flow breccia unit, likely related to weathering (**Photograph 9**).

Photograph 8. Tertiary perlitic aphyric rhyolite (Tfp) with parallel layering and fracturing

Photograph 9. Perlitic rhyolite breccia (Tfp)

Tal – Apache Leap Tuff (early Miocene)

The Apache Leap Tuff (Tal) is a gray to pink moderately to strongly welded ash-flow tuff. Most exposures of the Tal are crystal rich with phenocrysts of feldspars, quartz, and biotite. Some parts of the Tal contain lithic fragments. **Photograph 10** shows a typical exposure of the Tal at the Near West site (north center sec. 26, T. 1 S., R 11 E.). Near the base of the unit is a densely welded black porphyritic vitrophyre subunit; this subunit is exposed in Roblas Canyon southeast from the windmill (SE1/4 sec. 22, T. 1 S., R. 11 E.). The Tal is widespread east of Superior, but in the Near West area, it crops out chiefly in the western part of the site. The top of the Tal was encountered in the subsurface beneath the Tcg at a depth of about 943 m bls at monitor well DHRES-05 at West Plant site, and at depths ranging from about 188 to 933 m bls in the Bonanza and Arnett Creek (B and AC) exploration holes (**Figure 1**).

While the Tal is saturated at monitor well DHRES-05, airlift pumping was not sustainable during aquifer testing in 2010, indicating a very low hydraulic conductivity for the Tal at West Plant site to the east.

Photograph 10. Apache Leap Tuff (Tal)

Superstition Group volcanic rocks

The Superstition Group volcanic rocks occur in the northwestern part of the Near West site (**Figure 1**). These units pre-date the Tal.

Trdu and Trdt – Felsic lava flows and tuffs (early Miocene)

The felsic lavas and tuffs (Trdu and Trdt) in the northwestern part of the Near West site include rhyodacite and dacite lavas and associated tuffs that resemble other units classified as Superstition Group volcanic rocks. In Roblas Canyon, the Trdu is overlain by the Tal (SE 1/4 sec. 22, T. 1 S., R. 11 E.).

Tw – Whitetail Formation

The Whitetail Formation rocks occur in the northwest part of the Near West site. The sedimentary unit is generally non-volcaniclastic and was deposited prior to major mid-Tertiary volcanism (Scarborough, 1989, and Ferguson and Trapp, 2001).

The Tw is a massive conglomerate with subangular to subrounded pebbles and cobbles that include Apache Group and Paleozoic rocks in a poorly cemented reddish brown matrix. The Tw lacks clasts of Tertiary volcanic rocks. Area of outcrop is limited at the Near West site, with exposures near Roblas Butte and in Hewitt Canyon (**Figure 1**). The top of the Tw was encountered in the subsurface beneath the Tcg and Tal in the Bonanza and Arnett Creek (B and AC) exploration holes at depths ranging from 258 to 1,216 m bls (**Figure 1**).

Paleozoic sedimentary rocks

The Paleozoic sedimentary rocks occur chiefly in the northwest part of the Near West site in the Roblas Canyon area south of the Roblas Canyon Fault (**Figure 1**). The Paleozoic units in the vicinity of the Near West site include Cambrian, Devonian, and Mississippian age carbonate and clastic rocks. Mapping by Spencer and Richard (1995) appears to be generally accurate. Bedding planes generally strike northeast and dip southeast; however, bedding in at least one of the blocks strikes northwest and dips southwest (**Photograph 11 and Figure 1**). Part of the lower Paleozoic sequence occurs in the subsurface below the Tertiary units in Bonanza exploration hole B-2 near Silver King Wash.

The Paleozoic sedimentary rocks likely have low hydraulic conductivity except where enhanced along bedding planes and fracture zones. The pre-Tertiary units such as the Paleozoic sedimentary rocks occur in a series discrete fault blocks south of the Roblas Canyon Fault and display a moderate to high degree of fracturing. Where fractured, the Paleozoic sedimentary rocks likely have high hydraulic conductivity; however, the many fault blocks are laterally discontinuous and highly compartmentalized making the units unsuitable as an aquifer in the Near West area.

Me – Escabrosa Limestone (Mississippian)

The Escabrosa Limestone (Me) is a gray, thick bedded massive dolomitic limestone and limestone that forms prominent cliffs where exposed. The lower part of the Me is dolomitic and grades upward into slightly cherty fossiliferous limestone. The Me occurs southwest of the Roblas Canyon Fault in the south half of sec. 13, T. 1 S., R. 11 E. (**Photograph 11 and Figure 1**).

Photograph 11. View to the northwest showing Paleozoic fault blocks near Roblas Canyon Fault

Dm – Martin Formation (Devonian)

The Martin Formation (Dm) consists of a sequence of limestone, dolomite, and sandstone units, generally tan and gray, fossiliferous, and slightly cherty. Fossils include crinoids, brachiopods, and corals. The Dm occurs in several fault blocks exposed south of the Roblas Canyon Fault (**Figure 1**). **Photograph 12** shows an exposure of Dm in the NE1/4 sec. 24, T. 1 S., R. 11 E.

Photograph 12. Limestone bed in the Martin Formation (Dm) near Roblas Canyon Fault

Cb – Bolsa Quartzite (Cambrian)

The Bolsa Quartzite (Cb) is a brown to reddish brown, coarse to fine-grained, cross-bedded quartzite with blocky weathering habit. **Photograph 13** shows an exposure of Cb near the Roblas Canyon Fault in the NE1/4 sec. 24, T. 1 S., R. 11 E. The unit is commonly exposed in the fault blocks south of the Roblas Canyon Fault (**Figure 1**). The Cb rests depositionally on diabase of the underlying Apache Group in upper Roblas Canyon (Spencer and Richard, 1995).

Photograph 13. Brecciated Bolsa Quartzite (Cb) near Roblas Canyon Fault

Younger Precambrian sedimentary and igneous rocks

At the Near West site, the younger Precambrian rocks include the Apache Group and associated diabase of middle Proterozoic age. The Apache Group comprises an older sedimentary sequence and younger intrusive diabase. The younger Precambrian rocks crop out north of Happy Camp and in Whitford Canyon between the Concentrator and Roblas Canyon Faults, and in Roblas and Hewitt Canyons south of the Roblas Canyon Fault. In the Happy Camp and Whitford Canyon areas, bedding planes generally strike northeast and dip southeast. In the Roblas and Hewitt Canyon areas, strikes and dips are more variable due to complex faulting (**Figure 1**). The younger Precambrian sequence occurs in the subsurface below the Tertiary and Paleozoic units in the Bonanza and Arnett Creek exploration holes (B and AC holes) near Queen Creek.

Mapping by Spencer and Richard (1995) appears to be generally accurate; however, many of the small fault blocks near Roblas Canyon fault, and in Bear Tank Canyon and its tributaries, are not mapped in complete detail. For example, near the Roblas Canyon Fault

(NE1/4 sec. 24, T. 1 S., R. 12 E.), a fault block is mapped as diabase but also contains mineralized Mescal Limestone. Loss of detail in mapping may be due to small scale of some of the unmapped features in complexly faulted areas.

The younger Precambrian rocks likely have low hydraulic conductivity except where enhanced along bedding planes and fracture zones. The pre-Tertiary units, including the Paleozoic and younger Precambrian rocks, occur in a series discrete fault blocks south of the Roblas Canyon and Concentrator Faults and display a moderate to high degree of fracturing. Where fractured, the younger Precambrian sedimentary rocks likely have high hydraulic conductivity; however, the many fault blocks are laterally discontinuous and highly compartmentalized making the units unsuitable as an aquifer in the Near West area.

Yd – Diabase (middle Proterozoic)

The younger Precambrian diabase (Yd) generally has sub-ophitic texture with abundant whitish plagioclase crystals in a green to black pyroxene groundmass. The texture varies from aphanitic to phaneritic. The Yd is generally highly fractured and deeply weathered and forms a characteristic red-brown soil with rare rock outcrop. Outcrops typically occur in drainages and along road cuts. The Yd intruded the younger Precambrian sedimentary sequence as a series of dikes and sills (**Figure 1**). **Photograph 14** shows an exposure of Yd in an unnamed tributary in the SW1/4 sec. 26, T. 1 S., R. 11 E. The Yd is relatively widespread, generally highly fractured, and deeply weathered across the Near West site. Because of the degree of weathering and presence of clay, it likely has low hydraulic conductivity.

Photograph 14. Diabase (Yd) in a Bear Tank Canyon tributary

Ym – Mescal Limestone (middle Proterozoic)

The Mescal Limestone (Ym) is a light gray massive to wavy laminated limestone. It is the uppermost sedimentary unit of the Apache Group at Near West site (**Figure 1**). Most exposures of Ym display a high degree of fracturing. **Photograph 15** shows an exposure of Ym north of Happy Camp in the SE1/4 sec. 21, T. 1 S., R. 12 E.

Photograph 15. Mescal Limestone (Ym) in Happy Camp Canyon

Yds – Dripping Spring Quartzite (middle Proterozoic)

The Dripping Spring Quartzite (Yds, undivided) includes an upper (Ydsu) and lower unit (Ydsl); the lower unit has a distinctive basal conglomerate (Ydsb; Barnes Conglomerate) that forms a regional marker bed. The outcrop area is shown on **Figure 1**.

The Ydsu is characterized by reddish brown to black, thin bedded to laminated, fine-grained sandstone, siltstone, and argillite. Light tan or gray reduction spots, similar to those in the Pioneer Formation, occur in the Ydsu but are larger in diameter and less abundant. Also common to the Ydsu are Liesegang bands. **Photograph 16** shows an exposure of Ydsu in Whitford Canyon with ripple marks and mudcracks in the east center of sec. 21, T. 1 S., R. 12 E.

Photograph 16. Upper Dripping Spring Quartzite (Ydsu) in Whitford Canyon

The Ydsl is characterized by tan to pink medium to thin bedded feldspathic quartz arenite or feldspathic quartzite. Cross-bedding is common in the Ydsl. **Photograph 17** shows an exposure of Ydsu in Whitford Canyon in the east center of sec. 21, T. 1 S., R. 12 E. Most exposures of Yds display a high degree of fracturing.

Photograph 17. Lower Dripping Spring Quartzite (Ydsl) in Whitford Canyon

Yp – Pioneer Formation – (middle Proterozoic)

The Pioneer Formation (Yp) is a reddish brown to purple siltstone to fine-grained sandstone. The outcrop area is shown on **Figure 1**. The Yp is characterized by ubiquitous light gray circular reduction spots. **Photograph 18** shows the Ydsl, Ydsb, and Yp contacts in Whitford Canyon in the SE1/4 sec. 20, T. 1 S., R. 12 E. Most exposures of Yp display a high degree of fracturing. Where fractured, the Yp likely has high hydraulic conductivity.

Photograph 18. Pioneer Formation (Yp) in Whitford Canyon

Older Precambrian metamorphic rocks

The older Precambrian Pinal Schist is the oldest geologic unit in the Superior basin and forms the basement bedrock unit at Near West site. The Pinal Schist crops out in the north, south, and west parts of the site (**Figure 1**). Foliation generally strikes east-northeast and dips south-southeast, although localized variations are common. The protolith for the Pinal Schist is believed to be sedimentary (Spencer and Richard, 1995). Mapping of the Pinal Schist by Spencer and Richard (1995) appears to be generally accurate; however, in the vicinity of the Roblas Canyon Fault in sec. 19, T. 1 S., R. 12 E., the schist crops out along the road in an area mapped as undivided Quaternary sediments (Qs). The Pinal Schist likely has low hydraulic conductivity except where enhanced along fracture zones. The Pinal Schist generally displays a moderate to high degree of fracturing.

Xp – Pinal Schist (early Proterozoic)

Spencer and Richard (1995) indicate that the northern exposures are generally pelitic schist (Xps) while the southern exposures are psammitic schist (Xpm). Calc-silicate (Xpc), calc-silicate and schist (Xpcs), and quartzite (Xpq) facies were mapped in the zone between the Concentrator and Roblas Canyon Faults northwest of Whitford Canyon, and a phyllite facies (Xpp) was mapped south of Queen Creek (**Figure 1**). In the northern exposures, lineation of mineral grains is more obvious and the schist is more highly foliated. The schist is characterized by compositional banding which reflects a combination of metamorphic differentiation and original bedding (Spencer and Richard, 1995).

Exposures of the Xpm in the southern part of the site are typically dense, foliated, gray schist with silty to sandy texture, slightly micaceous sheen, and common quartz veining. **Photograph 19** shows an exposure of Xpm in Roblas Canyon in the NE1/4 sec. 27, T. 1 S., R. 11 E., near proposed drill site DS-L. Exposures of the Xpc in the north half of sec. 19, T. 1 S., R. 12 E. are typically dense, foliated, greenish gray to greenish black schist with common epidote and chlorite.

Photograph 19. Pinal Schist (psammitic facies) (Xpm) in Roblas Canyon

Geologic Structures

Outcrops of selected structures at the Near West site were inspected and documented. The largest mapped structure in the Near West area is the Roblas Canyon Fault, a fault related to the Concentrator Fault east of Superior. The Roblas Canyon and Concentrator Faults are associated with regional Oligo-Miocene extensional faulting. Faulting began during deposition of the Tw (Whitetail Formation), extended through mid-Tertiary volcanism (Superstition Group), and ended during deposition of the Tcg (Gila Group conglomerate) (Spencer and Richard, 1995).

The relationship between the Roblas Canyon and Concentrator Faults is poorly understood; however, two possible interpretations are being considered. The first interpretation assumes that Concentrator and Roblas Canyon Faults are two parts of one fault system, with a zone of accommodation where faulting shifts from the Concentrator Fault to the Roblas Canyon

Fault. The zone of accommodation occurs between Whitford and Happy Camp Canyons north of Barnett Camp and Happy Camp (**Figure 1**). Maximum displacement appears to be at the northernmost part of the Concentrator Fault and at the southernmost part of the Roblas Canyon Fault. The second interpretation, based on the Resolution Vulcan model, assumes that the Roblas Canyon Fault is the northwest extension of the Wood Canyon Fault. Drilling during Phase III field investigations may help to clarify which of the two interpretations is more likely.

Numerous faults are mapped in the western part of the site where the Tcg is absent and a complex series of fault blocks is exposed. Data from the Bonanza and Arnett Creek exploration holes (B and AC holes) suggest a similar set of faulted blocks underlies the Tcg in the central part of the Near West site where the Tertiary volcanic, Paleozoic sedimentary, and younger Precambrian sedimentary rocks were encountered in the subsurface beneath the Tertiary sedimentary cover. Also, the area of Whitford Canyon between the Concentrator and Roblas Canyon Faults contains numerous faults that are related to and generally parallel to the two major faults.

Roblas Canyon Fault

The Roblas Canyon Fault is a major structure near the northern extent of the proposed tailings footprint. This fault is a high-angle normal fault that strikes generally northwest and dips southwest (**Figure 1**). Rock units southwest of the fault were down dropped relative to the units northeast of the fault. The Roblas Canyon Fault is related to the Concentrator Fault to the east (Spencer and Richard, 1995) but the nature of the relationship is poorly understood at this time.

Displacement along the Roblas-Concentrator fault system was estimated based on displacement of the Tal. The White Unit at the top of the Tal on Apache Leap, east of the Concentrator fault, crops out at an elevation of about 1,460 m above mean sea level (amsl). The Tal White Unit crops out in the southwestern portion of the proposed tailings impoundment at an elevation of about 800 m amsl. Assuming that the elevation of the Tal north of the Roblas Canyon Fault was similar to the elevation of the Tal east of the Concentrator Fault prior to movement on the faults, this represents a displacement of approximately 660 m. In the Bonanza and Arnett Creek exploration holes and monitor well DHRES-05 (about 2 to 6 km west of the Concentrator Fault), the top of the Tal occurs at elevations ranging from about 550 m amsl at AC-1 to 100 m below mean sea level at DHRES-05. This represents a displacement of approximately 900 to more than 1,500 m.

Rock units adjacent to the Roblas Canyon Fault are generally highly sheared compared with exposures away from the fault. The fault is exposed in younger Precambrian diabase (Yd) in sec. 29, T. 1 S., R. 12 E. near Barnett Camp (**Figure 1**). Fault gouge and slickensides were observed at this location and fault plane strike and dip were measured at N28°W 77°SW. **Photograph 20** shows Yd gouge in the Roblas Canyon Fault in the east center of sec. 29, T. 1 S., R. 12 E. **Photograph 21** shows slickensides in the fault zone.

Photograph 20. Fault gouge in diabase (Yd) near Barnett Camp

Photograph 21. Slickensides in diabase (Yd) along Roblas Canyon Fault near Barnett Camp

Outcrops of the Roblas Canyon Fault were inspected in sec. 13 and 24, T. 1 S., R. 11 E. Near the head of Roblas Canyon in the SE1/4 sec. 13, T. 1 S., R. 11 E., the Xps (pelitic facies of Pinal Schist) east of the fault is highly sheared and secondary copper oxides occur in the shear zone. The younger Precambrian units adjacent to the fault are highly sheared as well. **Photograph 22** shows highly sheared Ydsl (lower Dripping Springs Quartzite) in the fault zone in the NE1/4 sec. 24, T. 1 S., R. 11 E.

Photograph 22. Sheared lower Dripping Spring Quartzite (Ydsl) near Barnett Camp

Fault gouge was observed in a fault contact between Xpm and Xpc (psammitic and calc-silicate facies of Pinal Schist) in the east center of sec. 19, T. 1 S., R. 12 E. in the zone between the Roblas Canyon and Concentrator Faults. **Photograph 23** shows the fault contact.

Photograph 23. Fault gouge in Pinal Schist (Xpm / Xpc contact)

Fractures within the Tertiary conglomerate (Tcg)

Mapping by Spencer and Richard (1995) shows few faults within the Tcg at the Near West site. Most of the faults mapped within the Tcg occur in the southwest part of the site. Joints and fractures within the Tcg are relatively uncommon, but where present, they are often enhanced by weathering. A large open fracture with strike and dip of N10°W 86°NE was observed in Bear Tank Canyon in the NE1/4 sec. 35, T. 1 S., R. 11 E.; **Photograph 24** shows this fracture. Material on the east side of the fracture appears to be cemented gouge. If there is displacement along this apparent structure, it is not obvious due to the nature of the conglomerate. The outcrops on either side of the feature are very similar.

Photograph 24. View to the north-northwest of fracture in Tertiary conglomerate (Tcg) in Bear Tank Canyon

Jointing within the Tcg was observed in exposures in the drainages. Jointing generally consists of relatively continuous small-aperture breaks without offset on either side of the break. Joints are best preserved in finer-grained sub-units of the Tcg. Sparse joints in the Tcg were observed in Happy Camp Canyon upstream from the headwall of the spring. A small-aperture joint in the SW1/4 sec. 28, T. 1 S., R. 12 E. strikes N44°W and dips 53°SW and is shown on **Photograph 25**. Other joints in the vicinity strike N65°E with steep dip to the SE.

Photograph 25. Joint in Tertiary conglomerate (Tcg) in Happy Camp Canyon

Compared to other geologic units exposed at Near West site, the Tcg has fewer apparent faults and fractures. This is due to the fact that the Tcg has not been highly deformed following deposition, the Tcg is more ductile than other geologic units, and fractures in the Tcg are not well exposed. Joints within the Tcg lack an obvious preferred orientation

Anticline in upper Dripping Spring Quartzite (Ydsu)

An anticlinal fold was observed in an unnamed drainage about 3/4 mile from the confluence with Queen Creek in the SE1/4 sec. 26, T. 1 S., R. 11 E. The unmapped fold is a small-scale feature and is shown on **Photograph 26**.

Photograph 26. Fold in Dripping Spring Quartzite (Ydsu)

SPRING SURVEY

The USGS Picketpost Mountain 7-1/2' Quadrangle (2004 edition) shows four springs in the vicinity of the Near West site. These include Happy Camp, Benson, and Perlite Springs and an unnamed spring in Bear Tank Canyon, referred to herein as Bear Tank Canyon Spring. Water samples were collected at Happy Camp and Bear Tank Canyon Springs, but not at Benson or Perlite Springs which were not discharging at the time of the survey. Water samples were analyzed for common and trace constituents, routine parameters, radiological parameters, stable isotopes, and radioactive/radiogenic isotopes. The analytical suite is summarized in **Table 1**; analytical results are summarized in **Appendix A**; **Tables A-1 through A-5**. At the time of report preparation strontium results had not been received.

Water quality parameters (temperature, pH, and specific conductance) were measured and recorded using a Myron-L parameter meter that was calibrated prior to sampling. Sample identifiers and water quality parameters for samples collected are provided in **Table 2**.

TABLE 2. FIELD PARAMETERS FOR WATER SAMPLES COLLECTED FROM SPRINGS						
				Field Parameters		
Sample Identifier	Sample Location	Date	Time	Temp (°C)	pH	Specific Conductance (µS/cm)
RESE-1003083	Happy Camp Spring	18-Feb-13	12:30	23.5	7.28	800
RESE-1003084	Bear Tank Canyon Spring	18-Feb-13	16:40	21.0	7.27	710

Happy Camp Spring

Happy Camp Spring is located on the floor of Happy Camp Canyon in SW1/4 sec. 28, T. 1 S., R. 12 E. (GPS: 486842 m E, 3685573 m N, WGS84), and is shown on **Photograph 27**. The spring occurs in the Tertiary conglomerate (Tcg) near the contact with Tertiary tuff (Tt) and younger Precambrian diabase (Yd). There are no faults mapped in the immediate vicinity of the spring, and no major joints were observed; however, Happy Camp Spring is located on the alignment with the Roblas Canyon Fault. If the fault is concealed beneath the Tertiary cover, there may be enhanced permeability due to fracturing in the Tcg at this location.

Photograph 27. Happy Camp Spring, February 18, 2013

Happy Camp Spring was visited on February 11, 12, and 18, 2013. Large trees and other riparian vegetation occur in the vicinity of the spring. The spring is developed with a concrete headwall to retain seepage and a black polyvinyl pipe that extends from behind the headwall to a stock pond located downstream approximately 600 feet. On February 11 and 12, flow was observed in the Happy Camp Canyon streambed upstream from the headwall, however, there was no flow observed above the headwall on February 18. Seepage was observed at the headwall and along the sides of the canyon below the headwall on all three dates.

On February 18, spring discharge rate was measured at the pipe at the stock pond using a 1-liter container and a stopwatch, and a water sample was collected. Discharge rate was 0.006 liters per second (L/s), (0.09 gallons per minute [gpm]).

Benson Spring

Benson Spring is located in the drainage of Benson Spring Canyon in the east-center of sec. 35, T. 1 S., R. 11 E. (GPS: 481593 m E, 3684540 m N, WGS84), and is shown on **Photograph 28**. The spring occurs in the Tcg approximately 200 feet upstream from the contact between the Tcg and Pinal Schist (Xpm).

Photograph 28. Benson Spring, February 12, 2013

Benson Spring was visited on February 11, 12, and 18, 2013. At the time of survey, three separate ponds occurred in the drainage. Large trees and riparian vegetation occur in the vicinity of the spring. There was no obvious seepage, but it appears that seepage occurs along a contact between an upper competent conglomerate bed and a lower weakly lithified tuff or tuffaceous sandstone bed. The spring area was enclosed with a metal fence in April 2001 by Arizona Game and Fish Department, TNF, and the Arizona Bowhunters Association. The enclosure was developed to protect the spring. A metal sign on the fence indicates that Bill Martin was a major contributor to the effort to protect the spring area. To the southeast of the area shown on **Photograph 28**, an area along the contact had been excavated, and a concrete headwall was installed downstream from the excavation to retain seepage along the contact. Black polyvinyl pipe was installed to convey water from the excavated area to stock tanks and ponds located downstream. Remnants of a pump are visible behind the concrete headwall. The developed area is shown on **Photograph 29**.

Photograph 29. Benson Spring developed area, February 12, 2013

The metal fence surrounding the spring area is partially collapsed and the area around the ponds has been impacted by cattle, evidenced by the presence of hoof prints and piles of dung. Water quality parameters were measured at selected ponds in the vicinity of the spring and are summarized in **Table 3**.

TABLE 3. SUMMARY OF WATER QUALITY PARAMETERS MEASURED IN THE BENSON SPRING AREA			
Location Description	Temperature (°Celsius)	pH	Specific Conductance (µS/cm)
Main uppermost pond, east side	20.2	8.57	224.4
Main uppermost pond, west side	20.8	8.41	224.3
Isolated pool, downstream from main pond	11.6	7.77	578
Lowermost pond	20.0	7.54	2,119

Precipitation prior to the time of inspection likely contributed a runoff component to the ponds in the Benson Spring area. The lowermost pond contained an orange-brown colloidal material near the head of the pond, the water had a tannic appearance, and the surface of the pond had a crackled metallic sheen. These characteristics and the elevated specific conductance suggest that the lowermost pond was stagnant at the time of the survey. Because seepage to the main uppermost pond was not observed, and because water quality parameters were highly variable in other ponds in the vicinity of the spring, a water sample was not collected. RCM personnel will inspect the site during quarterly monitoring rounds to determine if baseflow is evident. No flow was observed in Benson Spring Creek upstream from the main uppermost pool, but alluvium in the creek bed was moist following recent precipitation.

Bear Tank Canyon Spring

Bear Tank Canyon Spring is located in the drainage of Bear Tank Canyon in SE1/4 sec. 25, T. 1 S., R. 11 E. (GPS: 482383 m E, 3685658 m N, WGS84), and is shown on **Photograph 30**. The spring occurs in the Tcg. There are no faults mapped in the vicinity of the spring, and no major joints were observed. Inspection of aerial photographs shows a faint lineament extending west-northwest from the spring which may indicate a concealed structure such as a joint or fault that may provide enhanced permeability in the Tcg.

Photograph 30. Bear Tank Canyon Spring, uppermost pond, February 12, 2013

Bear Tank Canyon Spring was visited on February 12 and 18, 2013. A large pool occurs in the drainage, trees and riparian vegetation occur in the vicinity of the spring, and the floor of the creek below the main pond is covered by algae. There was no obvious seepage near the main pond, but it appears that seepage occurs between bedding planes in the Tcg. Downstream from the pond shown on **Photograph 30**, there are remnants of an old wall or dam on the west side of the channel. A steel pipe emits spring discharge from the conglomerate on the west side of the channel. The developed area is shown on **Photograph 31**.

Photograph 31. Bear Tank Canyon Spring outlet, February 12, 2013

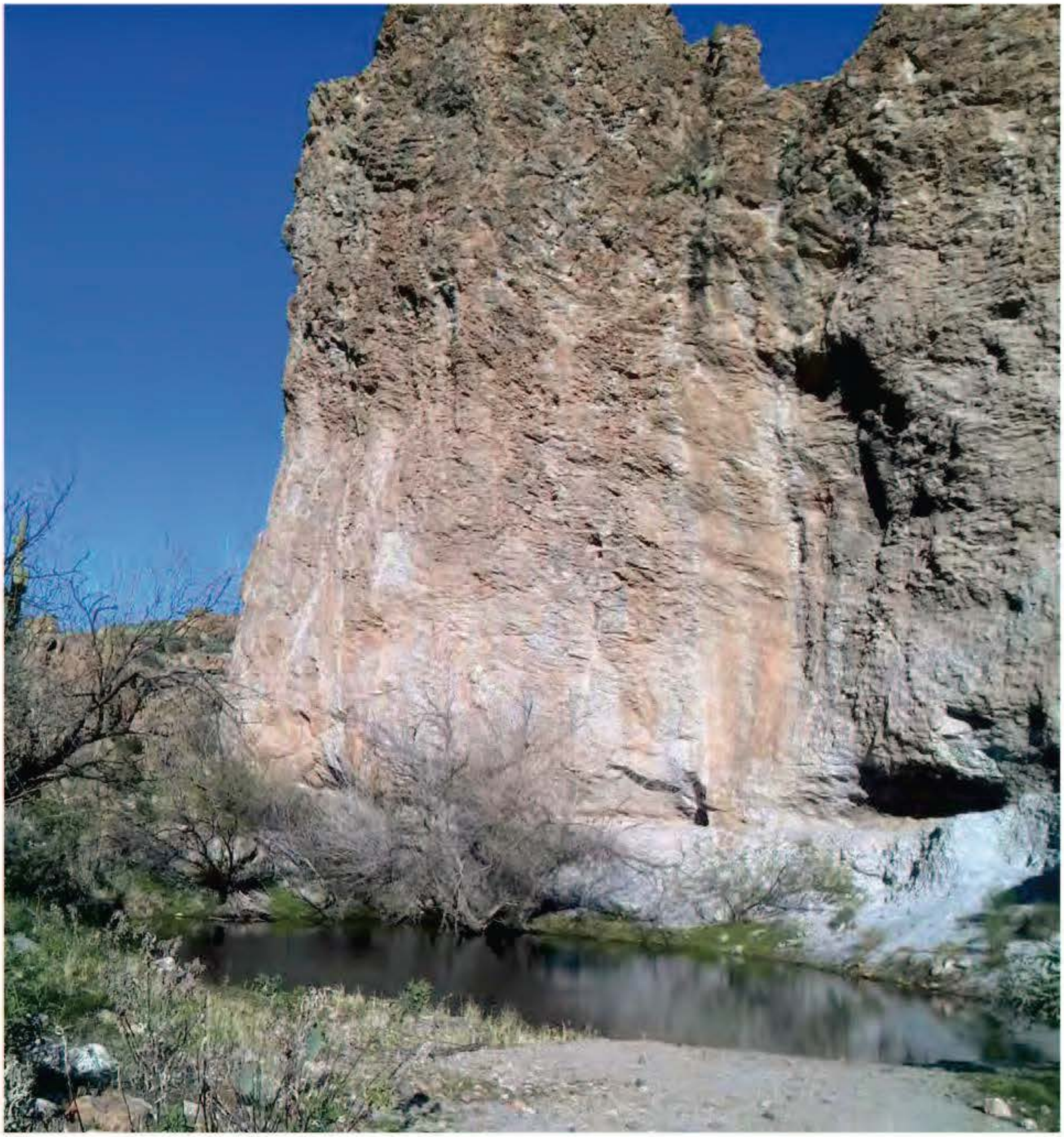
On February 12, flow was observed in Bear Tank Canyon Creek upstream from the main pond, however, there was no flow observed above the main pond on February 18. On February 18, spring discharge rate was measured at the outlet pipe using a 4-liter container and a stopwatch, and a water sample was collected. Discharge rate was 0.04 L/s (0.65 gpm).

Perlite pond area

The 2004 USGS Picketpost Mountain 7-1/2' topographic map has a feature labeled "Perlite Spring" in the SE1/4 sec. 19, T. 1 S., R. 12 E. The area was inspected on February 12 and 19, 2013. Historically, perlite was quarried in the area as evidenced by numerous prospect pits and excavations. Three ponds were present at the time of inspection, shown on **Photographs 32, 33, and 34**. **Photograph 35** shows the locations of the three ponds in the NE1/4 sec.30, and SE1/4 sec.19, T. 1 S., R. 12 E. All of the ponds occur on the surface of perlite outcrop. The uppermost pond (**Photograph 32**) is the location shown on the topographic map, and is behind an earthen berm. The area up drainage from the pond is partially cleared of vegetation from historic prospecting or mining. This area is covered by sparse desert vegetation with no indication of spring discharge. It is likely that the pond was constructed during historic mining operations to keep surface water runoff from entering the main quarry.

Photograph 32. Uppermost pond near perlite quarry (Perlite Spring?), February 19, 2013

Photograph 33. Middle pond, perlite quarry, February 19, 2013



Photograph 34. Lowermost pond, perlite quarry, February 19, 2013

Photograph 35. Locations of ponds in the vicinity of the perlite quarry, late 2012

The middle and lowermost ponds (**Photographs 33 and 34**) appear to be depressions created by historic quarrying that have become surface water runoff collection ponds. The lowermost pond (**Photograph 34**) has some large trees nearby, but there is no obvious inflow or seepage. The drainage near the head of the lowermost pond was inspected, but no flow or seepage was observed. A drill hole on the face of the cliff above the pond is indication that the overlying rhyolite was scaled away to expose the perlite for mining operations. Water quality parameters were measured at each pond and are summarized in **Table 4**.

TABLE 4. SUMMARY OF WATER QUALITY PARAMETERS MEASURED IN THE PERLITE PONDS AREA			
Location Description	Temperature (°Celsius)	pH	Specific Conductance (µS/cm)
Uppermost pond	17.5	8.61	148.2
Middle pond	14.1	8.44	110.2
Lowermost pond, northeast edge	10.1	6.86	268.0
Lowermost pond, south edge	9.8	7.19	267.5
Lowermost pond, north edge	9.9	7.30	267.3

Water in the uppermost and middle ponds has similar pH and specific conductance, while water in the lowermost pond has lower pH and higher specific conductance compared to the uppermost and middle ponds. Water in all three of the ponds has much lower specific conductance when compared with water from Happy Camp and Bear Tank Canyon Springs. Because seepage to the ponds was not observed, and because water quality parameters suggest that the ponds contain surface water runoff, water samples were not collected. RCM personnel will inspect the ponds during quarterly monitoring rounds to determine if baseflow is evident.

PILOT INFILTRATION TESTING

The primary purpose of the pilot infiltration testing program was to develop and evaluate a method that might be viable for determining infiltration capacity of exposed bedrock surfaces, and if successful, to obtain a preliminary indication of the potential infiltration rates and infiltration characteristics of selected bedrock types at the Near West site. The scope of the pilot program was intentionally limited, and only a few rock types and conditions were tested. Therefore, the pilot test results are not intended to support a reliable evaluation of surface infiltration rates across the site, but to identify considerations for developing the infiltration testing approach for the future full-scale testing program.

The surface geology of the Near West site consists chiefly of consolidated bedrock, overlain in many areas by a very thin veneer (<0.1 m) of unconsolidated material consisting of weathered bedrock, colluvium, and/or alluvium (**Figure 1**). Portions of the Near West site with a more substantial thickness of surficial unconsolidated material include areas mapped as unconsolidated alluvium or undivided surficial deposits along the modern drainages (Qal and Qs) and ridges of older alluvium (Qoa and QTs). Some ridge tops mapped as Tertiary conglomerate (Tcg), and areas in the eastern part of the site mapped as diabase (Yd), may also have a notable thickness of weathered bedrock ("regolith").

Many of the initially proposed trenches and infiltration test sites for the Near West site were located in the areas where bedrock is exposed at the surface or beneath a thin veneer of unconsolidated material. In these areas, trenching to any significant depth is not possible, and infiltration testing cannot be conducted using the more typical ring-infiltrometer method and/or downhole constant-head permeameter method without driving the infiltrometer rings or drilling a small borehole into the test surface. **Section 4.5** of the M&A report on Phase II hydrogeologic investigations for the Far West site (M&A, 2012a) provides a description of these more typical test methods. To obtain estimates of infiltration capacity for the bedrock areas of the Near West site, other infiltration test methods were investigated and a pilot infiltration testing program was conducted. The pilot infiltration testing program did not target those portions of the Near West site that have a significant thickness of surficial unconsolidated material, where the more typical infiltration test methods could be used.

Infiltration Test Method and Approach

The infiltration testing program targeted chiefly competent bedrock surfaces; some of the test surfaces included fine fractures (surface aperture of approximately 0.5 to 1.0 millimeter, although one test surface included a fracture with an aperture of approximately 1 cm), while other test surfaces appeared to be devoid of any fractures within the test footprint. In general, the test surfaces were selected to avoid large fractures that would allow rapid infiltration during a small-scale test. Rapid surface infiltration rates caused by large fractures in exposed rock outcrops would not be expected to represent infiltration characteristics of the rock body at larger depths. One test was conducted in highly weathered/decomposed conglomerate.

Based on review of potential infiltration test methods and equipment described in scientific journals and evaluation of their applicability to bedrock outcrops, the method determined to be appropriate for the pilot testing at the Near West site was a variation of the ring-infiltrometer method referred to as the "bottomless bucket" (BB) method (Nimmo and others, 2009; Mirus and Perkins, 2012). The BB method comprises the use of light-weight plastic buckets (with the bottoms removed) that can be sealed to a hard test surface (such as exposed bedrock) using common sealants. The bucket diameter should be relatively small, typically less than 15 cm; however, for the tests at the Near West site, a 5-gallon bucket with an inside diameter of 27 cm was used (infiltration area of 573 square cm or 0.057 square m). Due to the portable nature of the buckets and the generally small water supply needed for this application, this method is particularly useful for remote settings where access to test sites might require travel on foot. In addition, the bottom edge of a bucket can be modified/cut as needed to better fit the test surface. The BB test method is conducted as a falling-head test; the test results are used in an analytical solution to calculate field-saturated hydraulic conductivity (Ksat).

Because trenching or test pit excavation is not typically involved (or possible) and because the bucket is sealed to the test surface with little or no disruption of the surface, the BB tests have negligible impact on the test site. In addition, the health and safety concerns related to backhoe use, working in trenches/pits, and use of power tools are avoided.

Bottomless Bucket Test Procedures

As described previously, the BB method is essentially a ring-infiltrometer (Bouwer, 1986), but the bucket is sealed to the rock surface instead of being driven into the test zone. The BB method is similar to the "modified single-ring tests" conducted in carbonate-cemented (caliche) layers at the Far West site (M&A, 2012a). The test procedure consists of the following steps:

1. For each rock type to be tested, relevant outcrops were searched and one or two surfaces were selected that were judged to be reasonably representative of the bedrock unit as it likely occurs a few cm below the surface so that the infiltrating water is not simply moving laterally in only the top cm or two of the outcrop, whether in fractures or decomposed material. The test surface conditions were then described (degree of weathering and/or fracturing) and photographed.

2. For each of the selected test surfaces, the BB was placed and modified if necessary to conform to the bedrock surface.

    - All but one of the test surfaces consisted of competent bedrock (some were finely fractured). A relatively flat area was delineated and any loose sediment was swept off the surface.

    - For two tests, the surface was relatively rough or rugged. The BB was placed on the test surface and maneuvered to find the best fit possible, but substantial gaps still existed between portions of the bottom edge of the BB and the test surface due to irregularities of the surface. The bottom edge was then trimmed as necessary to reduce the gaps and improve the fit to the rock surface to the extent practicable. Note that the rock surface could be slightly sloped; the critical consideration was relative flatness.

    - One of the test surfaces consisted of weathered/decomposed rock (Gila Conglomerate). The test surface was prepared by shoveling and picking to a shallow depth (approximately 10 cm) to expose a relatively hard and level layer. Although the test surface was not competent bedrock, it was also not amenable for driving in steel rings as used for the standard ring-infiltrometer test.

3. The bottom edge of the BB was carefully sealed to the test surface using a quick-setting silicone sealant; an ample bead of sealant was used but was applied chiefly to the outside of the BB so that the sealant did not overlap onto a significant area inside the BB. After allowing approximately 30 minutes for curing, a small amount of water was added to the inside of the BB to check for leaks in the seal.

- For several test sites, leak points were noted, and it was necessary to place additional sealant and/or hydrated bentonite at leak points to secure the seal and stop all leaks.

- For the single infiltration test conducted in weathered/decomposed Gila Conglomerate, hydrated bentonite was used to seal the BB to the rock surface by packing around the outside edge of the BB because the silicone sealant did not adhere well to the weathered rock test surface.

4. A graduated fiberglass tape was installed on the inside wall of the BB to serve as a staff gage for water level measurements. For the purposes of the present pilot infiltration testing, which consisted of relatively short-duration tests, the graduated tape provided a sufficient means for measuring water level decline during the test. However, for future testing, a pressure transducer may be placed inside the BB to provide the primary and/or back-up water level measurements, and would be relied on for tests that are conducted for extensive periods (including overnight), when it is not practical to have continuous field staff oversight and manual measurements.

5. The infiltration test was started by carefully adding water inside the BB to achieve a relatively small head (water height) of approximately 9 cm (three of the tests had somewhat smaller or larger initial heads); a small head is used to prevent leakage and minimize the potential for lateral flow. The BB infiltration test was conducted as a falling-head test by measuring water level decline with time (infiltration rate). Because a primary purpose of the pilot infiltration testing program was to evaluate the viability of the test method and set-up, many of the tests were intentionally of short duration and most tests exhibited very little, if any, water level decline. Therefore, only one falling-head cycle was conducted. For future infiltration testing using the BB method, if significant water level decline occurs due to infiltration, the water level would be allowed to decline to just above the test surface, followed by addition of more water inside the BB to initiate another falling-head cycle. Depending on the infiltration rate, two or more falling-head cycles could potentially be conducted to confirm achievement of a steady infiltration rate.

6. During conduct of the tests, any sign of leakage and/or lateral wetting around the BB footprint was carefully monitored and recorded. It is important to distinguish leakage (undesired movement of water through the BB-to-rock seal) from lateral wetting, which is the radial movement of infiltrating water in the near-surface rock matrix and/or fine fractures away from the edge of the BB.

    - For three of the BB tests, minor leakage was observed shortly after commencement of the test but was successfully stopped by packing more bentonite around the outer edge of the BB (the silicone sealant could not be used at this point because it would not adhere to the wetted rock surface).

- Although the initial minor leakage was easily corrected for these pilot tests, if leakage would have been persistent and difficult to completely stop, the best course of action would have been to terminate the test and prepare a new test set-up rather than to continue patching while trying to distinguish if the leakage has actually stopped.

7. During conduct of the tests, a lid was placed on the top of the bucket to minimize evaporation loss and to prevent introduction of any windblown material. As described previously, for future testing, the test duration could be extensive due to the very small permeability anticipated for many of the rock types that would be tested. Although not implemented for the pilot testing program, for future tests that would be allowed to run overnight and/or without constant oversight by field staff, it might be necessary to install a protective enclosure over the test set-up to prevent encroachment by animals.

8. Following completion of each test, the BB was removed from the test surface and relevant observations regarding the test surface conditions were recorded (e.g. if a weathered surface might have disaggregated or softened). Excess sealant was also removed from the test surface by peeling and/or scraping. For most of the pilot tests conducted, there was no ability to "excavate" into the rock surface for potential determination of a subsurface wetting pattern. However, for these tests (on competent bedrock surfaces), there was negligible (or no) infiltration measured, so subsurface wetting was not relevant. For the one test conducted in the weathered/decomposed Gila Conglomerate, the post-test surface was excavated/dissected by hand shoveling to observe and document the subsurface wetting pattern.

9. The measured infiltration rates were used in an analytical equation to compute Ksat. The analytical solution is based on an empirical "soil factor" that accounts for capillary (unsaturated) flow, and results in a Ksat value that is theoretically representative chiefly of vertical flow. However, the computed Ksat value is more accurately a composite Ksat of 3-dimensional flow, with both horizontal and vertical components. Although use of the empirical "soil factor" introduces some uncertainty in the computed Ksat values, the analytical solution is not highly sensitive to the empirical factor.

Summary of Bottomless Bucket Test Results

On February 18 and 19, 2013, a total of eight BB infiltration tests were conducted on selected rock types at five different locations in the west part of the Near West site; locations for the tests are shown on **Figure 3**. The test sites were located and the tests were set up and conducted by two M&A field geologists with assistance by a RCM field geologist. The following locations and rock surfaces were tested:

- At each of two locations, near Benson Spring and in Bear Tank Canyon approximately 250 m downstream (south) from Bear Tank Canyon Spring, two tests were conducted in close proximity on Gila Conglomerate (Tcg) outcrops within an active stream bed; the two test sites at each location had differing surface characteristics.

- At a location approximately 400 m east of Benson Spring, two tests were conducted on basalt (Tb) outcrops within and adjacent to an active stream bed; the two test sites had differing surface characteristics.

- At a location in Roblas Canyon near the Roblas Windmill, one test was conducted on an elevated outcrop of Apache Leap Tuff vitrophyre of (Talv).

- At a location in Roblas Canyon approximately 500 m south of the Roblas windmill, one test was conducted on an outcrop of Pinal Schist (Xpm) within an active stream bed.

A summary of the BB test sites, rock types, and surface characteristics is given in **Table 5**. Photographic documentation of all the BB tests is provided in **Appendix B**. Relevant results and considerations for the eight BB infiltration tests are summarized as follows:

- Seven of the eight tests were conducted on hard, competent bedrock surfaces (the exception is BB-5, conducted in highly weathered/decomposed Gila Conglomerate) (**Appendix B**). For six of these seven tests (excludes BB-3), which were conducted on outcrops of basalt (Tb), Vitrophyre of Apache Leap Tuff (Tal), Pinal Schist (Xp), and Gila Conglomerate (Tcg), only a trace amount of infiltration was measured. The appropriate analytical solution was used to compute Ksat values for these tests, as given and described in the last column of **Table 5**; computed Ksat ranged from 0.1 to 0.8 centimeters per day (cm/day), although the short-duration test at site BB-8 had no measureable infiltration. The quantification of these very small values may be of questionable accuracy or resolution, particularly due to the inability to inspect the post-test subsurface wetting pattern. In addition, the lateral capillary flow observed in the rock matrix surrounding the sealed bucket, and the associated evaporation from this wetted area, was believed to account for the majority of the measured infiltration. Therefore, for these six tests with very small measured Ksat values (all less than 1.0 cm/day), the actual Ksat is believed to be smaller than measured, and the test result is reported as "less than the measured value" in **Table 5**.

- For the test at site BB-8 (on Pinal Schist outcrop [Xpm]), no infiltration was measured during the short-duration test (1 hour), even though the test surface included fractures, one of which had a surface aperture of approximately 1 cm. The Ksat value for the test would technically be "0" (impermeable); however, if the test duration would have been longer, a very small amount of infiltration might have occurred. Due to the short test duration, the Ksat value for this test is reported to be "negligible" in **Table 5**. For comparison, the the Ksat value determined for a downhole injection test conducted in Pinal Schist at the Far West site (piezometer FW-5S) was 3.5×10^{-6} centimeters per second (M&A, 2012a), which is equal to 0.3 cm/day.

- As described previously, Ksat values for the BB tests are computed based on measured infiltration using an analytical equation that accounts for capillary flow based on an empirical "soil factor", resulting in a Ksat value that is theoretically representative chiefly of vertical flow. However, it is important to reiterate that the computed Ksat is more accurately a composite Ksat of 3-dimensional flow with both horizontal and vertical components). Furthermore, for highly fractured surfaces (such as test BB-3, described further below), the horizontal Ksat is clearly the dominant component

- For the six tests referenced above, both fractured and non-fractured surfaces were represented, although the fractured surfaces (sites BB-2 and BB-8) were selected based on having relatively fine fractures (surface aperture of approximately 0.5 to 1.0 millimeter, but one fracture had a surface aperture of approximately 1 cm). Because the infiltration test results for these two fractured surfaces indicated a very small Ksat **(Table 5)**, it was apparent that the fractures were shallow, very tight at larger depths, and/or not sufficiently connected to allow water to move a significant distance vertically or horizontally from the test surface.

- For test BB-3, which was conducted on a highly fractured basalt surface **(Appendix B)**, substantial lateral flow occurred within the surface fractures; the wetted rock surface extended up to 60 cm away from the outside edge of the bucket. Based on careful early-time monitoring of the test, leakage of water did not occur through the bucket-to-rock seal, and it is believed that all observed lateral flow was due to movement in the fractures. Because the vertical wetting pattern could not be determined following the test, the computed Ksat is an unknown composite of vertical and horizontal flow, but represents predominantly horizontal flow as would be expected based on the extensive surface (and likely shallow) fracturing. If vertical Ksat would have been significant, the magnitude of infiltration would be expected to have been larger than measured (there was only 6 cm of total infiltration during the 16-hour test) and the lateral flow/surface wetting (combined with evaporation from the wetted surface) could have accounted for most of the observed infiltration.

- Test BB-5 was conducted in highly weathered/decomposed Gila Conglomerate, and was the only test not conducted on a competent bedrock surface. The test surface (after clearing loose and/or easily excavated rock slabs and sediments) consisted of relatively hard but weathered/fractured rock (with weaker cementation than unweathered Gila Conglomerate) with horizontal bedding planes beneath the surface. This surface would not be amenable for driving in steel rings as used for the standard ring-infiltrometer test. During the test, there was substantial lateral flow together with notable vertical flow. The lateral flow was due to both capillary movement in the more weathered soil-like material and saturated flow along the subsurface bedding planes. The measured and reported Ksat is an unknown composite of vertical and horizontal flow, but is believed to be more influenced by horizontal flow.

Applicability of Bottomless Bucket Tests

Overall, the BB method provided a viable and appropriate means for measuring infiltration rates and Ksat of exposed bedrock surfaces. The method is very portable and relatively quick to set up, and due to the generally small infiltration capacity of most bedrock surfaces, a small water supply is needed. After trimming the bottom edge of the buckets to better fit the rock surfaces, the buckets were successfully sealed to the rock using silicone sealant, and could be augmented with bentonite, if needed, after the start of a test. For this pilot testing program, the BB's were successfully applied to several different rock types, including both smooth and relatively rough or rugged surfaces, to provide a water-tight seal. Although there is little basis of comparison for evaluating the accuracy of the BB test results, the generally very small Ksat values determined by these pilot tests on bedrock surfaces are consistent with the general magnitude of Ksat values that would be expected for these bedrock units.

Due to the limited scope of the pilot testing program, the duration of the BB tests was generally short and the infiltration rates could not be continuously monitored to provide a better data set for evaluating the change in infiltration rate with time. However, if the BB method would be employed in the future for full-scale testing, the test duration would be longer and monitoring would be more frequent. In addition, the use of pressure transducers installed inside the buckets for continuous water level monitoring would be considered. The primary challenge in using pressure transducers is that they would need to have a very high sensitivity/resolution to measure the typically very slight rates of water level decline during a test, and would have to be accurately corrected for barometric pressure changes (if a non-vented transducer is used); specialized transducers would likely be required. Other refinements to the BB method would be evaluated and pursued for a full-scale testing program, and it may also be necessary to construct protective enclosures around the test setup to prevent encroachment by animals for tests that would be conducted over-night or for several days.

The primary drawback of the BB method is that the applicability of the results depends on how well the test surfaces (exposed outcrops) represent the physical and hydraulic characteristics of the rock body at larger depths. Rock outcrops are exposed to forces of weathering and are likely more fractured and weathered than at larger depths, perhaps even at depths just a few centimeters below the surface. However, this limitation would apply to any surface test method and doesn't diminish the advantages of the BB method if measurements of Ksat on rock outcrops are desired. In addition, the scale of the BB method is small, and the test results will depend to some degree on the geologist's discretion in choosing/ delineating the test footprint on a rock outcrop. As described previously, for the purposes of this pilot testing program, test surfaces were selected to avoid large fractures that would clearly allow rapid infiltration during a small-scale test, since this would not be considered representative of larger-scale infiltration characteristics of the rock body at larger depths. As for all surface infiltration tests, a larger test surface or test pit would typically provide more representative results for hydraulic properties of the medium being tested. However, for the typically rugged and uneven surfaces of a rock outcrop, large-scale infiltration tests would be very difficult and time-consuming to set up so that leakage is prevented.

Another significant disadvantage of infiltration tests conducted on bedrock surfaces is the bedrock surface cannot be excavated, and therefore, there is no ability to determine the wetting pattern below the surface. Although a subsurface wetting pattern is not present or relevant for tests in which there is negligible infiltration, for tests where significant infiltration might occur (including tests such as BB-3 where there was large apparent lateral flow in extensive surface fractures), the inability to determine and document subsurface wetting is a potentially important limitation for confirming or delineating the relative contribution of vertical and lateral flow to the measured infiltration rate and computed Ksat.

CONCLUSIONS

The following conclusions are based on results of the Phase I hydrogeologic field investigations at the Near West site:

1. Geologic reconnaissance of the site indicates that published geologic maps are generally accurate, with some relatively minor exceptions at a local scale. Small-scale features were not always mapped locally, and small inconsistencies were noted along some of the traverses. Near the southwest corner of the proposed tailings impoundment, faulting was observed to be more complex than shown on the published geologic map.

2. Inspection of geologic units exposed at the site indicates that, with the exception of Quaternary alluvium along ephemeral stream channels, permeability for all geologic units at the site would be very small except where fractured. Fracturing of rock units was most evident along and adjacent to mapped faults in the northern part of the proposed tailings impoundment. However, some evidence of fracturing was also observed in the western and southwestern parts of the proposed tailings impoundment.

3. Results of the spring survey indicate the occurrence of very small, but measureable rates of groundwater discharge at Happy Camp Spring and Bear Tank Canyon Spring at the time of the survey in February 2013. Discharge was not observed at Benson Spring but evidence of spring discharge is present. Ponds in the "Perlite Spring" area appear to be surface water impoundments related to historic mining operations.

4. Results of pilot infiltration testing indicate that the BB method provided an appropriate means for measuring infiltration rates and Ksat of exposed bedrock surfaces. The generally very small Ksat values determined by these pilot tests are consistent with the general magnitude of Ksat values that would be expected for these bedrock units.

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TABLE 1. SUMMARY OF ANALYTICAL SUITE FOR GROUNDWATER AND SURFACE WATER SAMPLING RESOLUTION COPPER MINING LLC, PINAL COUNTY, ARIZONA

Routine Parameters		
pH	Temperature	
Electrical Conductivity (EC)	Total Dissolved Solids (TDS)	
Common Constituents		
Calcium (Ca)	Sulfate (SO_4)	
Magnesium (Mg)	Silica (SiO_2)	
Sodium (Na)	Bromide (Br)	
Potassium (K)	Fluoride (F)	
Chloride (Cl)	Nitrate (NO_3)	
Carbonate (CO_3)	Nitrite (NO_2)	
Bicarbonate (HCO_3)		
Trace Constituents		
Aluminum (Al)	Cobalt (Co)	Manganese (Mn)
Antimony (Sb)	Copper (Cu)	Nickel (Ni)
Arsenic (As)	Cyanide (CN)	Selenium (Se)
Barium (Ba)	Iron (Fe)	Silver (Ag)
Beryllium (Be)	Lead (Pb)	Sulfide (S)
Boron (B)	Mercury (Hg)	Thallium (Tl)
Cadmium (Cd)	Molybdenum (Mo)	Zinc (Zn)
Chromium (Cr)		
Radiological Consituents		
Gross Alpha	Radium-226 (^{226}Ra)	Uranium (U)
Gross Beta	Radium-228 (^{228}Ra)	
Stable Isotopes		
Oxygen-18 ($\delta^{18}O$) in water	Carbon-13 ($\delta^{13}C$) in dissolved inorganic carbon	Oxygen-18 in dissolved sulfate ($\delta 18O_{SO4}$)
Deuterium ($\delta^{2}H$) in water	Sulfur-34 ($\delta^{34}S$) in dissolved sulfate	
Radioisotopes		
Tritium (^{3}H)	Strontium (Sr)	Uranium-234 (^{234}U)
Carbon-14 (^{14}C)	Strontium-87/Strontium-86 ($^{87}Sr/^{86}Sr$)	Uranium-235 (^{235}U)
		Uranium-238 (^{238}U)

MONTGOMERY & ASSOCIATES

TABLE 5. SUMMARY OF PILOT INFILTRATION TESTS AND ROCK TYPES TESTED AT NEAR WEST TAILINGS SITE DURING PHASE 1 HYDROGEOLOGIC FIELD INVESTIGATIONS RESOLUTION COPPER COMPANY, SUPERIOR, ARIZONA

Infiltration Test Identifier	General Location	Mapped Geologic Unit (Spencer and others, 1998)	Rock Characteristics and Test Surface Conditions[a]	Ksat[b] cm/day[c]	Comments
BB-1	Benson Spring; outcrop in active stream channel	Gila Conglomerate Tcg (Pliocene to Late Miocene)	Hard, flat, non-fractured surface; fine-grained rock matrix with few, poorly sorted, subangular to rounded clasts up to 1 cm diameter	< 0.1[d]	Test was monitored for 2 hours with no infiltration, and then allowed to run overnight (total of 16 hours) during which time the computed (average) Ksat was 0.1 cm/day but was due chiefly to lateral capillary flow in the rock matrix (wetting noted around outside of BB)
BB-2	Benson Spring; outcrop in active stream channel	Gila Conglomerate Tcg (Pliocene to Late Miocene)	Hard, uneven, slightly fractured surface with poorly sorted, subangular to rounded clasts up to 10 cm diameter (test surface consists chiefly of gravel cemented in fine-grained matrix)	< 0.1[d]	Same comment and result as above for test BB-1
BB-3	Near Benson Spring; outcrop adjacent to active stream channel	Tertiary Basalt Tb (Miocene)	Hard, rough, highly fractured surface, but fracture depth appears shallow (1 to 2 cm); basalt has aphanitic texture with some feldspar phenocrysts and quartz/feldspar veins	4.5 (chiefly horizontal flow in fractures)	Test was monitored for 1.7 hours with a Ksat of 11.5 cm/day, and then allowed to run over night (total of 16.5 hours) during which time the computed (average) Ksat was 4.5 cm/day but was due chiefly if not entirely to near-surface lateral flow through the extensive fractures (wetting noted to distances up to 60 cm from outside edge of BB)
BB-4	Near Benson Spring; outcrop in active stream channel	Tertiary Basalt Tb (Miocene)	Hard, semi-smooth, non-fractured surface; basalt has aphanitic texture with some feldspar phenocrysts	< 0.8[d]	Test was monitored for 1.5 hours with a Ksat of 2.3 cm/day, and then allowed to run over night (total of 16.5 hours) during which time the computed (average) Ksat was 0.8 cm/day but was due chiefly to lateral capillary flow in the rock matrix (wetting noted around outside of BB)

TABLE 5. SUMMARY OF PILOT INFILTRATION TESTS AND ROCK TYPES TESTED AT NEAR WEST TAILINGS SITE DURING PHASE 1 HYDROGEOLOGIC FIELD INVESTIGATIONS RESOLUTION COPPER COMPANY, SUPERIOR, ARIZONA

Infiltration Test Identifier	General Location	Mapped Geologic Unit (Spencer and others, 1998)	Rock Characteristics and Test Surface Conditions[a]	Ksat[b] cm/day[c]	Comments
BB-5	Bear Tank Canyon; outcrop adjacent to active stream channel	Gila Conglomerate Tcg (Pliocene to Late Miocene)	Highly weathered/decomposed rock; test surface was cleared of loose and/or easily excavated rock slabs and sediments, and consists of relatively hard but weathered/ fractured rock; horizontal bedding planes occurr beneath surface	37 (combined vertical and horizontal flow)	Test was monitored for 1.2 hours with a Ksat of 37 cm/day, and then allowed to run unattended for another 6 hours, during which time the water completely drained and a final Ksat could not be determined; substantial lateral flow occurred in the shallow weathered rock and "soil"; computed Ksat is for combined vertical and horizontal flow
BB-6	Bear Tank Canyon; outcrop in active stream channel	Gila Conglomerate Tcg (Pliocene to Late Miocene)	Similar to BB-1; hard, flat, non-fractured surface; fine-grained rock matrix with many poorly-sorted, subangular to rounded clasts up to 2 cm diameter	< 0.8[d]	Test was monitored for 1 hour with a Ksat of 0.8 cm/day, and then allowed to run another 6 hours, during which time the computed (average) Ksat was 1.7 cm/day but a small amount of leakage through the seal was noted; most infiltration was likely due to lateral capillary flow in the rock matrix (wetting noted around outside of BB)
BB-7	Roblas Canyon; elevated outcrop	Vitrophyre unit of Apache Leap Tuff Tal (Early Miocene)	Hard, uneven (rugged), non-fractured surface	< 0.6[d]	Test was conducted for 1 hour with a Ksat of 0.6 cm/day during this short test duration
BB-8	Roblas Canyon; outcrop in active stream channel	Pinal Schist Xpm (Precambrian)	Hard, smooth surface with several fractures, one with a surface aperture of 1 cm	negligible[e]	Test was conducted for 1 hour; essentially no infiltration was measured during this short test duration

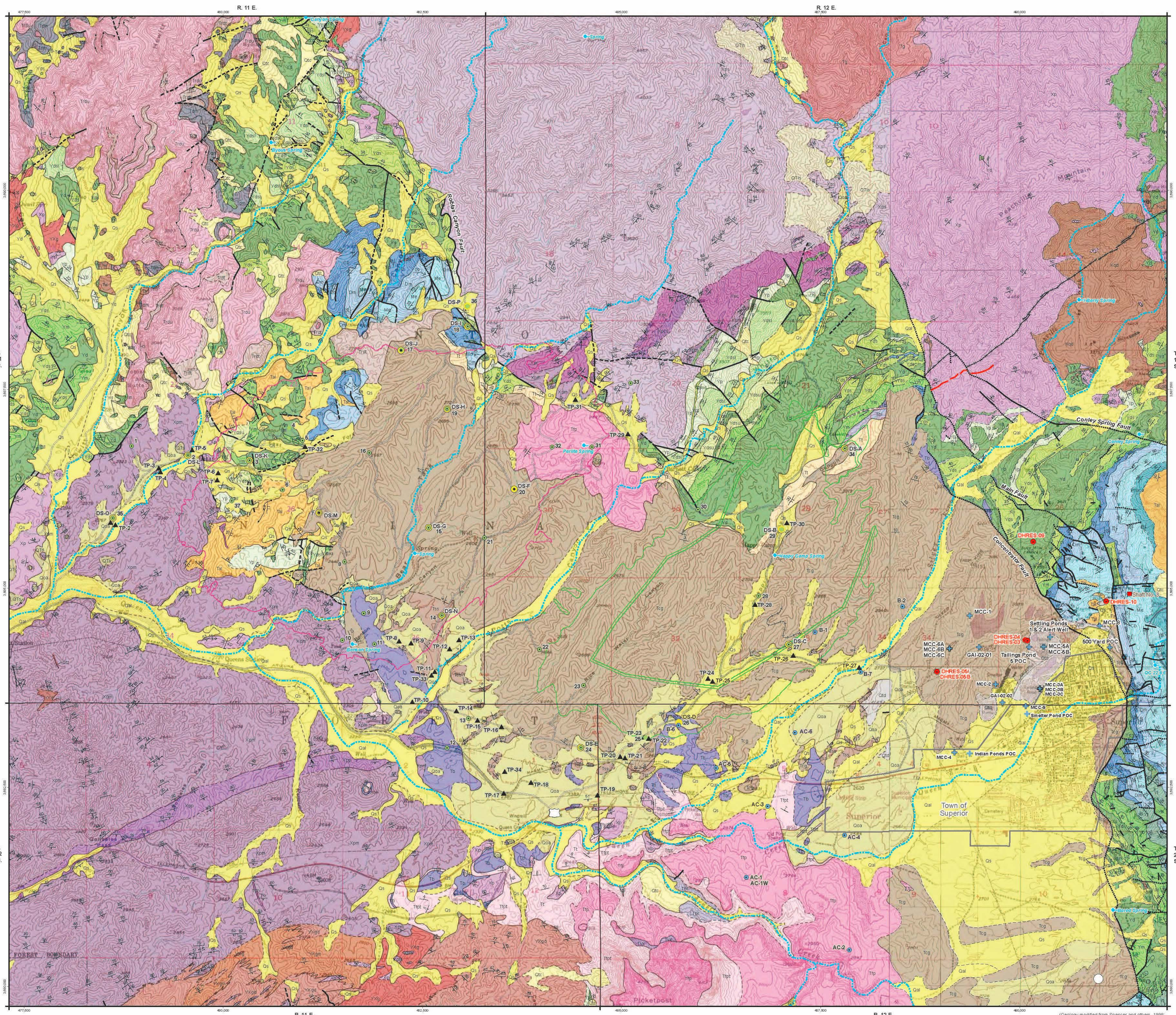
[a] Although all tests were conducted on outcrops exposed to forces of weathering, with the exception of test BB-5, all test surfaces consisted of well-lithified, competent rock; test BB-5 was conducted in a slightly excavated bank of highly weathered and decomposed conglomerate.

[b] Ksat = field-saturated hydraulic conductivity

[c] cm/day = centimeters per day

[d] Ksat value is reported as "less than" the Ksat determined for the BB test; the very small amount of infiltration that occurred during the test was due chiefly to lateral capillary flow in the rock matrix around the outside edge of the BB and evaporation from this wetted rock surface. Therefore, the actual Ksat value for the rock surface tested is believed to be smaller than measured by the test.

[e] "negligible" = no infiltration was measured during the short-duration test at site BB-8; therefore the Ksat value for the test would be "0". However, due to the short duration of the test, a Ksat value of "0" (impermeable) is not supportable.



EXPLANATION

- Proposed Hydrologic Drill Site
- Proposed Geotechnical Drill Site
- Proposed Test Trench

Geologic Structural Features

- Felsic Dike
- Fault
- Fault - approximate
- Fault - concealed
- Quartz Vein

Contact

- Contact
- Contact - approximate
- Contact - inferred
- Marker Horizon
- Contact Between Pinal Schist Clast-rich Congomerate Below and Dripping Spring Quartzite Clast-rich Conglomerate Above

FOLIATION; strike and dip

Broken and wavy lines may be used to indicate approximate measurments or curviplanar foliation in conjunction with any symbol

Primary foliation

BEDDING

upright vertical overturned irregular approximate

dots on strike line indicate facing direction based on primary features

FLOW FOLIATION

flow banding in lavas or hypabyssal intrusions, eutaxitic foliation in welded tuffs; igneous flow foliation in plutons

Tetonic foliations

- Generic foliation

Compositional banding, > 1 cm-scale

- Banding formed by transposed bedding
- Banding of uncertain or metamorphic origin

Compositional banding, < 1 cm-scale

- Banding of metamorphic origin
- Schistosity, continuous cleavage
- Disjunct cleavage (fracture cleavage)
- Disjunct cleavage parallel to bedding

Superimposed Fabrics symbols as above, double dip tics indicate that fabric is superimposed

- Axial surface to small-scale crenulation
- Disjunct cleavage
- Compositional layering <1cm thick, formed by transposition of thin compositional layering
- Similar to above, but fabric is very planar; quartz veins mostly transposed to concordant lenses

LINEAR FEATURES; trend and plunge

MINOR FOLD HINGE, showing plunge direction

- upright, symmetrical fold
- cascade fold
- asymmetrical fold showing vergence ('S' or 'Z')

LINEATIONS

- Mineral lineation in L-tectonites

APPARENT DIP

- Trace of bedding on cliffs or steep slopes

GEOLOGIC UNITS

Symbol	Unit
Qs	Undivided Surficial Deposits (Quaternary)
Qtd	Disturbed Surficial Deposits (Holocene)
Qtc	Talus and Colluvium (Quaternary)
Qal	Unconsolidated Alluvium (Holocene)
Qoa	Old Alluvium (late Pleistocene to early Pleistocene)
QTls	Older Landslide Deposits (early Quaternary to late Tertiary)
QTs	Older Alluvium (early Quaternary to late Tertiary)
Tbl	Lower Basalt (middle Tertiary)
Tdf	Felsic Dikes (middle or early Tertiary or Cretaceous)
Tda	Aphanitic Felsic to Intermediate Dikes (middle Tertiary)
Tdb	Basaltic Dikes (middle Tertiary)
Tg	Granite of Wood Camp Canyon (middle Tertiary)

Superstition Volcanic Complex

Gila Group

Symbol	Unit
Tcg	Conglomerate (Miocene)
Tss	Sandstone (Miocene)
Tb	Basalt (middle to early Miocene)
Tt	Tuff (poorly welded) (Miocene)

Picketpost Mountain Formation

Symbol	Unit
Tfp	Felsic Lava Flows (middle to early Miocene)
Tfpt	Felsic Tuffs (middle to early Miocene)
Tvx	Volcanogenic Breccia (middle to early Miocene)

Apache Leap Tuff

Symbol	Unit
Tal	Apache Leap Tuff (early Miocene)

Superstition Group

Symbol	Unit
Trdu	Undifferentiated Felsic Lavas (early Miocene)
Trdt	Tuffs associated with Trdu (early Miocene)
Tdm	Intermediate to mafic lavas (early Miocene)

Whitetail Formation

Symbol	Unit
Tw	Conglomerate (Miocene to late Oligocene)
Tx	Rock Avalanche Breccia (Miocene or Oligocene)

Symbol	Unit
Kqd	Quartz Diorite of Peachville Wash (late Cretaceous)
Kd	Quartz Diorite of Arnett Creek (late Cretaceous)
Pnaco	Naco Formation (Pennsylvanian)
Me	Escabrosa Limestone (Mississippian)
Dm	Martin Formation (Devonian)
Cb	Bolsa Quartzite (Cambrian)
Yd	Diabase (middle Proterozoic)
Yt	Troy Quartzite (middle Proterozoic)
Yb	Basalt (middle Proterozoic)
Ym	Mescal Limestone (middle Proterozoic)
Yds	Dripping Spring Quartzite, undivided (middle Proterozoic)
Ydsu	Dripping Spring Quartzite, Upper Unit (middle Proterozoic)
Ydsl	Dripping Spring Quartzite, Lower Unit (middle Proterozoic)
Yds+Yp	Dripping Spring Quartzite and Pioneer Formation (middle Proterozoic)
Yp	Pioneer Formation (middle Proterozoic)
Ypt	Pioneer Formation, Tuff Unit (middle Proterozoic)
YXd	Diorite (early or middle Proterozoic)
YXg	Granite (early or middle Proterozoic)
YXgd	Granodiorite (early or middle Proterozoic)
YXgm	Mixed Schist and Granite (early or middle Proterozoic)
Xp	Pinal Schist, undivided (early Proterozoic)
Xpc	Pinal Schist, Calc-silicate Facies (early Proterozoic)
Xpcs	Pinal Schist, Calc-silicate and Schist Facies (early Proterozoic)
Xpm	Pinal Schist, Psammite Facies (early Proterozoic)
Xpp	Pinal Schist, Phyllite Facies (early Proterozoic)
Xpq	Pinal Schist, Quartzite Layers (early Proterozoic)
Xps	Pinal Schist, Pelitic Schist (early Proterozoic)

0 250 500 750 1,000
Meters
0 1,000 2,000 3,000 4,000
Feet

(Geology modified from Spencer and others, 1998; Peterson, 1969, and Spencer and Richard, 1995)

Resolution Copper Mining

GEOLOGIC FEATURES

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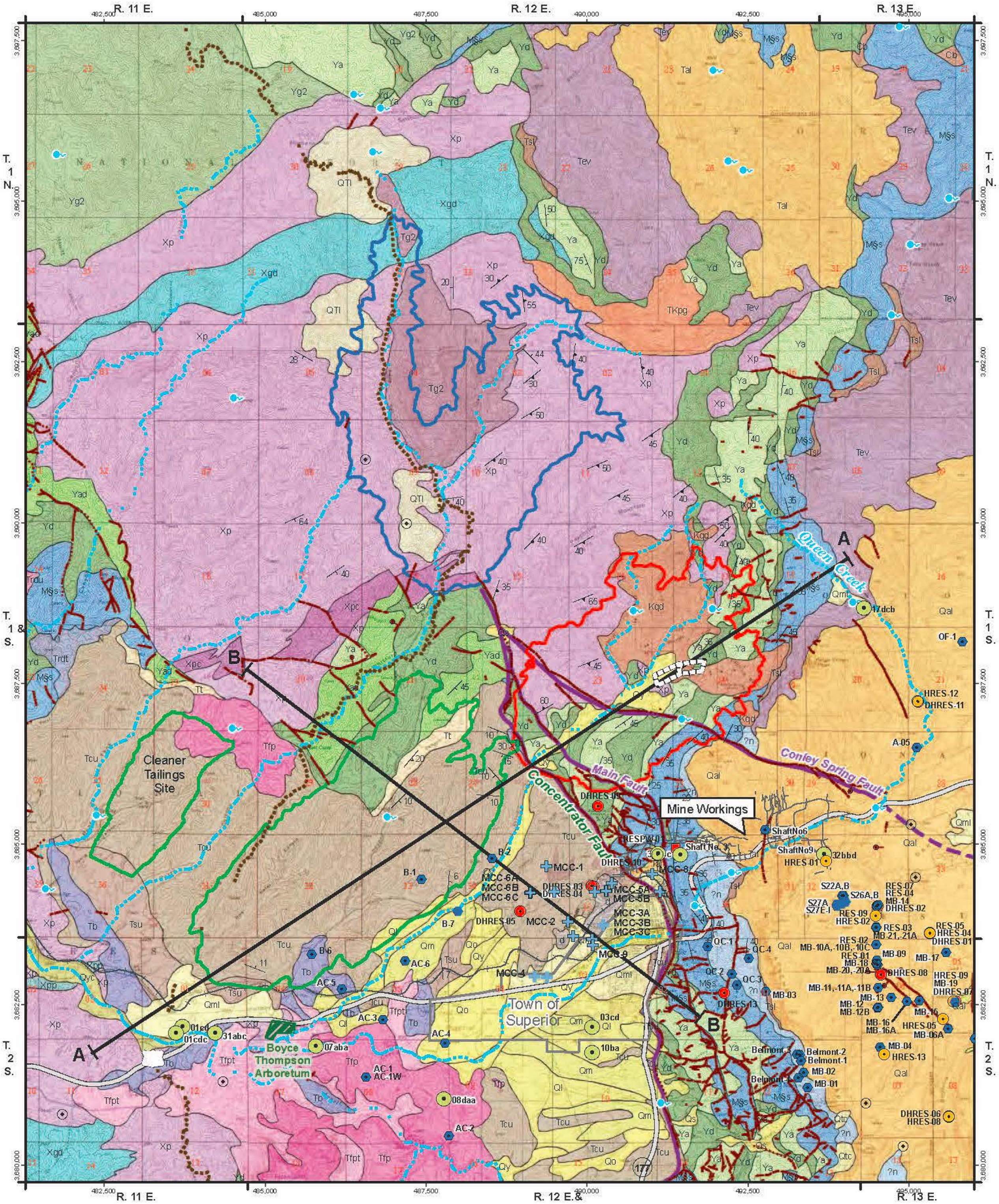
FIGURE 1

GIS-TUC\605\605.76\NearWestDetailGeology_UPDATE2013.mxd\30Apr2013



(Geology from Spencer and others, 1998; Faults from Peterson, 1969, and Spencer and Richard, 1995)

EXPLANATION

- Apache Leap Tuff Aquifer Monitor Well
- Deep Groundwater System Monitor Well
- West Plant Monitor Well
- Shaft
- Historic/Current Point of Groundwater Withdrawal
- Exploration Borehole
- Spring
- Watershed Boundary
- Silver King Canyon Site
- Whitford Canyon Site
- Happy Camp Site
- Arizona Trail
- Resolution Claims

Geologic Structural Features

- Fault; dashed where approximately located; dotted where concealed. Bar and Ball on Downthrown Side.
- 40 Strike and Dip of Beds
- 30 Strike and Dip of Metamorphic Foliation
- 15 Strike and Dip of Igneous Foliation
- A A& Location of Hydrogeologic Section

Geologic Units

- d-Holocene Disturbed Surficial Deposits
- Qyc- Holocene Active Alluvium
- Qtc-Holocene & Pleistocene Talus & Colluvium
- Qy-Holocene Low Terrace & Alluvial Fan Deposits
- Qml-Late Pleistocene to Middle Pleistocene Alluvium Undifferentiated
- Qm-Mid Pleistocene Dissected Alluvial Fan & Terrace Deposits
- Ql-Late Pleistocene Moderately Dissected Alluvial Fan & Terrace Deposits
- Qo-Early Pleistocene Deeply Dissected Alluvium Undifferentiated
- Qs-Quaternary Surficial Deposits
- Qtc-Holocene & Pleistocene Talus & Colluvium
- Qal-Quaternary Alluvium
- QTl-Holocene or Pliocene Landslide Deposits
- Tcu-Miocene Conglomerate
- Tsu-Miocene Sandstone
- Tt-Miocene Tuff (poorly welded)
- Tfp-Mid Miocene to Early Miocene Felsic Lava Flows Picketpost Mountain
- Tfpt-Mid Miocene to Early Miocene Tuffs Picketpost Mountain
- Tb-Mid Miocene to Early Miocene Basalt Picket Post Mountain
- Tg2-Miocene Granitoid Stock of Wood Camp Canyon
- Trdu-Middle Miocene Undifferentiated Felsic Lava
- Tal-Early Miocene Apache Leap Tuff
- Trdt-Early Miocene Undifferentiated Felsic Tuffs
- Tev-Early Miocene Volcanic Rocks
- Tsl-Miocene to Late Oligocene Clastic Rocks
- TKpg-Late Cretaceous or Paleocene Porphyry of Government Hill
- Kqd-Late Cretaceous Quartz Diorite of Peachville Wash
- ?n-Naco Formation
- M§s-Missisipian/Devonian/Cambrian Undifferentiated Escabrosa, Martin & Bolsa
- Cb-Bolsa Quartzite
- Yad-Mid Proterozoic Apache Group, Troy Quartzite & Diabase
- Yd-Mid Proterozoic Diabase
- Ya-Mid Proterozoic Apache Group
- Yg2-Mid Proterozoic Porphyritic Biotite Granite
- Xgd-Early Proterozoic Granodiorite to Granite
- Xp-Early Proterozoic Pinal Schist
- Xpc-Pinal Schist Calc - Silicate & Amphibolite Facies
- Xpp-Pinal Schist - Phyllite Facies

0 1,000 2,000 Meters

0 2,000 4,000 6,000 8,000 Feet

Resolution Copper Mining

REGIONAL HYDROGEOLOGIC FEATURES

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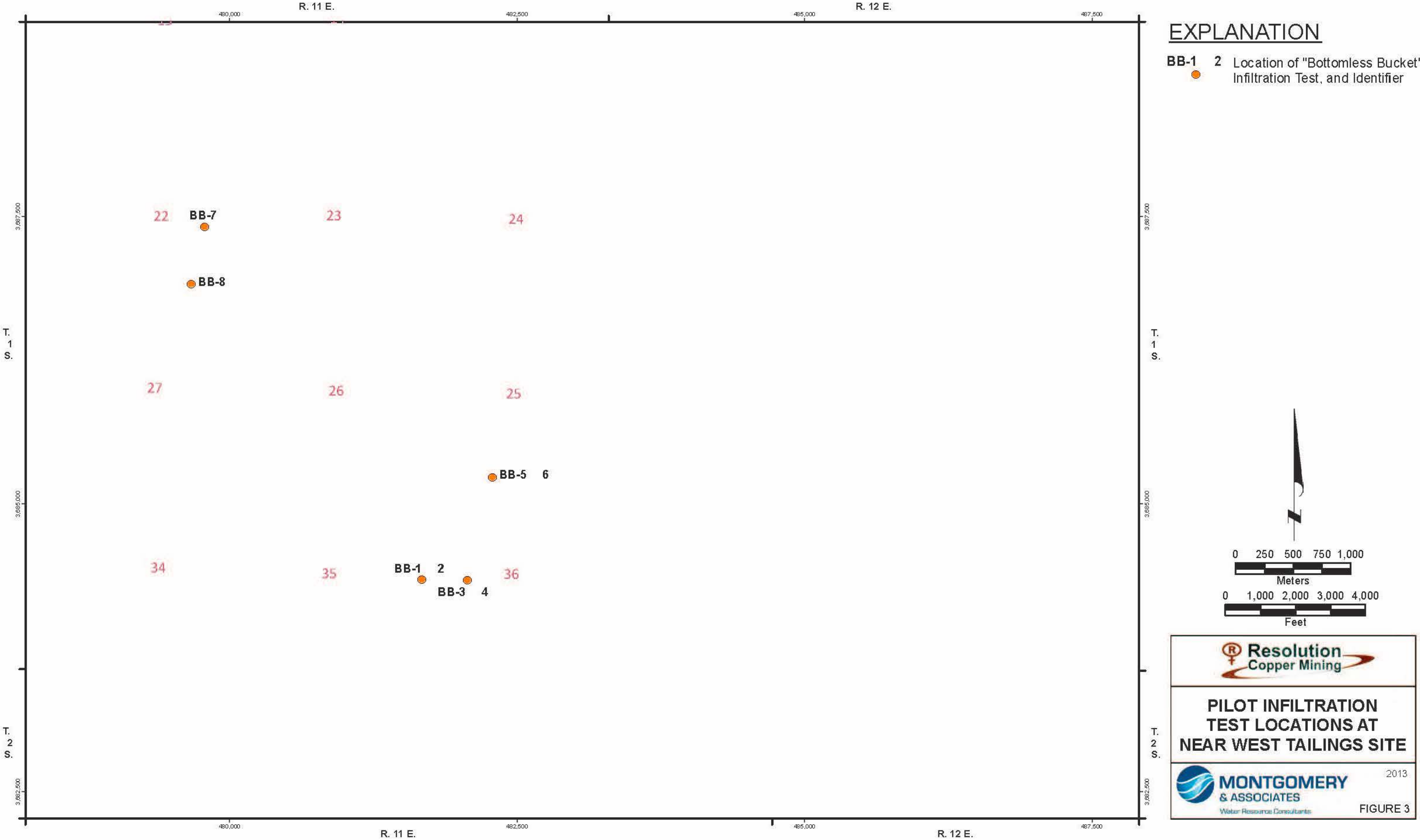
FIGURE 2

GIS-TUC\605\605.76\Geology2012_extended area_FINAL.mxd\01 May2013



PILOT INFILTRATION TEST LOCATIONS AT NEAR WEST TAILINGS SITE

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FIGURE 3

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APPENDIX A

SUMMARY TABLES OF ANALYTICAL RESULTS

TABLE A-1 COMMON CONSTITUENTS AND ROUTINE PARAMETERS
FOR SURFACE WATER SAMPLES OBTAINED AT NEAR WEST SITE DURING PHASE I HYDROLOGIC FIELD INVESTIGATIONS

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	COMMON CONSTITUENTS[a] (mg/L)[b]													ROUTINE PARAMETERS					ANALYTICAL LABORATORY
																FIELD			LABORATORY		
			Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4	SiO_2	Br	F	$NO_3 + NO_2$ (as N)	TDS	TEMP (°C)[c]	pH	SC (µS/cm)[d]	pH	SC (µS/cm)	
Surface Water																					
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	—	—	—	—	—	—	—	—	—	—	—	—	—	21.0	7.27	710.4	—	—	
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	—	—	—	—	—	—	—	—	57.6	—	—	—	—	—	—	—	—	—	SVL
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	—	—	—	—	37.9	–	332	81.2	—	0.35	0.49	—	482	—	—	—	—	—	SVL
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	60.9	17.4	51.7	1.29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	SVL
Happy Camp Spring	RESE-1003083	18-Feb-13	—	—	—	—	—	—	—	—	—	—	—	—	—	23.5	7.28	800	—	—	
Happy Camp Spring	RESE-1003083	18-Feb-13	—	—	—	—	—	—	—	—	49.5	—	—	—	—	—	—	—	—	—	SVL
Happy Camp Spring	RESE-1003083	18-Feb-13	—	—	—	—	26.1	–	505	109	—	0.24	0.62	—	[illegible]	—	—	—	—	—	SVL
Happy Camp Spring	RESE-1003083	18-Feb-13	100	34.6	35.3	1.19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	SVL
U.S. EPA National Primary Drinking Water Regulations			—	—	—	—	—	—	—	—	—	—	4.0	10	—	—	—	—	—	—	
U.S. EPA National Secondary Drinking Water Regulations			—	—	—	—	250	—	—	250	—	—	2.0	—	500	—	6.5 to 8.5	—	6.5 to 8.5	—	
Arizona Numeric Aquifer Water Quality Standards			—	—	—	—	—	—	—	—	—	—	—	10	—	—	—	—	—	—	

Values in bold red are out of compliance with EPA primary water quality standards
Values in red italics are out of compliance with EPA secondary water quality standards
Values in red italic underline are out of compliance with Arizona numeric aquifer water quality standards
Values in blue indicate that detection limit exceeds standard

— = Not available, not applicable
– = Not calculated due to non-detect
* = Value reported as Na+K

Shading indicates dissolved results
Shading indicates total results
Shading indicates total recoverable results
Shading indicates unknown filtration or no filtration method provided for analyses

[a] Ca = Calcium
Mg = Magnesium
Na = Sodium
K = Potassium
Cl = Chloride
CO_3 = Carbonate
HCO_3 = Bicarbonate
SO_4 = Sulfate
SiO_2 = Silica
Br = Bromide
F = Fluoride
NO_3+NO_2 (as N) = Nitrate plus Nitrite, in equivalent milligrams of nitrogen per liter
TDS = Total dissolved solids

[b] mg/L = milligrams per liter

[c] TEMP (°C) = Temperature, in degrees Celsius

[d] SC (µS/cm) = Specific Conductance in microsiemens per centimeter

Explanation of Codes
Absent = Analyte not present
ge = Greater than or equal to reported value
i = Insufficient sample
j = Estimated value
j+ = Estimated value, high bias
j- = Estimated value, low bias
Lost = Sample lost in processing
n = Not measured
na = Not available
ND = Not Detected
np = Analyte not applicable
Present = Analyte was detected
q = Uncertain value
r = Unusable data
< = Less than reported detection limit
> = Greater than reported value
d = Diluted. Diluted samples are indicated only when value is estimated.
DUP = Field Duplicate
LD = Laboratory duplicate
SP = Split sample
SPD = Split-Duplicate

TABLE A-2 TRACE CONSTITUENTS
FOR SURFACE WATER SAMPLES OBTAINED AT NEAR WEST SITE DURING PHASE I HYDROLOGIC FIELD INVESTIGATIONS

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	TRACE CONSTITUENTS[a] (mg/L)[b]																						ANALYTICAL LABORATORY
			Al	Sb	As	Ba	Be	B	Cd	Cr	Co	Cu	CN	Fe	Pb	Mn	Hg	Mo	Ni	Se	Ag	S	Tl	Zn	
Surface Water																									
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	<0 080	<0 00300	<0.025	—	—	—	<0 00003	—	<0 0060	0 00134	—	<0 060	<0 000016	<0 0040	—	<0 008	0 00261	—	<0 000100	—	<0 00100	<0 0100	SVL
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<0 00020	—	—	—	—	—	—	—	SVL
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	—	<0 00300	<0.025	<0 0020	<0 0020	0 048	<0 0020	<0 0060	—	<0 010	—	—	<0 00300	<0 0040	—	—	<0 010	0 00174 jd	<0 0050	—	<0 00100	<0 0100	SVL
Happy Camp Spr ng	RESE-1003083	18-Feb-13	<0 080	<0 00300	<0.025	—	—	—	<0 00003	—	<0 0060	0 00768	—	<0 060	<0 000016	<0 0040	—	<0 008	0 00500	—	<0 000100	—	<0 00100	0 0101	SVL
Happy Camp Spr ng	RESE-1003083	18-Feb-13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<0 00020	—	—	—	—	—	—	—	SVL
Happy Camp Spr ng	RESE-1003083	18-Feb-13	—	<0 00300	<0.025	0 0583	<0 0020	0 042	<0 0020	<0 0060	—	<0 010	—	—	<0 00300	0 0046	—	—	<0 010	0 00074 jd	<0 0050	—	<0 00100	0 0111	SVL
U S EPA Nat ona Pr mary Dr nk ng Water Regu at ons			—	0 006	0 010	2	0 004	—	0 005	0 1	—	1 3	0 20	—	0 015	—	0 002	—	—	0 05	—	—	0 002	—	
U S EPA Nat ona Secondary Dr nk ng Water Regu at ons			0 05 to 0 2	—	—	—	—	—	—	—	—	1 0	—	0 3	—	0 050	—	—	—	—	0 1	—	—	5	
Ar zona Numer c Aqu fer Water Qua ty Standards			—	0 006	0 05	2 0	0 004	—	0 005	0 1	—	—	0 20	—	0 05	—	0 002	—	0 1	0 05	—	—	0 002	—	

Values in bold red are out-of-compliance with EPA primary water quality standards
Values in red italics are out-of-compliance with EPA secondary water quality standards
[illegible]
Va ues n b ue nd cate that detect on m t exceeds standard

—= Not ava ab e not app cab e
— = Not ca cu ated due to non-detect

Shad ng nd cates d sso ved resu ts
Shad ng nd cates tota resu ts
Shad ng nd cates tota recoverab e resu ts
Shad ng nd cates unknown f trat on or no f trat on method prov ded for ana yses

[a] A = A um num
Sb = Ant mony
As = Arsen c
Ba = Bar um
Be = Bery um
B = Boron
Cd = Cadm um
Cr = Chrom um (tota)
Co = Coba t
Cu = Copper
CN = Cyan de (amenab e)
Fe = Iron
Pb = Lead
Mn = Manganese
Hg = Mercury
Mo = Mo ybdenum
N = N cke
Se = Se en um
Ag = S ver
S = Su f de
T = Tha um
Zn = Z nc

[b] mg/L = m grams per ter

Explanation of Codes

Absent = Ana yte not present
ge = Greater than or equa to reported va ue
= Insuff c ent samp e
j = Est mated va ue
j+ = Est mated va ue h gh b as
j- = Est mated va ue ow b as
Lost = Samp e ost n process ng
n = Not measured
na = Not ava ab e
ND = Not Detected
np = Ana yte not app cab e
Present = Ana yte was detected
q = Uncerta n va ue
r = Unusab e data
< = Less than reported detect on m t
> = Greater than reported va ue
d = D uted D uted samp es are nd cated on y when va ue s est mated
DUP = F e d Dup cate
LD = Laboratory dup cate
SP = Sp t samp e
SPD = Sp t-Dup cate

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TABLE A-3 RADIOLOGICAL DATA
FOR SURFACE WATER SAMPLES OBTAINED AT NEAR WEST SITE DURING PHASE I HYDROLOGIC FIELD INVESTIGATIONS

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	RADIOLOGICAL CONSTITUENTS[a]							ANALYTICAL LABORATORY
			Gross Alpha (pCi/L)[b]	Gross Beta (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Total U (pCi/L)	Total U (mg/L)[c]	
Surface Water										
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	<2	<4.4	<0.06	<1.6	—	—	0.0046	ACZ
Happy Camp Spring	RESE-1003083	18-Feb-13	10 ± 4	5.7 ± 3.3	<0.12	<1.2	—	—	0.0073	ACZ
U.S.EPA National Primary Drinking Water Regulations			15 pCi/L	50 pCi/L[d]	—	---	5 pCi/L	—	0.03 mg/L	
Arizona Numeric Aquifer Water Quality Standards			15 pCi/L	50 pCi/L	—	---	5 pCi/L	—	0.035 mg/L	

Values in bold red are out of compliance with EPA primary water quality standards.
Values in red italics are out of compliance with Arizona numeric water quality standards.
Values in blue indicate that detection limit exceeds standard

[a] Ra-226 = Radium 226
Ra-228 = Radium 228
U = Uranium

< = Less than reported detection limit
— = Not available, not applicable
-- = Not calculated due to non-detect

[b] pCi/L = picocuries per liter

[c] mg/L = milligrams per liter

[d] pCi/L alert level for EPA and Arizona Numeric Standard of 4 mrem/year (milliroentgen equivalent man per year)

Explanation of Codes
Absent = Analyte not present
ge = Greater than or equal to reported value
i = Insufficient sample
j = Estimated value
j+ = Estimated value, high bias
j- = Estimated value, low bias
Lost = Sample lost in processing
n = Not measured
na = Not available
ND = Not Detected
np = Analyte not applicable

Present = Analyte was detected
q = Uncertain value
r = Unusable data
< = Less than reported detection limit
> = Greater than reported value
d = Diluted. Diluted samples are indicated only when value is estimated.
DUP = Field Duplicate
LD = Laboratory duplicate
SP = Split sample
SPD = Split-Duplicate

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TABLE A-4 STABLE ISOTOPE DATA

FOR SURFACE WATER SAMPLES OBTAINED AT NEAR WEST SITE DURING PHASE I HYDROLOGIC FIELD INVESTIGATIONS

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	ISOTOPES					ANALYTICAL LABORATORY
			$\delta^{18}O$ [a] (‰)	δD [b] (‰)	$\delta^{13}C$ in DIC [c] (‰)	$\delta^{34}S$ [d] (‰)	$\delta^{18}O$ in SO_4 [e] (‰)	
Surface Water								
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	—	--	-17.0	—	—	Beta Analytic
Bear Tank Canyon Spring	RESE-1003084	18-Feb-13	-8.04	-59.7	—	0.7	4.1	Isotech
Happy Camp Spring	RESE-1003083	18-Feb-13	—	--	-18.8	—	—	Beta Analytic
Happy Camp Spring	RESE-1003083	18-Feb-13	-8.61	-64.2	—	-0.3	6.6	Isotech

a $\delta^{18}O$ (‰) = delta oxygen-18 (per mil)
b δD (‰) = delta deuterium (per mil)
c $\delta^{13}C$ in DIC (‰) = delta carbon-13 in dissolved inorganic carbon (per mil)
d $\delta^{34}S$ (‰) = delta sulfur-34 (per mil)
e $\delta^{18}O$ in SO_4 (‰) = delta oxygen-18 in sulfate (per mil)

— = Not available, not applicable
-- = Not calculated due to non-detect

Explanation of Codes

Absent = Analyte not present
ge = Greater than or equal to reported value
I = Insufficient sample
j = Estimated value
j+ = Estimated value, high bias
j- = Estimated value, low bias
Lost = Sample lost in processing
n = Not measured
na = Not available
ND = Not Detected
np = Analyte not applicable

Present = Analyte was detected
q = Uncertain value
r = Unusable data
< = Less than reported detection limit
> = Greater than reported value
d = Diluted. Diluted samples are indicated only when value is estimated.
DUP = Field Duplicate
LD = Laboratory duplicate
SP = Split sample
SPD = Split-Duplicate

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TABLE A-5 RADIOISOTOPE DATA
FOR SURFACE WATER SAMPLES OBTAINED AT NEAR WEST SITE DURING PHASE I HYDROLOGIC FIELD INVESTIGATIONS

SAMPLE LOCATION	SAMPLE IDENTIFIER/ DESCRIPTION	SAMPLE DATE	RADIOISOTOPE DATA								ANALYTICAL LABORATORY
			^{3}H (TU)[a]	^{14}C (pmC)[b]	Sr (ppm)[c]	$^{87}Sr/^{86}Sr$[d]	^{234}U (pCi/L)[e]	^{235}U (pCi/L)[f]	^{238}U (pCi/L)[g]	$^{234}U/^{238}U$[h]	
Surface Water											
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	---	—	—	---	3.2 ± 1.6	<1.2	1.65 ± 1.4	1.9	ACZ
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	---	92.69 ± 0.34	—	---	—	—	—	—	Beta Ana yt c
Bear Tank Canyon Spr ng	RESE-1003084	18-Feb-13	1.39 ± 0.17	—	—	---	—	—	—	—	Isotech
Happy Camp Spr ng	RESE-1003083	18-Feb-13	---	—	—	---	5.3 ± 2.1	<1.3	1.86 ± 1.6	2.8	ACZ
Happy Camp Spr ng	RESE-1003083	18-Feb-13	---	103.42 ± 0.38	—	---	—	—	—	—	Beta Ana yt c
Happy Camp Spr ng	RESE-1003083	18-Feb-13	2.02 ± 0.19	—	—	---	—	—	—	—	Isotech

a ^{3}H = Tr t um; tr t um un t (1 TU = 1 tr t um atom per 10^{18} atoms of hydrogen)
b ^{14}C = carbon-14; pmC = percent modern carbon
c Sr = stront um; ppm = parts per m on
d Mass of stront um-87 sotope d v ded by mass of stront um-86 sotope
e Uran um-234 sotope; pC /L = act v ty n p coCur es per ter
f Uran um-235 sotope; pC /L = act v ty n p coCur es per ter
g Uran um-238 sotope; pC /L = act v ty n p coCur es per ter
h Act v ty of uran um-234 sotope d v ded by act v ty of uran um-238 sotope

— = Not ava abe, not app cabe
-- = Not ca cu ated due to non-detect

Explanation of Codes

Absent = Ana yte not present
ge = Greater than or equa to reported va ue
= Insuff c ent samp e
j = Est mated va ue
j+ = Est mated va ue, h gh b as
j- = Est mated va ue, ow b as
Lost = Samp e ost n process ng
n = Not measured
na = Not ava abe
ND = Not Detected
np = Ana yte not app cabe

Present = Ana yte was detected
q = Uncerta n va ue
r = Unusabe data
< = Less than reported detect on m t
> = Greater than reported va ue
d = D uted. D uted samp es are nd cated on y when va ue s est mated.
DUP = Fe d Dup cate
LD = Laboratory dup cates
SP = Sp t samp es
SPD = Sp t-Dup cates

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APPENDIX B

PHOTOGRAPHS OF PILOT INFILTRATION TESTS AT NEAR WEST TAILINGS SITE, RESOLUTION COPPER COMPANY, ARIZONA

APPENDIX B. PHOTOGRAPHS OF PILOT INFILTRATION TESTS AT NEAR WEST TAILINGS SITE, RESOLUTION COPPER COMPANY, ARIZONA

Infiltration tests **BB-1 and BB-2** were conducted on a bedrock outcrop of Gila Conglomerate (Tcg), located above Benson Spring. The outcrop was characteristic of well-lithified, poorly sorted conglomerate.

Test **BB-1** (left photo) was conducted on a smoother surface of fine-grained matrix with few small clasts. Test **BB-2** (right photo) was conducted on a rougher surface with many larger clasts cemented in a fine-grained matrix.

The "Bottomless Bucket" infiltration test method was used to conduct tests on the bedrock surfaces. Quick-drying silicone gel and hydrated bentonite crumbles were used to seal the bucket to the test surface and prevent leakage.

Tests **BB-1 and BB-2** were conducted after the seals were confirmed to have no leakage and were conducted for 16 hours (including overnight).

Test **BB-3** was conducted on an outcrop of basalt (Tb), located near Benson Spring.

Test **BB-4** was located on another nearby outcrop of basalt (Tb), which intersected an active stream channel.

The two basalt surfaces tested at **BB-3 and BB-4** were distinctly different. Test **BB-3** (left photo) was conducted on a surface with extensive shallow fracturing and quartz/feldspar veining. Test **BB-4** (right photo) was conducted on a relatively smooth and non-fractured surface.

Both silicone gel and bentonite crumbles were used to seal the buckets to the test surface at **BB-3 and BB-4**, which required some patching after the initial water was added. The tests began after the seal was confirmed to be water tight, and were conducted for 16 hours (including overnight).

Test **BB-3** (left photo) demonstrated substantial lateral flow through the extensive shallow fractures at the surface. The distance of lateral wetting ranged up to 60 centimeters from the edge of the bucket. Test **BB-4** (right photo) demonstrated a small amount of lateral capillary flow in the rock matrix, as shown by the faint ring of wetting extending about 5 centimeters from the edge of the bucket.

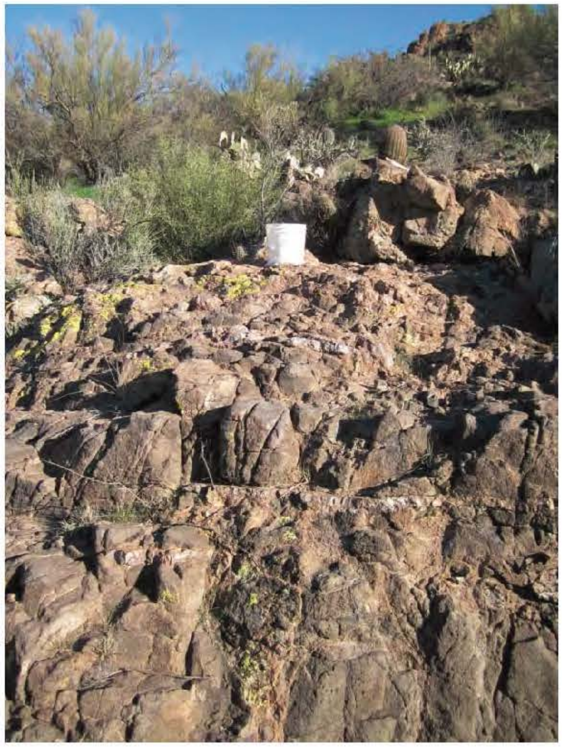
Tests **BB-5 and BB-6** were conducted on an outcrop of Gila Conglomerate (Tcg) located in Bear Tank Canyon on the side of an active stream channel. Two different rock conditions/surfaces at this site were tested.

Test **BB-5** (both photos) was conducted in highly weathered/decomposed conglomerate, in which a relatively hard surface was exposed and cleared; the test zone included layers of bedrock and "soil" with subsurface horizontal bedding planes.

Test **BB-6** (both photos) was conducted on a well-lithified and non-fractured conglomerate surface that included poorly-sorted clasts in a fine-grained matrix.

The bucket at test **BB-5** (left photo) was sealed to the test surface exclusively using hydrated bentonite crumbles; the test was conducted for 7 hours. Post-test observations for test **BB-5** (right photo) revealed substantial lateral flow (both saturated and capillary flow) along the subsurface bedding planes and in the "soil" zones.

The bucket at test **BB-6** (left photo) was sealed to the test surface exclusively with silicone gel; the test was conducted for 7 hours. Post-test observations for test **BB-6** (right photo) revealed lateral capillary flow within the rock matrix, as seen by the faint ring of wetting up to 7 centimeters from the edge of the bucket.



Test **BB-7** was conducted on an outcrop of Apache Leap Tuff vitrophyre (Talv), located in Roblas Canyon.

The test surface at **BB-7** was rugged and non-fractured, and the bucket was sealed exclusively with silicone gel.

Test **BB-8** was conducted on an outcrop of Pinal Schist (Xpm) in an active stream channel in Roblas Canyon.

The test surface at **BB-8** was relatively smooth and contained several fine fractures and one fracture with a surface aperture up to 1 centimeter; the vertical extent of selected fractures may have been significant (right photo). Silicone gel was used exclusively to seal the bucket to the test surface.