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REPORT

June 29, 2020

Conceptual Hydrogeologic Model: Skunk Camp Tailings Storage Facility Alternative

Prepared for:

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Contents

Contents – continued

Tables

Figures

Figures – continued

Appendix

1 INTRODUCTION

In response to Water Work Group Action item WR30, Montgomery & Associates (M&A) has prepared this report describing the conceptual hydrogeologic model of the Skunk Camp site. The conceptual model encompasses the entire Skunk Camp model domain, with specific detail given to the vicinity of the proposed Skunk Camp tailings storage facility (TSF). Skunk Camp was selected by the United States Forest Service (USFS) as the preferred TSF location in the Resolution Copper Draft Environmental Impact Statement (DEIS) alternatives analysis.

Overall, this conceptual model report largely confirms and expounds on the same geology and geologic units and general hydrogeologic units and settings as described in the DEIS.

1.1 Objectives

The purpose of this report is to use available hydrogeologic data to prepare a cohesive conceptual understanding of the Skunk Camp site groundwater system. The intent is that this report will concisely describe the groundwater system at a level of detail appropriate to support evaluation of the proposed TSF location and quantitative modeling of potential impacts associated with the TSF.

1.2 Location

The conceptual model area comprises approximately 166,000 acres (240 square miles) and is bounded by the Pinal Mountains and Mescal Mountains to the northeast, Mineral Creek to the northwest, Ray Mine to the west, and the Gila River to the southwest and southeast (Figure 1-1). The boundary between Pinal and Gila counties transects the conceptual model area from the northwest to southeast, resulting in approximately one-third of the area (86 square miles) being located in Pinal County to the west and two-thirds of the area (174 square miles) located in Gila County to the east. The proposed Skunk Camp TSF lies within the upper Dripping Spring Wash watershed and is also transected by the Pinal-Gila Counties boundary. Collectively this area is referred to as the Skunk Camp study area/model domain.

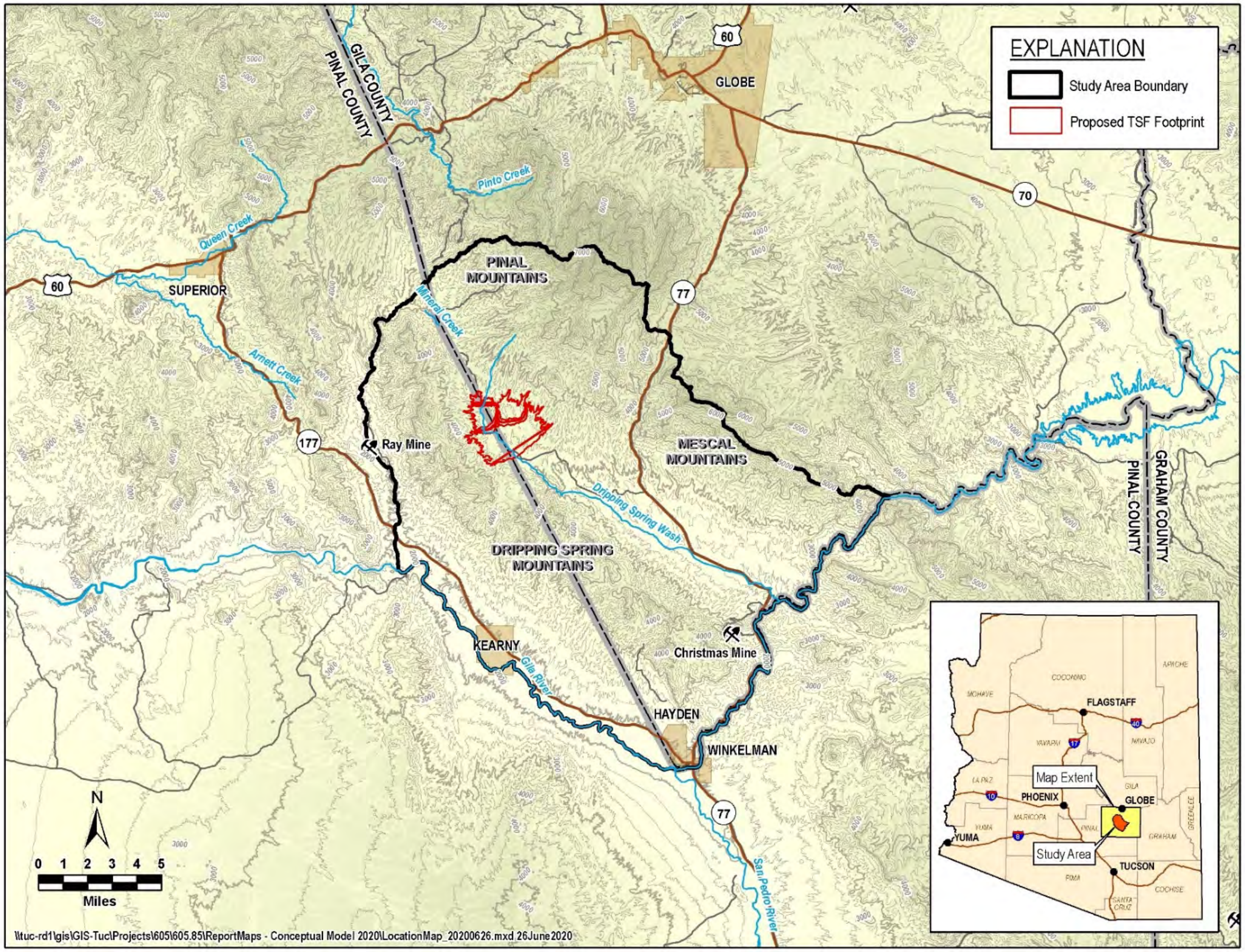

Figure 1-1. Location Map

1.3 Proposed Tailings Storage Facility

RC has proposed to develop a new mine that targets the Resolution ore body using a method known as panel caving. The Resolution ore body is located east of the town of Superior. Residual material from the processing of ore would be piped and stored at a TSF. The proposed TSF location is approximately 3 miles northeast of the Asarco Ray Open pit Mining complex, shown on Figure 1-1.

The proposed Skunk Camp TSF includes two cells to store pyrite tailings contained by a full downstream embankment and one centerline-raised, cross-valley, cycloned sand embankment that would separately store scavenger tailings (Klohn Crippen Berger [KCB], 2018). The pyrite tailings cells would include engineered, low-permeability layers to minimize seepage and maintain a pond for pyrite tailings saturation.

1.4 Previous Investigations

Several reports have included hydrogeologic descriptions of the Skunk Camp site and provide valuable data to support the conceptual model presented in this report. The following reports are relevant resources for reviewing this report:

- Resolution Copper Project: DEIS Design for Alternative 6 – Skunk Camp, Klohn Crippen Berger, 2018
- Skunk Camp Investigations – Results of Site Reconnaissance, Montgomery & Associates, 2018
- KCB Consultants Ltd. (KCBCL). Resolution Copper Project Skunk Camp Site Investigation Doc. #: CCC.03-81600-EX-REP-00012 – Rev. 0, November 1, 2019
- Aquifer Testing Results for Skunk Camp Hydrogeologic Investigation, Montgomery & Associates, 2019
- Spring and Seep Catalog V 3.0: Resolution Copper Project Area, Montgomery & Associates and WestLand Resources, 2020
- Skunk Camp Area Data Submittal – Response to Water Working Group Action Item WR-7, Montgomery & Associates, 2020
- Summary of Results for 2020 Site Investigations at the Skunk Camp Tailings Storage Facility Site, Montgomery & Associates, 2020 (forthcoming)

2 HYDROLOGIC SETTING

The Skunk Camp study area encompasses approximately 166,000 acres and is bounded by the Gila River to the south and southeast, Mineral Creek to the northwest, and the Pinal and Mescal Mountains to the northeast (Figure 1-1). The physical and hydrologic setting of the Skunk Camp study area is described in the following sections. The Skunk Camp study area was selected to match the domain of the numerical groundwater flow and transport model, which will be described in subsequent reports.

2.1 Physiography

The location of the proposed Skunk Camp TSF is in Dripping Spring Wash, a north-northwest-trending valley bounded by the Dripping Spring Mountains to the west and the Pinal and Mescal Mountains to the northeast within the Transition Zone physiographic province of central Arizona (Wilson and Moore, 1959). The Transition Zone is characterized by deeply incised drainages and rugged topography. The study area includes the Dripping Spring Wash watershed from its headwaters to its confluence with the Gila River, small channels that drain the western slope of the Dripping Spring Mountains, and the southeastern portion of the Mineral Creek Watershed (Figure 2-1). Land surface elevation in the study area ranges from 7,850 feet above mean sea level (ft amsl) in the Pinal Mountains northeast of the proposed TSF to about 827 ft amsl at the bottom of the Ray Mine Pit.

2.1.1 Climate

The climate of the Skunk Camp study area is arid to semi-arid, with temperatures exceeding 100 degrees Fahrenheit in the summer in the lower elevations and dipping below freezing in the winter at higher elevations. Precipitation typically occurs in two seasons, with strong, short-duration storms during the months of July through September, and longer-duration storms of moderate intensity during the months of November through March. While most of this precipitation falls as rain, snowfall can occur in the winter months, particularly at higher elevations. Mean monthly precipitation and monthly air temperatures calculated by the Parameter-elevation Relationships on Independent Slopes Model (PRISM, 2019) for the general area of the TSF (exact location: Latitude 33.1699, Longitude -110.8804, Elevation 3,196 feet amsl) are shown on Figure 2-1. Average annual precipitation for this location from 1980-2018 is 17.6 inches (standard deviation is +/- 5.89 inches).

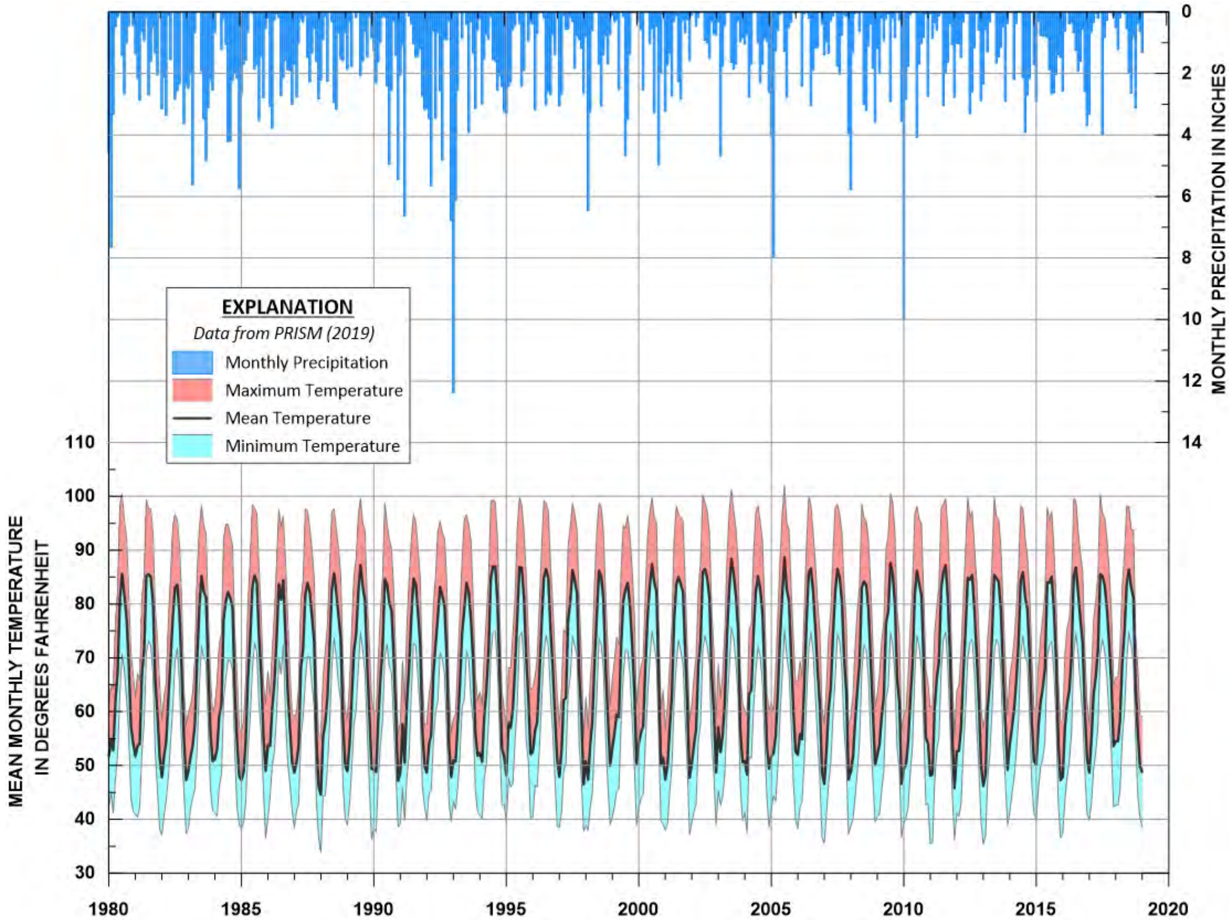

Figure 2-1. Monthly Precipitation and Monthly Mean, Maximum and Minimum Air Temperature (PRISM, 2019)

2.1.2 Vegetation

The Skunk Camp TSF area includes three major plant communities: semi-desert grassland in the north, central, and south parts; interior chaparral in the west part; and Arizona upland Sonoran Desert scrub in the southeast part. The most common trees include one-seed juniper, palo verde, velvet mesquite, and whitethorn acacia. Other common species include various shrubs, grasses, and cacti (WestLand Resources [WRI], 2019).

Riparian trees such as Goodding's willow, Arizona sycamore, and Fremont cottonwood are common near springs and along stream channels. Others observed include seepwillow, desert broom, Arizona walnut, net-leaf hackberry, sugar sumac, barberry, oak, buckthorn, mesquite, and catclaw acacia (WRI, 2019).

2.1.3 Land Use and Stakeholders

Principal stakeholders with respect to land and water use at the Skunk Camp study area include mining, ranching, potable water supply, and agricultural irrigation.

2.1.3.1 Mining

One of the largest active mining operations in the country, ASARCO's Ray Mine, is in the western edge of the study area. The Christmas Mine, approximately 10 miles to the south in the Dripping Spring Mountains was active until the early 1980s, and smaller properties located in the Dripping Spring Mountains were active until the 1950s to 1960s.

The ASARCO Ray and Hayden Operations include an open-pit mine, two concentrators, a leach-solvent extraction-electrowinning plant, an INCO Oxygen Flash smelter, oxygen plant, and metallurgical acid plant. The facilities are active and have a history dating back to the 1880s. As of 2014, ASARCO reported ore reserves through 2044. The Ray open pit is located about 5 miles west of the proposed TSF and is excavated into Mineral Creek, which is the western study area boundary. Water for the Ray and Hayden operations is supplied by in-pit dewatering and an industrial wellfield located near Winkelman. The wells in the wellfield are completed in alluvium.

http://www.asarco.com/about-us/our-locations/ray-operations/

The Christmas Mine, located near the south end of the Dripping Spring Mountains, was operated intermittently from 1905 to early 1982 as both an underground and open pit mine by various mining companies. Water for the mine was supplied by an industrial wellfield located in Dripping Spring Wash near the Gila River.

Several small-scale underground mines were active from the early 1900s to the 1960s in the Dripping Spring Mountains. They produced gold, copper, silver, zinc, tungsten, and vanadium.

https://minedata.azgs.arizona.edu/search?f%5B0%5D=field_keywords_spatial%3Adripping%20springs%20mts.%20physiographic%20area

2.1.3.2 Ranching

Ranching has had a long history in the Skunk Camp area. Much of the land in the area is controlled by the State of Arizona with a lesser amount as privately held property. Ranches operating in the area have both private holdings and grazing allotments on state lands. The ranches depend on springs, stock wells, and tanks to support watering of cattle on their allotments.

2.1.3.3 Small Communities and Irrigated Agriculture

Although there are no towns or large communities within the study area, several small, scattered farms and homes are dispersed in Dripping Spring Wash. This area does not support large scale agriculture, but some farms and small ranches appear to irrigate at least intermittently. Water for potable supply and small-scale irrigation is sourced principally from alluvium and upper Tertiary conglomerate. The amount of groundwater pumping in Dripping Spring Wash is not reported to local or state agencies and is unknown. However, based on population, the amount of groundwater pumping is likely small in comparison to the overall water budget of the basin.

2.2 Surface Water and Springs

The Skunk Camp study area encompasses all or part of two principal watersheds as defined in the United States Geological Survey (USGS) National Hydrologic Database: Dripping Spring Wash-Gila River (HUC10) to the east, and Mineral Creek-Gila River (HUC10) to the north and west (Figure 2-2). Two portions of the Dripping Spring Wash subbasin do not contribute flow to Dripping Spring Wash and are identified in the figure.

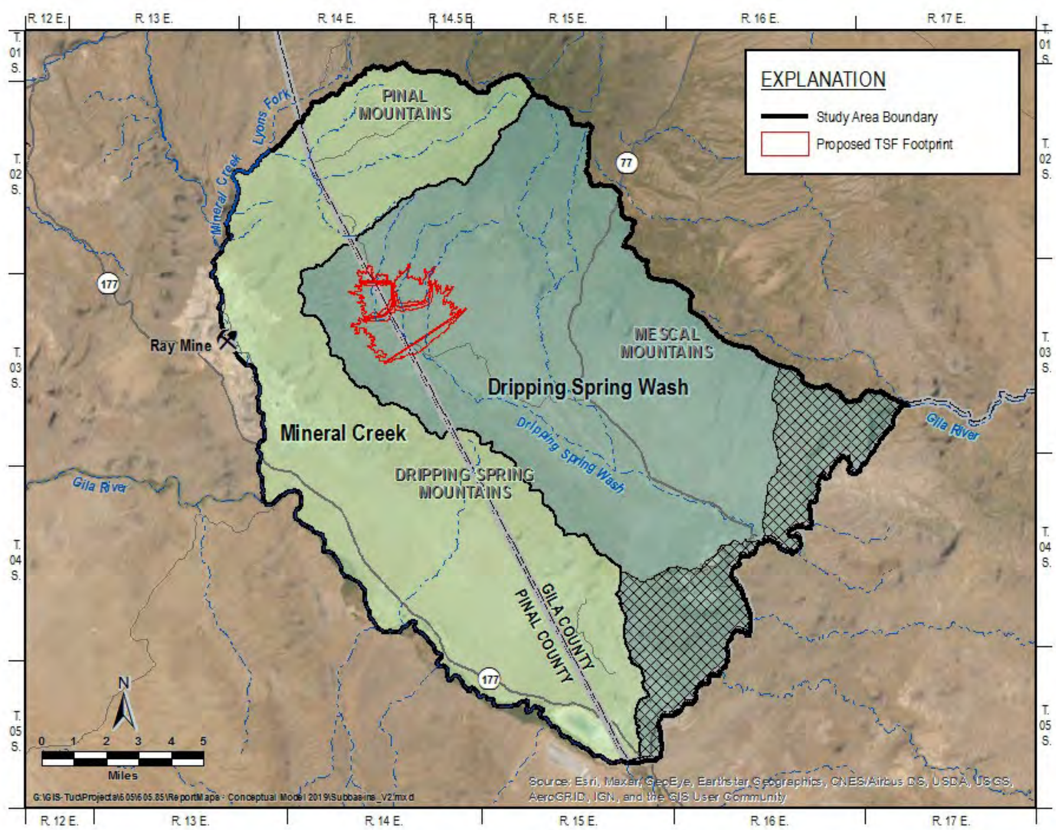

Figure 2-2. Study Area Basins

Within these watersheds, 24 springs/seeps are mapped in the Arizona Department of Water Resources (ADWR) surface water rights database, the ALRIS database. All mapped locations have been visited and springs have been identified in 21 of these locations. The spring/seep locations are shown on Plate 1 and are described in the following sections.

2.2.1 Principal Drainages and Sub-basins

The portion of the Mineral Creek watershed within the study area is approximately 116,000 acres and drains the southern slopes of the Pinal Mountains and the western flank of the Dripping Spring Mountains. Mineral Creek is diverted around the Ray mine open pit and discharges to the Gila River via several small washes near the town of Kearny (Figure 2-2).

The Dripping Spring Wash watershed is approximately 92,000 acres. Dripping Spring Wash drains towards the southeast, including the western slope of the Mescal Mountains and the eastern slope of the Dripping Spring Mountains (Figure 2-2). Dripping Spring Wash watershed discharges to the Gila River approximately 7 miles upstream from the town of Winkelman.

2.2.2 Streams – Flow Rates and Persistence / Frequency of Flow

Dripping Spring Wash and the other drainages within the Skunk Camp TSF area are ephemeral (ADWR, 2009). The Gila River and a portion of Mineral Creek flow perennially (M&A, 2017c).

Within the study area there are two USGS stream gaging stations located on the Gila River, one below Coolidge Dam (Station #09469500), and the other at Kelvin (#0947000). The Coolidge Dam gage is located approximately 13 miles upstream from the Dripping Spring Wash confluence with the Gila River, and the Kelvin gage is located approximately 15 miles downstream from Winkelman. Locations for the gaging stations are shown on Plate 1.

Daily streamflow data for the Gila River at the Coolidge Dam and Kelvin gages for the period from January 1980 through January 2018 are shown on Figure 2-3. Streamflows at the Coolidge Dam gage are controlled releases from San Carlos Lake, which it impounds. Water is released from the dam to provide flow to agricultural users and typically peaks during the summer growing season.

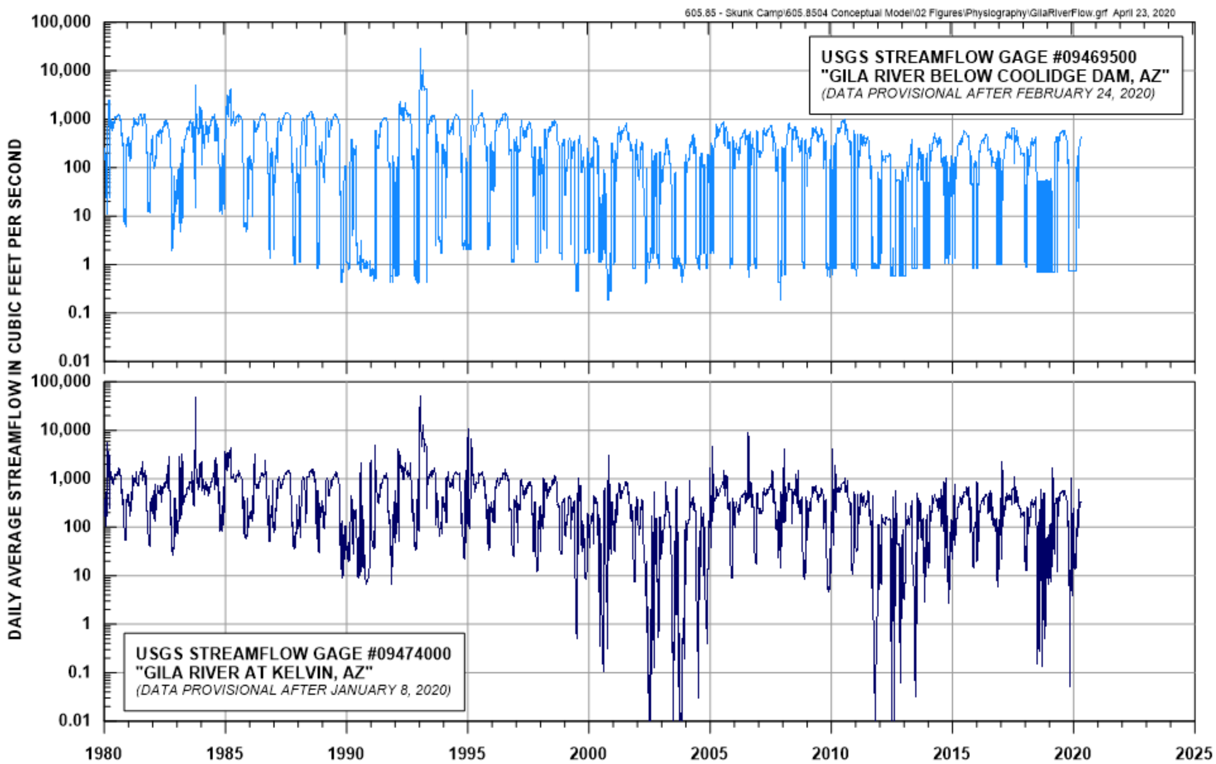

Figure 2-3. Gila River Streamflow Measured at Coolidge Dam and Kelvin

Maximum recorded flow at the Coolidge gage was 29,300 cubic feet per second (cfs) on January 21, 1993. Mean flow at this site from January 1980 – April 2020 was 424 cfs. At the Kelvin gage, the maximum recorded flow was 52,400 cfs on January 21, 1993. Mean flow at the Kelvin gage from January 1980 – April 2020 was 512 cfs.

Streamflow in upper Mineral Creek is monitored at two data sonde locations, Upper Mineral and Lower Mineral (Plate 1). Streamflow at each sonde location is shown on Figure 2-4. Mean flow at this site from January 2011 – September 2017 is 1 cfs. At the Lower Mineral site, the mean flow from March 2011 – September 2019 is 3.1 cfs. At Big Box Dam, flow is captured and diverted around the Ray Mine operations. Mineral Creek ultimately discharges to the Gila River near Kearny.

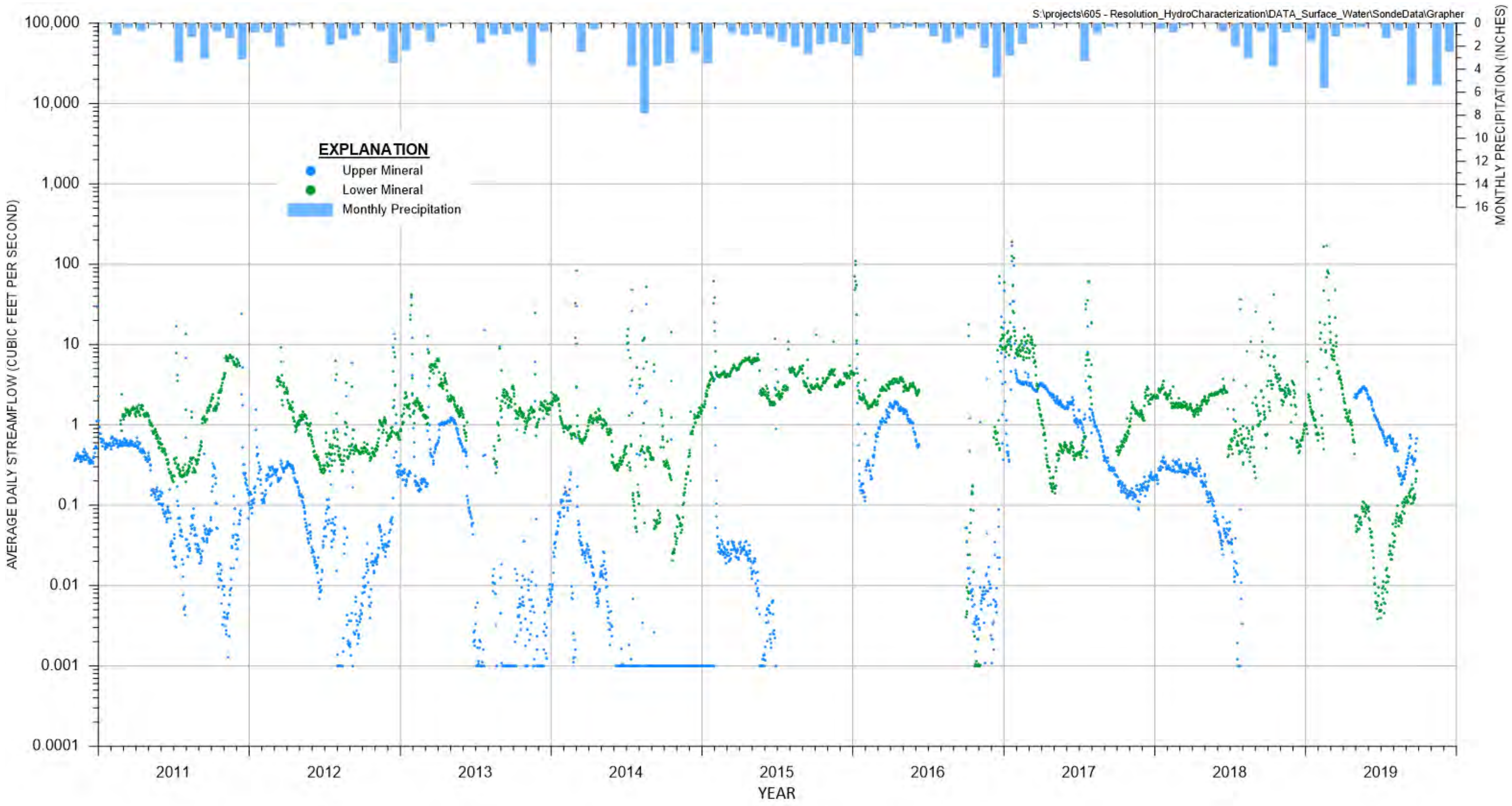

Figure 2-4. Mineral Creek Streamflow

2.2.3 Springs – Flow Rates and Persistence

Springs and seeps are broadly recognized as places where water emerges from the ground. For the purposes of this study, springs and seeps are not differentiated. Two generalized spring categories (Springer and Stevens, 2008) occur within the study area:

1. Rheocrene springs are flowing springs that emerge into one or more channels due to upwelling, a geologic contact, and/or a fault or fracture system.

2. Hillslope springs emerge from unconfined or confined aquifers on non-vertical hillslopes. They often have indistinct or multiple sources and may be associated with geologic contacts or fracture systems.

Springs and seeps identified within the Skunk Camp study area are mapped on Plate 1. Springs and seeps of the Skunk Camp area are described in detail in Version 3.0 of the RC Spring Catalog (M&A/WRI, 2020). Although no springs and seeps are in the TSF footprint, a number of springs and seeps are located in the vicinity of the proposed Skunk Camp TSF site within 3 miles are summarized below in Table 2-1.

Table 2-1. Principal Springs

Spring Name	Local Geology	Observed Flow Rate
Armstrong Spring	Troy Quartzite	No surface water observed, but lush vegetation present
Big Springs	Gila Conglomerate	5 to 6.5 gallons per minute (gpm)
Chimney Spring	Barnes Conglomerate and diabase	No measurable flow but slight seepage over the dam
Cockleburr Spring	Dripping Spring Quartzite	No flow observed; apparent tinaja
Dripping Spring	Paleozoic carbonates and diabase	0.37 to 0.5 gpm
Dripping Springs	Unknown	No evidence of spring
Dry Spring	Alluvium and Troy Quartzite	0.42 to 12 gpm
Government Springs #1 & #2	Breccia zone in Tertiary conglomerate, sandstone, and tuff	0.1 to 0.5 gpm
Elkins Spring	Alluvium and Gila Conglomerate	1 gpm
Haley Spring	Dripping Spring Quartzite and diabase	No flow observed; damp stream bottom; pools downstream from geologic contact
Hot Rod Spring	Troy Quartzite and diabase	0.2 to 0.5 gpm
Indian Spring	Dripping Spring Quartzite and diabase	0.2 gpm
Laguna Spring	Dripping Spring Quartzite and diabase	0.01 gpm dripping in August 2019; 0.25 gpm in November 2019
Looney Spring	Dripping Spring Quartzite, Mescal Limestone, and diabase	Pooled water; no flow observed
Mine Spring	Unknown	No evidence of spring
Seger Spring	Unknown	No evidence of spring
Skunk Spring	Dripping Spring Quartzite and diabase	0-.13 gpm
Spirit Spring	Unknown	No evidence of spring
Stone Cabin Box Spring	Alluvium and Bolsa Quartzite	0-2 gpm
Stone Cabin Spring	Mescal Limestone and diabase	0-2 gpm
Sump Spring	Dripping Spring Quartzite and diabase	Pooled water; no flow observed
Walnut Spring	Dripping Spring Quartzite and diabase	1-1.4 gpm
Well Spring	Gila Conglomerate west of the Dripping Spring Wash	0.5 gpm
Wet Leg Spring (AKA MC 3.4W)	Emerges along hillslope from fractured Apache Leap Tuff	3.1 gpm
Woodchopper Spring	Fault in Dripping Spring Quartzite	0.3 gpm

3 GEOLOGIC SETTING

The Skunk Camp study area is located on the eastern edge of the Basin and Range physiographic province of the southwestern United States, and lies within all or most of the Hot Tamale Peak (formerly Sonora), El Capitan Mountain, and Hayden quadrangles, and parts of the Pinal Ranch, Pinal Peak, Mescal Warm Spring, Kearny, Christmas, and Winkelman 7.5’ quadrangles. The geology of the study area ranges in age from Holocene alluvium in active stream channels to older Precambrian schist basement rock. A geologic map of the study area is shown on Plate 1.

Dripping Spring Valley is approximately 2-4 miles wide and contains Tertiary (Miocene age) basin-fill deposits (Gila Group) with Holocene alluvium along the active stream channels. The valley is flanked by bedrock mountain blocks with older rock units ranging in age from Tertiary to Precambrian (Plate 1).

3.1 Geologic Structure

The Dripping Spring basin is a half-graben basin, bounded on the west side by a steeply dipping normal fault, herein referred to as the Dripping Spring fault, with the east side down-dropped relative to the west side. The fault reportedly has more than 2,900 ft of displacement in the northern part of the valley and more than 1,470 ft south of the toe of the TSF footprint based on historic drillhole data (Cornwall and others, 1971). The rocks in the Dripping Spring Mountains west of Dripping Spring Wash are complexly faulted. The central part of the Dripping Spring Mountains to the west of the proposed TSF footprint comprises a graben bounded by north-south trending faults. The eastern Ransome fault and a splay to the east of the Ransome fault extend into the Tertiary Gila conglomerate (Tcg) in the western portion of the TSF footprint (Cornwall and others, 1971). The Dripping Spring and Ransome faults join in Sec. 33 (T. 2 S., R. 14 E.) near the north end of the proposed TSF footprint and continue to the north (Plate 1).

Although surficial evidence of faulting was not observed at the proposed footprint of the TSF site during mapping and deep investigative drilling by KCB, the fault was encountered outside of the TSF footprint during drilling in well RC20-2D, but not in Gila Conglomerate. Results of aquifer testing indicate that there is enhanced groundwater flow along the fault in the Bolsa Quartzite downstream from the TSF (RC20-2D) and there may be enhancement of groundwater movement near the fault trace in the Gila conglomerate downstream of the Skunk Camp TSF footprint site. The recirculation of pumped water during the test at well RC19-7, located near the projected Ransome fault splay (Plate 1), suggests possible flow along fractures in the Gila Conglomerate (M&A, 2019).

3.2 Depth to Bedrock

Quaternary alluvial deposits and Tertiary basin-fill deposits (Gila Group) underlie most of the proposed TSF footprint. The alluvial deposits and basin fill overlie Paleozoic and younger Precambrian bedrock units. The bedrock units bound the west and east sides of Dripping Spring basin (Plate 1). The basin is asymmetric with a thick wedge of Quaternary alluvium and Tertiary basin-fill deposits (Gila conglomerate and sandstone) along the western edge of the basin. The wedge of sediments tapers toward the eastern edge of the basin (Cornwall and others, 1971). The combined thickness of the Quaternary alluvium and Tertiary Gila basin-fill deposits decreases east of the Dripping Spring fault. Paleozoic and Precambrian bedrock units outcrop in the Pinal Mountains on the east side of Dripping Spring Valley. These units generally dip to the southwest.

The thickness of the Quaternary alluvial deposits in Dripping Spring Valley is generally less than 100 ft. During characterization drilling in the vicinity of the TSF, the Quaternary alluvium, where present, had thicknesses ranging from 11 to 75.5 ft (KCB, 2019).

To date, the total thickness of Gila Group basin-fill deposits in Dripping Spring Valley has not been fully characterized. During site characterization drilling, the base of the Gila units was encountered in only four locations: DH19-3A, DH19-11, DH19-12, and DH19-17. On the west side of the valley at DH19-11, the base of the Gila is at 110 feet below land surface (ft bls), and at DH19-3A, at 890 ft bls. In the center of the valley at DH19-17, the base of the Gila is at 830 ft bls; and on the east side of the valley at DH19-12, the base of the Gila is at 635 ft bls. At the north end of the valley at RC19-15, the Gila is more than 985 ft thick (Plate 1) (KCB, 2019).

Historic drillhole data (borehole DDH-1) indicate more than 2,900 ft of combined Quaternary alluvium and Gila Group deposits east of the Dripping Spring fault in Sec. 20, T. 2 S., R. 14 E. in the north-central part of the valley (Cornwall and others, 1971) (Figure 3-1). Depth to bedrock is more than 2,900 ft at this location. Well 55-622471, located in the center of Dripping Spring Valley, about 1 mile south of the TSF footprint, penetrated more than 1,470 ft of combined Quaternary alluvium and Gila Group (Cornwall and others, 1971) (Plate 1). It is assumed that depth to bedrock is more than 1,470 ft in this area.

3.3 Hydrogeologic Units

General descriptions of the principal hydrogeologic units (HGUs) within the Skunk Camp study area are provided in the following sections. Detailed characterizations of the geology comprising these HGUs have been described by Cornwall and others, 1971 (Sonora); Cornwall and Krieger, 1978 (El Capitan); Banks and Krieger, 1977 (Hayden); Peterson, 1963, (Pinal Ranch); Willden, 1964 (Christmas); and Krieger, 1974 (Winkelman). These detailed characterizations were compiled, correlated, and digitized by the Arizona Geological Survey in Richard, 1998 (Globe 30’ x 60’) and Spencer and others, 1998 (Mesa 30’ x 60’).

This report focuses on the principal HGUs identified within the study area which include in order of increasing age: Quaternary alluvial deposits, Tertiary basin-fill deposits, and mountain block bedrock units including Tertiary volcanic rocks, older Tertiary sedimentary units, Tertiary-Cretaceous intrusive igneous rocks, Cretaceous volcanic and sedimentary rocks, Paleozoic sedimentary rocks and associated talus and colluvium, younger Precambrian diabase and associated talus and colluvium, younger Precambrian sedimentary rocks and associated talus and colluvium, Precambrian intrusive igneous rocks, and older Precambrian Pinal Schist (Plate 1). The principal HGUs are provided in Table 3-1 below with a correlation to geologic units shown on Plate 1.

Table 3-1. Principal Hydrogeologic Units

Hydrogeologic Unit (HGU) Name	HGU Abbrev.	Geologic Unit Equivalents[a]
Quaternary alluvium	Qal	Qal
Tertiary Gila Group conglomerate and sandstone and Pleistocene to Holocene pediment veneer and older alluvium	Tcg	Qoa, Tcg, Tss
Mountain Block units		
Tertiary volcanic rocks		Tvy, Tal, Tvo
Older Tertiary sedimentary units		Tw, Tsm, Tcl
Tertiary - Cretaceous intrusive rocks		TKg, Ki
Cretaceous volcanic rocks and sedimentary units		Kv, Ks
Paleozoic sedimentary rocks		Pz, (QTls)
Naco Limestone		
Escabrosa Limestone		
Martin Limestone		
Abrigo Formation		
Bolsa Quartzite	b	
Younger Precambrian diabase		Yd (QTls)
Younger Precambrian sedimentary rocks		Ya (QTls)
Troy Quartzite		
Apache Group		
Basalt		
Mescal Limestone		
Dripping Spring Quartzite		
Pioneer Formation		
Younger and Older Precambrian intrusive rocks		Yg, YXg, Xg
Older Precambrian Pinal Schist		Xp

[a] Abbreviations correlate with the formation abbreviations shown in the explanation of Plate 1.

3.3.1 Quaternary Alluvium (Qal)

Deposits of Quaternary alluvium (Qal) are Holocene age and comprise poorly sorted, unconsolidated pebbles, cobbles, boulders, sand, and silt in active stream channels and on young low-lying terraces. These deposits display little or no evidence of weathering or soil development. They have been mapped along the Gila River, Dripping Spring Wash and its tributaries, and Mineral Creek and its tributaries (Plate 1). The thickness of the Qal is generally less than 100 ft. In the upper reaches of the Dripping Spring Valley where characterization drilling was conducted, the Qal thickness ranged from about 14.5 ft at DH19-3 and RC19-3 to 75.5 ft at DH18-8B. The Qal is absent at DH18-5, DH19-7, RC19-7, DH18-8, DH19-11, DH19-14, and RC19-15 (Plate 1) (KCB, 2019).

3.3.2 Tertiary Gila Group Conglomerate, Sandstone and Lacustrine Deposits (Tcg)

3.3.2.1 Quaternary Older Alluvium (Qoa)

The older Quaternary alluvium (Qoa) is early Pleistocene age and includes older surficial deposits. The deposits include slightly to moderately indurated conglomerate and sandstone, colluvial veneer on the basin-fill conglomerate and sandstone units, and older terrace deposits in Dripping Spring Wash and its tributaries and along the Gila River (Plate 1). These deposits are characterized by moderately to strongly developed soils. During characterization drilling in the upper reaches of the Dripping Spring Valley, the unit was observed at DH19-7, DH18-8, RC19-10, and DH19-14 where it ranged from 6.3 to 25 ft thick (Plate 1) (KCB, 2019).

3.3.2.2 Tertiary Conglomerate and Sandstone (Tcg)

The Tertiary Gila conglomerate (Tcg) is Miocene age and includes slightly to moderately indurated massive conglomerate and sandstone in the Dripping Spring and Gila River Valleys. Less extensive deposits occur along Mineral Creek. The Tcg in the Dripping Spring Valley has been assigned a Miocene age, whereas Tcg members west of the Dripping Spring Mountains include deposits from Pliocene to Miocene age (Richard, 1998; Spencer and others, 1998). Sandstone \was observed in the subsurface in many of the characterization drill holes in the north part of the valley (KCB, 2019). The sandstone is weakly to moderately indurated and has gradational contacts with conglomerate members of the Tcg.

Optical borehole image (OBI) logs obtained during characterization drilling shows that the Tcg includes interbedded weakly to moderately indurated conglomeratic sandstone, matrix-dominated conglomerate, and clast-dominated conglomerate. The matrix is typically tuffaceous sandstone. Clasts include a wide variety of locally derived, subangular to subrounded pebbles to boulders. Structure within the beds is mostly absent, but some beds display fining upward sequences. The Tcg shows sparse evidence of fracturing. Sub-horizontal bedding planes are evident in most OBI and acoustic borehole image logs.

During characterization drilling, the base of the Tcg was encountered at 108.9 ft bls on the west side of the valley at DH19-11, and 891.4 ft bls at DH19-3A; at 827.6 ft bls in the center of the valley at DH19-17; and at 635.2 ft bls on the east side of the valley at DH19-12; however, near the north end of the valley the Tcg is more than 985 ft thick at RC19-15 (Plate 1) (KCB, 2019). Historic drill hole data suggest that the Tcg may be more than 2,900 ft thick in the Mineral Creek watershed north of the Dripping Spring watershed drainage divide (T. 2 S., R. 14 E., Sec. 20), and more than 1,470 ft thick in the northern part of the Dripping Spring Valley (T. 3 S., R. 14 E., Sec. 24) (Cornwall and others, 1971).

3.3.2.3 Tertiary Lacustrine Deposits (Tss)

The Tertiary Gila lacustrine deposits (Tss) are Miocene age and include interbedded sandstone, siltstone, claystone, and limestone where they outcrop in the center part of the Dripping Spring Valley (Plate 1). The lateral extent and thickness of the Tss is unknown; however, sandstone units are shown to interfinger with conglomerate units in some wells in the center and south parts of the valley (Arizona Department of Water Resources [ADWR] imaged records).

3.3.3 Bedrock Mountain Block Units (b)

3.3.3.1 Tertiary Volcanic Rocks, undivided (Tvy, Tal, and Tvo)

The undivided Tertiary volcanic rocks include volcanic rock units younger than the Apache Leap Tuff (Tvy), Apache Leap Tuff (Tal), and volcanic rock units older than the Apache Leap Tuff (Tvo). None of these units occur in the vicinity of the proposed Skunk Camp TSF, but the Tal and Tvy occur along the northwest edge of the groundwater flow model domain boundary.

The Tvy is exposed along Mineral Creek north of Ray near the northwest edge of the model domain boundary and east of Lyons Fork (Plate 1). Here the Tvy is an airfall tuff that lies on top of the Tcg (Cornwall and others, 1971). Outside the model domain there are scattered occurrences of Tvy east and west of the model domain boundary. The Tvy has not been encountered near the proposed Skunk Camp TSF.

The Tal, a regional stratigraphic marker unit, is present along the northwest edge of the model domain, and to the north and west of the model domain boundary (Plate 1). The Tal has not been encountered at Skunk Camp but is present in the RC East Plant area (located near Shafts 9 and 10) and at the RC Near West site (located approximately 5 miles west of Superior).

The Tvo has not been encountered at Skunk Camp but occurs southeast of model domain boundary (Plate 1).

3.3.3.2 Older Tertiary Sedimentary Units (Tw, Tsm, and Tcl)

The older Tertiary sedimentary units include the older Miocene to late Oligocene pre-volcanic units including the Whitetail Formation (Tw), San Manuel Formation (Tsm), and Cloudburst

Formation (Tcl). None of these units occur in the vicinity of the proposed Skunk Camp TSF or in Dripping Spring Valley, but the Tsm occurs along the southwest edge of the model domain adjacent to the Gila River. Southwest of the model boundary the Tsm outcrops in Ripsey Wash (Plate 1).

The Tw is a regional stratigraphic marker unit and is exposed in Devils Canyon and to the west of the model domain (Plate 1). It is dominantly conglomerate with lesser sandstone, siltstone, mudstone, limestone, gypsum, avalanche breccia, and minor volcanics. The Tw and Tsm are probably equivalent (Ferguson and Trapp, 2001). The Tw has not been encountered at Skunk Camp but is present in the RC East Plant area.

The Tcl occurs outside the southwest boundary of the model domain west of the Gila River (Plate 1). In the San Manuel area, the Tcl pre-dates the Tsm. The Tcl is not present at the Skunk Camp site.

3.3.3.3 Tertiary – Cretaceous Intrusive Rocks (TKg and Ki)

The Tertiary – Cretaceous age intrusive rocks outcrop in the Dripping Spring and Mescal mountain blocks and include a laccolith at Granite Basin, stocks, small irregular intrusive bodies, and numerous dikes with phaneritic to porphyritic textures and chemical compositions including quartz monzonite, granodiorite, quartz diorite, quartz latite, rhyodacite, and andesite. The units include Tertiary-Cretaceous (Laramide) dikes and intrusive bodies (TKg) and small Cretaceous intrusive bodies (Ki). The units do not occur in the vicinity of the proposed Skunk Camp TSF but are widely scattered throughout the Dripping Spring Mountains and near the southern part of the Mescal Mountains (Plate 1).

In addition to widespread Laramide age dikes, the Ki includes the Rattler Granodiorite to the south of the proposed TSF and Tortilla Quartz Diorite to the west outside the model domain boundary (Plate 1). The Rattler Granodiorite shows extensive fracturing and subsequent intrusion by Laramide dikes (Cornwall and others, 1971). During the 2018-2019 characterization drilling at DH19-17, the Rattler Granodiorite was encountered in the depth interval from 827.6 – 1,435 ft bls. The unit is fractured and jointed with iron oxide staining on fracture surfaces. Some fractures show slickensides or calcite filling. A porphyry dike was encountered in the depth interval from 1,084 – 1,088 ft bls. The Dripping Springs fault was not encountered during drilling as might have been expected. However, the fault in this area appears to be an annealed ductile shear zone lacking brittle fault fabric, and thus is less permeable (Plate 1) (KCB, 2019).

The TKg is present near and southeast of the southeastern model domain boundary and west of the boundary near Ray (Plate 1). The TKg was not encountered during the 2018-2019 drilling program; however, it does not occur in or near the proposed Skunk Camp TSF footprint.

3.3.3.4 Cretaceous Volcanic and Sedimentary Rocks (Kv and Ki)

The Cretaceous age volcanic and sedimentary rocks (Kv and Ks) include two rock sequences: an older sedimentary sequence (Ks) of sandstone, shale, coal, and conglomerate; and a younger volcaniclastic sequence (Kv) of interbedded basaltic to andesitic flow breccias, minor tuff, conglomerate, sandstone, mudstone, agglomerate, mudflows, and reworked tuff. The Ks likely correlates with the Pinkard Formation (Willden, 1964), and the Kv includes the Williamson Canyon volcanics (Willden, 1964 and Richard, 1998).

The Kv outcrops near and southeast of the southeast model domain boundary, and the Ks outcrops entirely southeast of the boundary (Plate 1). Neither of these units occur in or near the proposed Skunk Camp TSF.

3.3.3.5 Paleozoic Sedimentary Rocks, undifferentiated (Pz)

The Paleozoic sedimentary rocks (Pz) outcrop in the Dripping Spring, Mescal, and Pinal mountain blocks (Plate 1). The Paleozoic rock sequence includes from oldest to youngest: middle Cambrian Bolsa Quartzite, middle and upper Cambrian Abrigo Formation, upper Devonian Martin Limestone, Mississippian Escabrosa Limestone, and middle Pennsylvanian Naco Limestone. The sequence is complexly faulted in the Dripping Spring Mountains and forms a more continuous, southwest dipping outcrop belt in the Pinal and Mescal Mountains (Plate 1). The Naco Limestone is absent in the Pinal Mountains. The Pz units' outcrop along the east and west edges of the proposed Skunk Camp TSF, and underly the Tertiary basin-fill deposits on the east side of Dripping Spring Valley (Cornwall and others, 1971).

The Naco Limestone includes interbedded resistant limestone and less resistant shaley or silty limestone. Thin beds of siltstone and shale occur throughout the unit (Cornwall and others, 1971). The Naco Limestone has not been encountered at the Skunk Camp site.

The Escabrosa Limestone includes upper and middle sequences of resistant limestone layers and lower sequence of dolomite and limestone (Cornwall and others, 1971). During characterization drilling at the Skunk Camp site, the Escabrosa Limestone was encountered at DH19-12 at a depth of 635.2 ft bls. The limestone layers are jointed with iron oxide staining on some surfaces, calcite veining, and some dissolution features (Plate 1) (KCB, 2019).

The Martin Limestone includes dolomite with few thin sandstone and shaley limestone interbeds (Cornwall and others, 1971). The unit has not been encountered at Skunk Camp.

The Abrigo Formation includes thin layers of interbedded mudstone, siltstone, sandstone, and quartzite (Cornwall and others, 1971). The unit has not been encountered at Skunk Camp.

The Bolsa Quartzite includes thin beds of sandstone consisting of rounded grains of sand in a siliceous matrix (Cornwall and others, 1971). The unit was encountered in well RC20-2D.

During 2018-2019 characterization drilling, an unspecified Paleozoic limestone unit was encountered at DH19-3A in the depth interval from 891.4 ft bls to the bottom of the hole at 1,032.5 ft bls, with a jointed and fractured basalt dike from 986 – 1,013.2 ft bls. This limestone intercept shows weathered seams and closely spaced calcite-filled joints (Plate 1) (KCB, 2019).

3.3.3.6 Younger Precambrian Diabase (Yd)

The younger Precambrian diabase (Yd) outcrops in the Dripping Spring, Mescal, and Pinal Mountains (Plate 1). The Yd intruded older Precambrian units including Pinal Schist, Precambrian granitoid rocks, Troy Quartzite, and Apache Group basalt and sedimentary rocks (described below) as a series of mafic dikes and sills.

During characterization drilling, the diabase was encountered at DH19-11 and DH19-14 as sills within Apache Group rock units and dikes within older Precambrian granitoids. The unit is typically jointed and locally fractured and has quartz veining, calcite joint filling, and clay alteration along fracture surfaces (Plate 1) (KCB, 2019). The Yd was encountered in the RC Near West area (M&A, 2017b).

3.3.3.7 Troy Quartzite and Apache Group Sedimentary Rocks, undifferentiated (Ya)

The younger Precambrian Troy Quartzite and Apache Group sedimentary units (Ya) outcrop in the Dripping Spring, Mescal, and Pinal Mountain blocks (Plate 1). The Troy Quartzite unconformably overlies the Apache Group sedimentary units which include from youngest to oldest: basalt, Mescal Limestone, Dripping Spring Quartzite, and Pioneer Formation. Both Troy Quartzite and Apache Group were intruded by diabase (Yd) sills and dikes. Like the Pz units, the Ya units are complexly faulted in the Dripping Spring Mountains, and form a more continuous, southwest dipping outcrop belt in the Mescal and Pinal Mountains (Plate 1).

The Troy Quartzite is common in the Dripping Spring Mountains but was not encountered during characterization drilling at the site. The unit is predominantly cliff-forming quartzite, sandstone, with minor interbeds of pebble and granule conglomerates (Cornwall and others, 1971).

The Apache Group basalt includes one or more flows of deeply weathered porphyritic basalt (Cornwall and others, 1971). The unit was not encountered during characterization drilling at the site but was encountered at the RC Near West site (M&A, 2017b).

The Mescal Limestone includes laminated to thin bedded partly calcareous dolomite. Parts of the unit contain chert and algal stromatolite beds (Cornwall and others, 1971). During site characterization drilling in 2018 and 2019, the Mescal Limestone was encountered at DH19-11 and DH19-14 in the Dripping Spring mountain block (Plate 1 and KCB, 2019). The Mescal Limestone was also encountered at the RC Near West site (M&A, 2017b).

The Dripping Spring Quartzite includes a basal conglomerate (Barnes Conglomerate), siltstone, shale, arkose, and feldspathic quartzite (Cornwall and others, 1971). During site characterization drilling in 2018 and 2019, the Dripping Spring Quartzite was encountered at DH19-11 and DH19-14 (Plate 1 and KCB, 2019). The Dripping Spring Quartzite was also encountered at the RC Near West site (M&A, 2017b).

The Pioneer Formation includes a basal conglomerate (Scanlan Conglomerate), tuffaceous siltstone and arkosic sandstone (Cornwall and others, 1971). During site characterization drilling in 2018 and 2019, the Pioneer Formation was encountered at DH19-11 and DH19-14 (Plate 1 and KCB, 2019).

At the Skunk Camp site, the Ya units are sparsely to closely jointed and locally highly fractured to brecciated with evidence of rehealing. Quartz veining is locally common. At DH19-14, fault blocks are evidenced by repeat sections of the geologic units. The units are jointed and locally highly fractured to brecciated. Calcite and silicate veining are common (KCB, 2019).

3.3.3.8 Precambrian Intrusive Rocks (Yg, YXg, and Xg)

The Precambrian intrusive rocks outcrop in the Pinal Mountains at the north end of the Dripping Spring basin with smaller more scattered outcrops in the Dripping Spring and Mescal Mountains (Plate 1). Within the Skunk Camp study area, the units include the younger Ruin Granite (Yg) and older Madera Diorite (YXg or Xg).

During characterization drilling, the Yg was encountered in several fault blocks at DH19-11 in the depth intervals from 1,189 – 1,491 ft bls, 1,747 – 2,334.5 ft bls, and 2,633.1 – 2,693 ft bls. The unit is widely jointed, locally highly fractured, and shows calcite veining and strong chlorite alteration (Plate 1) (KCB, 2019).

3.3.3.9 Pinal Schist (Xp)

The older Precambrian Pinal Schist (Xp) outcrops in the Pinal Mountains at the north end of Dripping Spring basin. Smaller, more scattered outcrops are present in the Dripping Spring and Mescal Mountains (Plate 1). The Xp is the oldest geologic unit in the study area, but to date, it has not been encountered during characterization drilling. The Xp was encountered at the RC Near West site (M&A, 2017b).

3.4 Geologic Sections

Two geologic sections were prepared using the Skunk Camp Leapfrog Model developed by M&A (Figure 3-1). The geologic sections have a vertical exaggeration of 2 and include the simplified geology of the site: Qal, Tcg, and b units. Figure 3-1 includes a west-east section (Section A) and a northwest-southeast section (Section B). Section A shows the topographic relief from the Ray Mine Pit, through the Dripping Spring Mountains, the proposed Skunk Camp TSF, and to the Tcg contact at the Pinal Mountains. The Dripping Spring fault is shown in this section offsetting the bedrock and varying thickness of the Tcg across the fault to form the half-graben basin. The offset of the bedrock was estimated based on site investigation wells to be closer to 1,000 feet instead of the 2,900 feet as documented by the exploration borehole north of the proposed Skunk Camp TSF. Section B shows the thickness of the Tcg along the axis of the proposed TSF to range between 1,500 and 2,000 feet.

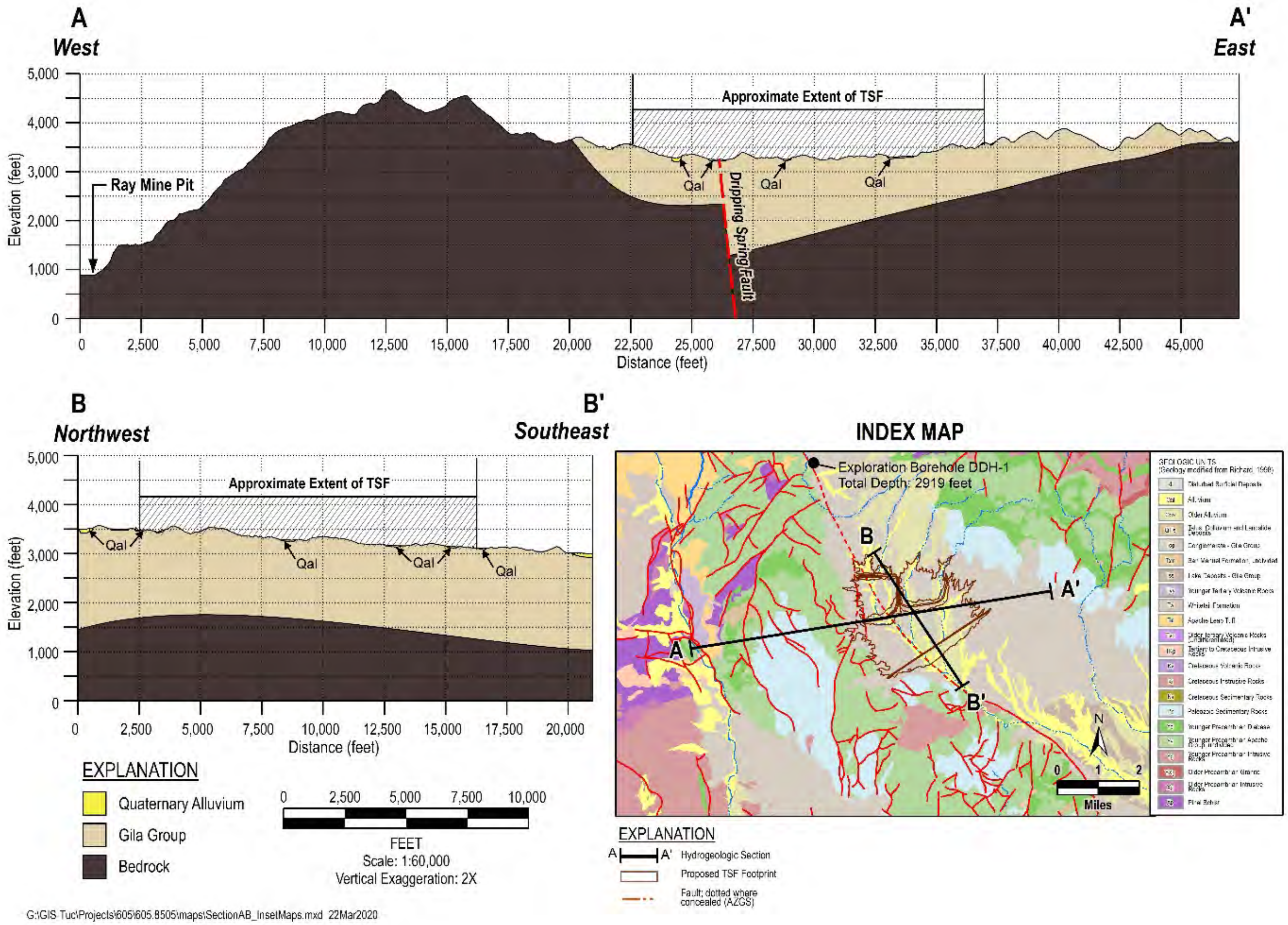

Figure 3-1. Skunk Camp Geologic Sections

4 HYDRAULIC CONDUCTIVITY

An aquifer testing program was conducted to estimate the hydraulic conductivity in the geologic units beneath and surrounding the proposed TSF site.

Testing conducted at the Skunk Camp TSF site consisted of:

- Packer tests in boreholes during coring
- Open hole falling head tests in saturated and unsaturated intervals
- Slug tests
- Constant-head tests in saturated and unsaturated intervals
- Step aquifer pumping tests
- Constant-rate aquifer pumping tests
- Infiltration testing in test pits
- Triaxial permeability tests on core samples

Testing methods were selected based on the drilling technique, borehole diameter, water level, water production, and data collection needs. Testing was conducted over multiple campaigns by KCB and M&A over the period 2018 through 2020.

Table 4-1 summarizes the tests conducted to determine the hydraulic conductivity of the Qal and Tcg at the Skunk Camp site.

Table 4-1. Skunk Camp Aquifer Testing Summary

Test Type	Formation	
	Qal	Tcg
Constant-Head	10	5
Falling Head	2	16
Slug		4
Step Aquifer Pumping		3
Constant-Rate Aquifer Pumping		10
Infiltration Test Pits	2	5
TOTAL	14	43

Criteria used to classify permeabilities based on measured hydraulic conductivity are shown in Table 4-2 below.

Table 4-2. Hydraulic Conductivities

Permeability	Hydraulic Conductivity, K (cm/sec)
Very low	< $1x10^{-7}$
Low	$1x10^{-7}$ to $1x10^{-6}$
Moderately low	$1x10^{-6}$ to $1x10^{-5}$
Moderate	$1x10^{-5}$ to $1x10^{-4}$
Moderately high	$1x10^{-4}$ to $1x10^{-3}$
High	$1x10^{-3}$ to 0.1
Very high	> 0.1

4.1.1 Quaternary Alluvium (Qal)

Fourteen tests were conducted in wells in the Qal: 10 constant-head tests and two falling-head tests. In addition, two ring infiltrometer tests were conducted in test pits. If multiple tests were conducted in an interval within a well or borehole, the hydraulic conductivity for that interval was taken as the geometric mean of the tests for that interval. Additional details on each type of test are provided in the following sections.

4.1.1.1 Injection Tests

Ten constant-head injection tests and two falling-head injection tests were conducted in Qal wells. The results of the downhole testing in Qal are summarized in Table 4-3. The geometric mean hydraulic conductivity for the downhole injection testing of the Qal is $1.05x10^{-2}$ cm per second (cm/sec).

Table 4-3. Summary of Qal Injection Testing

Hole	Interval ft bls	K cm/sec	Test Type
RC18-8C	31 to 71	$8.09 x10^{-3}$	Constant Head
RC18-9	16.3 to 18.6	$4.00 x10^{-2}$	Constant Head
RC18-9	37.1 to 39.5	$4.00 x10^{-2}$	Constant Head
RC19-8	17.3 to 18.7	$2.06 x10^{-2}$	Constant Head
RC19-8	39 to 40.3	$3.57 x10^{-3}$	Constant Head
RC19-8	57.3 to 60.3	$1.75 x10^{-1}$	Falling Head
RC19-8	64.3 to 70.3	$1.90 x10^{-3}$	Falling Head
RC19-8A	17.3 to 19	$6.38 x10^{-3}$	Constant Head
RC19-8A	36.1 to 39	$4.00 x10^{-3}$	Constant Head
RC19-8B	15.5 to 19.5	$3.90 x10^{-2}$	Constant Head
RC20-2C	29 to 69	$3.00 x10^{-3}$	Constant Head
RC20-18A	52 to 91	$2.00 x10^{-3}$	Constant Head

4.1.1.2 Test Pits

Two falling-head infiltration tests were conducted in two test pits using a 12.2-inch diameter infiltration ring. The results of the falling head tests are summarized in Table 4-4. The geometric mean hydraulic conductivity for the Qal based on test pit infiltration testing is 1.98 x10^{-2} cm/sec.

Table 4-4. Falling-Head Testing Summary

Hole / Test Pit	Interval ft bls	K cm/sec
TP-19-8	0 to 3	1.09 x10^{-2}
TP-19-9	0 to 1	3.59 x10^{-2}

4.1.1.3 Summary

Fourteen tests were conducted in nine locations to estimate the hydraulic conductivity of the Qal. Hydraulic conductivity within the Qal shows variability within a reasonably tight range from 1.9 x10^{-3} to 1.75 x10^{-1} cm/sec (Figure 4-2). This is classified as a “high” permeability based on Table 4-2. The geometric mean of all tests in the Qal was 1.02 x10^{-2} cm/sec and is considered a representative value for the unit. For locations with multiple hydraulic conductivity intervals tested, an interval thickness weighted geometric mean was estimated for the location.

4.1.2 Tertiary Conglomerate and Sandstone (Tcg)

Forty-three tests were conducted in the Tcg at the Skunk Camp site consisting of aquifer constant rate and step pumping tests, packer tests, slug tests, and constant-head and falling head injection tests. Most of the tests were conducted downhole below the water table; however, some tests were conducted in the unsaturated zone or at the surface in test pits.

Packer test data were not used to characterize the Tcg at the Skunk Camp site as the radius of influence of packer tests is typically limited to the immediate vicinity of the borehole and hydraulic conductivities determined by packer testing tended to be much lower than pumping tests conducted in the same holes.

Additional details on each type of test are provided in the following sections.

4.1.2.1 Constant-Rate Pumping Tests

Constant-rate aquifer pumping tests were conducted in wells RC19-3, RC19-7, RC19-8B, RC19-8D, RC19-13, RC19-15, RC20-2, RC20-2A, and 55-205266. Tests were analyzed using the methods of Cooper-Jacob (1946), Moench (1997), and Agarwal (1980). Results of the constant-rate aquifer pumping tests are summarized in Table 4-5.

Table 4-5. Constant-Rate Aquifer Pumping Test Results

Hole	Duration, days	K cm/sec
RC19-3	3	7.50 x10^{-4}
RC19-7	1	1.10 x10^{-3}
	1	1.30 x10^{-3}
RC19-8B	1	2.00 x10^{-4}
RC19-8D	3	1.10 x10^{-4}
RC19-13	7	1.10 x10^{-4}
RC19-15	7	5.70 x10^{-4}
RC20-2	1	2.20 x10^{-4}
RC20-2A	1	1.50 x10^{-4}
55-205266	<1	5.30 x 10^{-5}

Results from 55-205266 stand out because they are about an order of magnitude lower than results from other wells. The furthest east of any site wells is 55-205266. It is also further from the mapped fault trace than other wells. The geometric mean hydraulic conductivity for the Tcg estimated by constant-rate pumping tests is 2.76 x10^{-4} cm/sec.

4.1.2.2 Infiltration Testing

Infiltration tests were conducted in five test pits using a 12.2-inch diameter infiltration ring. Falling head tests were conducted in all test pits; a constant-head test was also conducted in test pit TP19-9. The results of the infiltration tests are summarized in Table 4-6.

Table 4-6. Infiltration Testing Results

Test Pit	Interval bls	Test Type	K cm/sec
TP19-10	0 to 2.5	Falling Head Test	2.00 x10^{-4}
TP19-11	0 to 3.5	Constant Head Test	5.40 x10^{-5}
TP19-13	0 to 2	Falling Head Test	8.39 x10^{-4}
TP19-8A	0 to 2	Falling Head Test	7.60 x10^{-5}
TP19-9	0 to 4	Falling Head and Constant Head Tests	7.94 x10^{-5}

The geometric mean hydraulic conductivity for the Tcg estimated by infiltration testing is 1.40 x10^{-4} cm/sec.

4.1.2.3 Unsaturated Zone Testing

Twenty-one falling-head or constant-head tests were conducted above the water table in 6 wells. The results of the downhole unsaturated zone testing are summarized in Table 4-7.

Table 4-7. Unsaturated Zone Testing Results

Hole	Interval bls	Test type(s)	K cm/sec
RC19-10	17 to 18.5	Falling head	7.90 $\times 10^{-5}$
	27.8 to 32.2	Falling head	2.50 $\times 10^{-5}$
	46.6 to 50.4	Falling head	3.70 $\times 10^{-5}$
	67 to 70	Falling head	5.60 $\times 10^{-5}$
	87.8 to 91	Falling head	7.80 $\times 10^{-5}$
	108 to 113.8	Falling head	2.10 $\times 10^{-4}$
	128 to 134	Falling head	5.30 $\times 10^{-5}$
RC19-15	17 to 20.9	Constant head	1.10 $\times 10^{-4}$
	36.8 to 45.8	Constant head	1.30 $\times 10^{-5}$
	57.5 to 65.2	Constant head	8.60 $\times 10^{-6}$
	76.5 tot 84.8	Constant head	7.60 $\times 10^{-5}$
	80 to 123.8	Falling head	2.90 $\times 10^{-5}$
RC19-3	17.6 to 20	Falling head	4.20 $\times 10^{-4}$
	27.2 to 31	Falling head	1.10 $\times 10^{-4}$
	134 to 169	Falling head	9.90 $\times 10^{-5}$
RC19-7	4 to 42	Falling head	1.20 $\times 10^{-4}$
	4 to 62	Falling head	3.70 $\times 10^{-5}$
	4 to 82	Falling head	4.50 $\times 10^{-4}$
RC19-8A	58 to 60	Falling head	9.45 $\times 10^{-4}$
RC19-8B	40 to 43.8	Constant head	8.90 $\times 10^{-4}$
	56 to 57	Falling head	1.60 $\times 10^{-3}$

The geometric mean hydraulic conductivity for the Tcg estimated by unsaturated zone downhole testing is 9.03 $\times 10^{-5}$ cm/sec.

4.1.2.4 Slug Testing

Nineteen slug tests were conducted in four wells. Slug test results from well RC19-13 were not used for characterizing the Tcg as they were superseded by an aquifer pumping test conducted at this well. The results of the slug testing are summarized in Table 4-8.

Table 4-8. Slug Testing Results

Hole	K cm/sec
RC18-4	1.37 $\times 10^{-4}$
RC19-10	7.30 $\times 10^{-7}$
RC19-8AD	7.25 $\times 10^{-5}$
RC19-8AS	3.00 $\times 10^{-4}$

Results from RC19-10 stand out because they are much lower than results from other wells. Similarly to 55-205266, RC19-10 is further northeast than most other wells and is also further from the mapped fault trace than other wells. The geometric mean hydraulic conductivity for the Tcg estimated by slug testing is 3.83 $x10^{-5}$ cm/sec.

4.1.2.5 Step Test

Three step tests were analyzed for hydraulic conductivity in two wells, RC18-9 and RC19-8. The results of the step tests are presented in Table 4-9.

Table 4-9. Step Testing Results

Hole	K cm/sec
RC18-9	2.17 $x10^{-4}$
RC19-8	2.63 $x10^{-4}$
RC19-8	2.74 $x10^{-4}$

The geometric mean hydraulic conductivity for the Tcg estimated by step testing is 2.50 $x10^{-4}$ cm/sec.

4.1.2.6 Summary and Spatial Variability

The Tcg hydraulic conductivity data were reviewed to determine if the hydraulic conductivity values were dependent upon the type of test, depth, or location. Individual tests within the Tcg reflect a wide range of hydraulic conductivities from 7.30 $x10^{-7}$ to 1.60 $x10^{-3}$. Table 4-10 shows the geometric mean hydraulic conductivity for each Tcg testing location. For testing locations with multiple testing intervals, individual tests were weighted by the testing interval to preferentially weight tests with larger test intervals.

Table 4-10. Geometric Mean Hydraulic Conductivity for Each Location

Hole	K cm/sec
RC18-4	1.37 $x10^{-4}$
RC18-9	2.2 $x10^{-4}$
RC19-10	1.2 $x10^{-6}$
RC19-13	1.1 $x10^{-4}$
RC19-15	3.36 $x10^{-4}$
RC19-3	4.83 $x10^{-4}$
RC19-7	4.24 $x10^{-4}$
RC19-8	2.7 $x10^{-4}$
RC19-8A	9.5 $x10^{-4}$
RC19-8AD & RC19-8AS	1.7 $x10^{-4}$
RC19-8B	2.38 $x10^{-4}$
RC19-8D	1.1 $x10^{-4}$
TP19-9	7.94 $x10^{-5}$
TP19-10	2.00 $x10^{-4}$
TP19-13	8.39 $x10^{-4}$
55-205266	5.30 $x10^{-4}$
RC20-2	2.30 $x10^{-4}$
RC20-2A	2.50 $x10^{-4}$

After averaging the values from each testing location, the geometric mean of tests at all locations is 1.69x10-4 cm/sec. It also becomes clear that almost all locations have a “moderately high” hydraulic conductivity on the order of 1x10-4 cm/sec. However, two aquifer tests have lower hydraulic conductivities (RC19-10 and 55-205266) and extend the hydraulic conductivity of the Tcg into the “moderately low” range (Figure 4-1). These tests are different in that they are both in the eastern portion of the TSF footprint and further from the mapped trace of the Dripping Spring Fault (Figure 4-2). This suggests that hydraulic conductivity in the eastern portion of the Tcg is lower than it is in the western portion of the Tcg. Since more tests were conducted in the western portion of the Gila Conglomerate, the geometric mean hydraulic conductivity for the Tcg may be biased high.

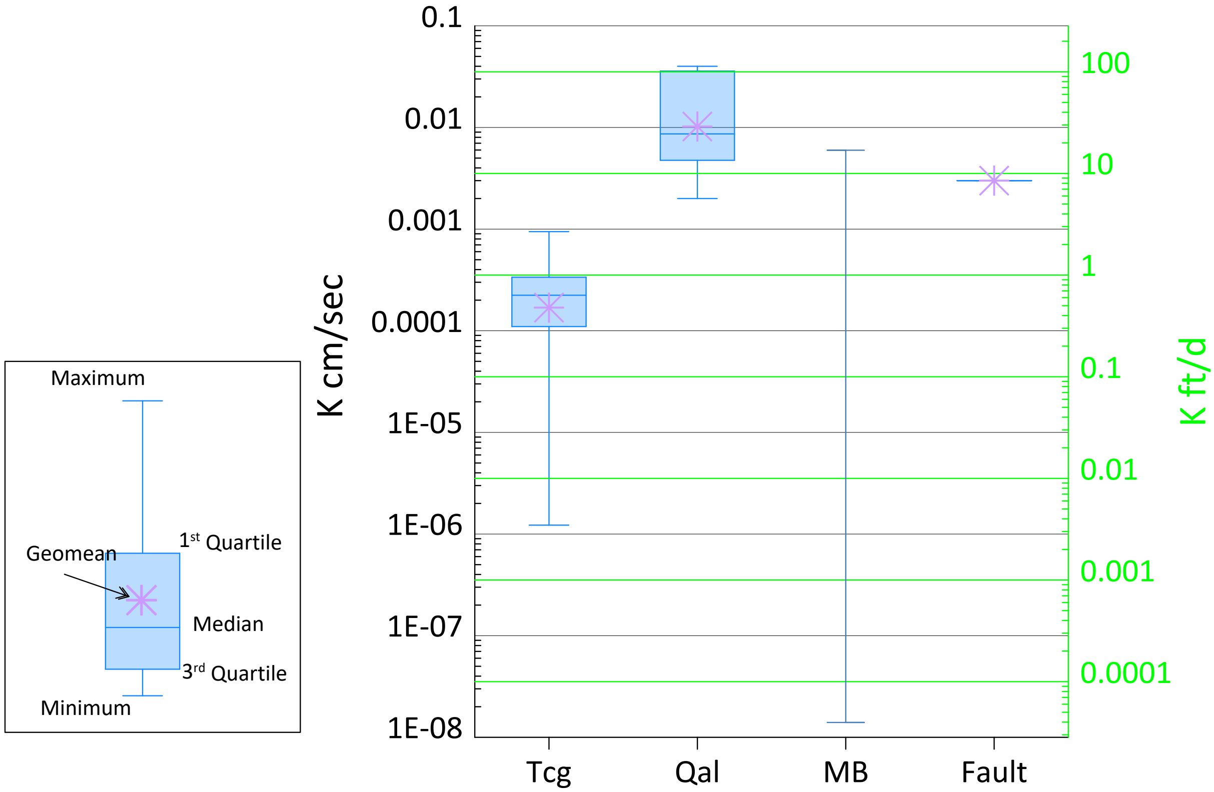

Figure 4-1. Range and Distribution of Hydraulic Conductivity for Each Hydrogeologic Unit

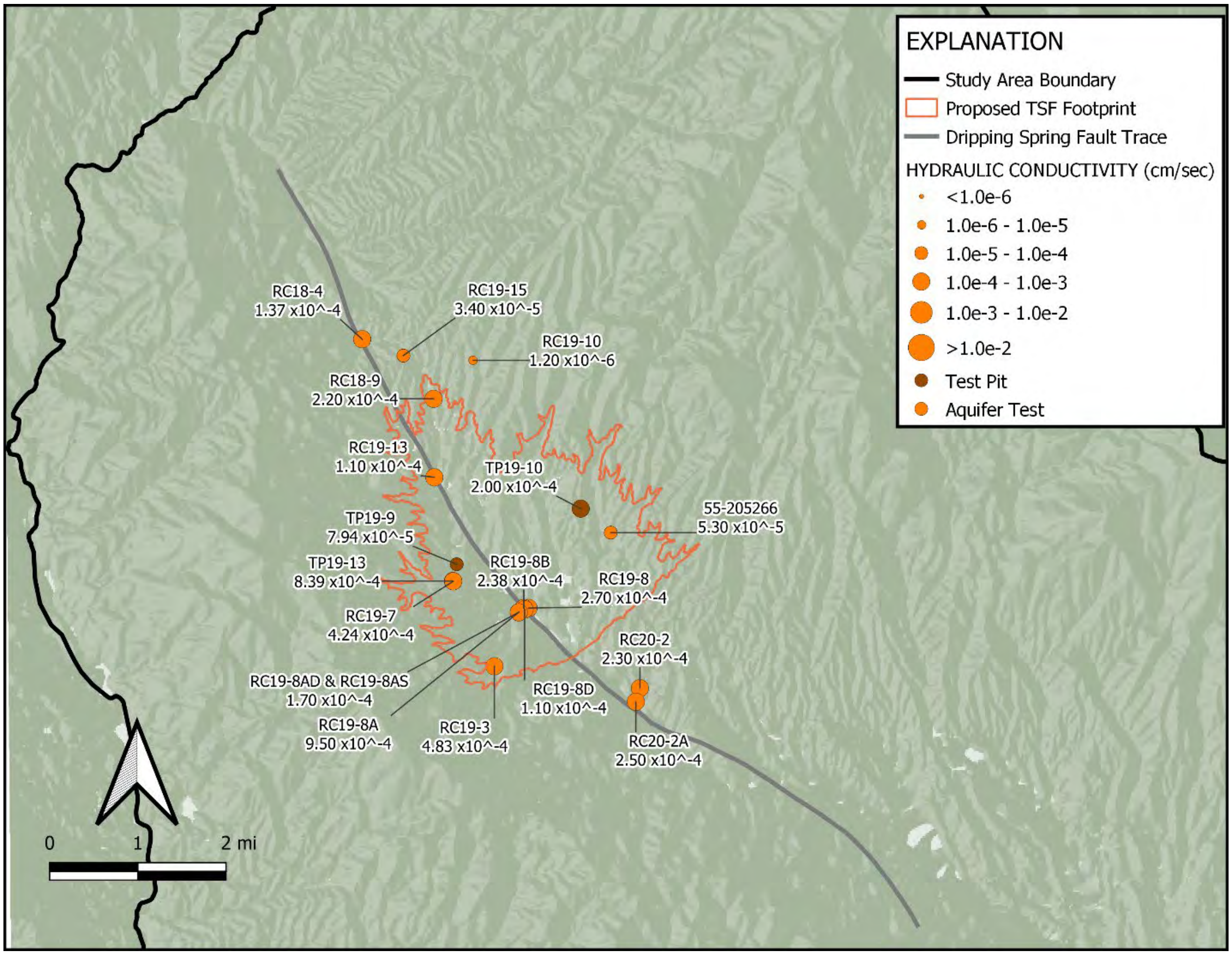

Figure 4-2. Spatial Variation of Hydraulic Conductivity in the Tcg

The hydraulic conductivity of each test was plotted against the midpoint of the test interval to determine if hydraulic conductivity is a function of depth (Figure 4-3). Hydraulic conductivity values based on aquifer pumping tests are approximately one order-of-magnitude higher than those obtained from slug tests or open-hole falling-head tests. This is not unexpected – slug testing was selected as the testing method when constant pumping rates could not be sustained in the well. The unsaturated constant and falling-head tests were conducted during drilling and tested a limited area of influence around the test interval. They are less likely to reflect the influence of preferred flow pathways (such as bedding planes and fractures) and are likely biased low. After accounting for the bias introduced by the test type, there is no clear trend between hydraulic conductivity and depth.

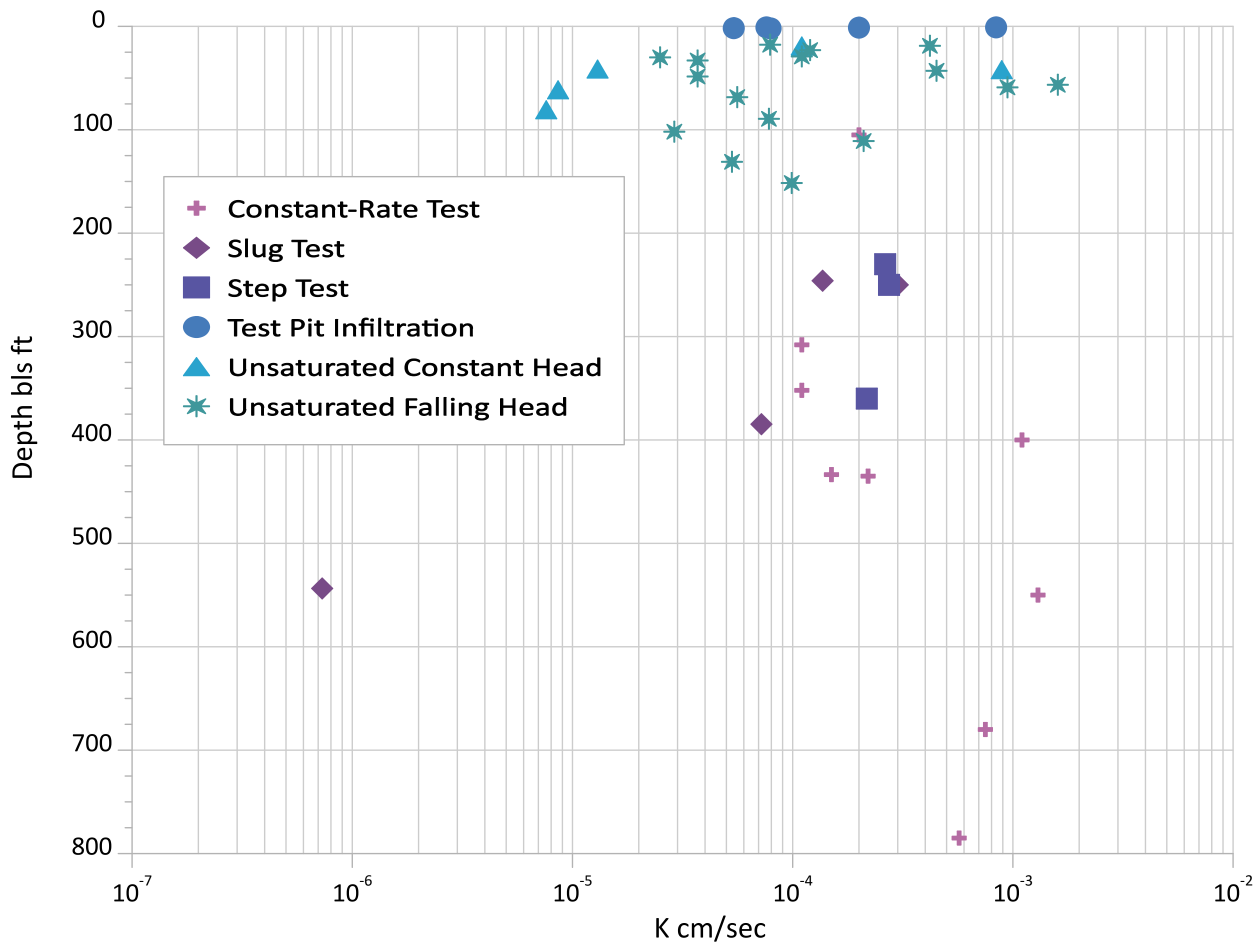

Figure 4-3. Tcg Hydraulic Conductivity and Depth

4.1.3 Mountain Block (b)

The mountain block units at the Skunk Camp site is composed of multiple units located within the Mescal, Pinal, and Dripping Spring Mountain areas. Limited local data is available to support determination of a representative hydraulic conductivity of the mountain block units. However, some data are available from testing throughout the Resolution project area for the geologic units within the mountain blocks. These data provide a sense of the plausible range of hydraulic conductivities in the mountain blocks, which spans over four orders of magnitude (Table 4-11 and Figure 4-1). Given the diversity of geologic units and complexity of geologic structures within the mountain block, a testing program would not be able to effectively characterize the bulk hydraulic conductivity of the mountain blocks. However, the bulk hydraulic conductivity of the mountain blocks would likely be controlled by the lowest hydraulic conductivity units and the presence of faults and fractures. The prevalence of “very low” hydraulic conductivity diabase (Yd) within the Dripping Spring and Pinal mountain blocks would likely be a controlling influence on the effective hydraulic conductivity of the mountain blocks. This may be partially offset if connected fracture systems provide pathways through the units.

Table 4-11. Mountain-Block Hydraulic Conductivity Values for Selected Units

Formation	Geomean K cm/s
Yd	8.43×10^{-7}
Xp	7.43×10^{-6}
Ya	1.54×10^{-5}
Pz	1.70×10^{-5}
Tal	4.45×10^{-5}
Tw	3.60×10^{-8}

5 OCCURRENCE AND MOVEMENT OF GROUNDWATER

5.1 Groundwater Level Elevation

Groundwater levels in the Skunk Camp study area have been measured at wells located in the vicinity of the proposed TSF footprint and northwest of the TSF footprint in the upper Mineral Creek watershed. Additional groundwater level data were obtained from ADWR Groundwater Site Inventory (GWSI) database for the area south of the TSF along Dripping Spring Wash to the Gila River and from ASARCO for the area west of the Dripping Spring Mountains near the Ray Mine.

The highest groundwater elevations in the study area occur in the Pinal Mountains in the northeast, where land surface elevations reach nearly 8,000 ft amsl. Other upland areas include the Mescal Mountains to the east and Dripping Spring Mountains to the west. The Dripping Spring Mountains are located between the Ray Mine and proposed TSF footprint and create a hydrologic divide between the Dripping Spring Wash – Gila watershed to the east and Mineral Creek – Gila watershed to the west. Groundwater levels in the Skunk Camp study area are estimated to range from greater than 5,000 ft amsl in the Pinal Mountains in the northeast to approximately 800 ft amsl at the bottom of the Ray Mine pit in the west.

Groundwater levels were selected from available data at each well to contour steady state groundwater elevation (Figure 5-1 and Figure 5-2). Figure 5-1 shows contours of the entire study area and Figure 5-2 shows detailed contours in the vicinity of the proposed TSF. Due to water level disturbances from well drilling, aquifer testing, well development and groundwater sampling activities, no single point in time could be identified to represent steady state water conditions at all well locations. Groundwater level elevations at wells installed during characterization drilling range from about 3,349 ft amsl at RC18-4 to about 3,100 ft amsl at the RC-8 series wells (Figure 5-2).

Based on the geology and geologic structures believed to control the emergence of groundwater at most of the springs, as well as the high elevations of the springs relative to nearby wells, most of the springs are considered perched above the regional phreatic groundwater surface.

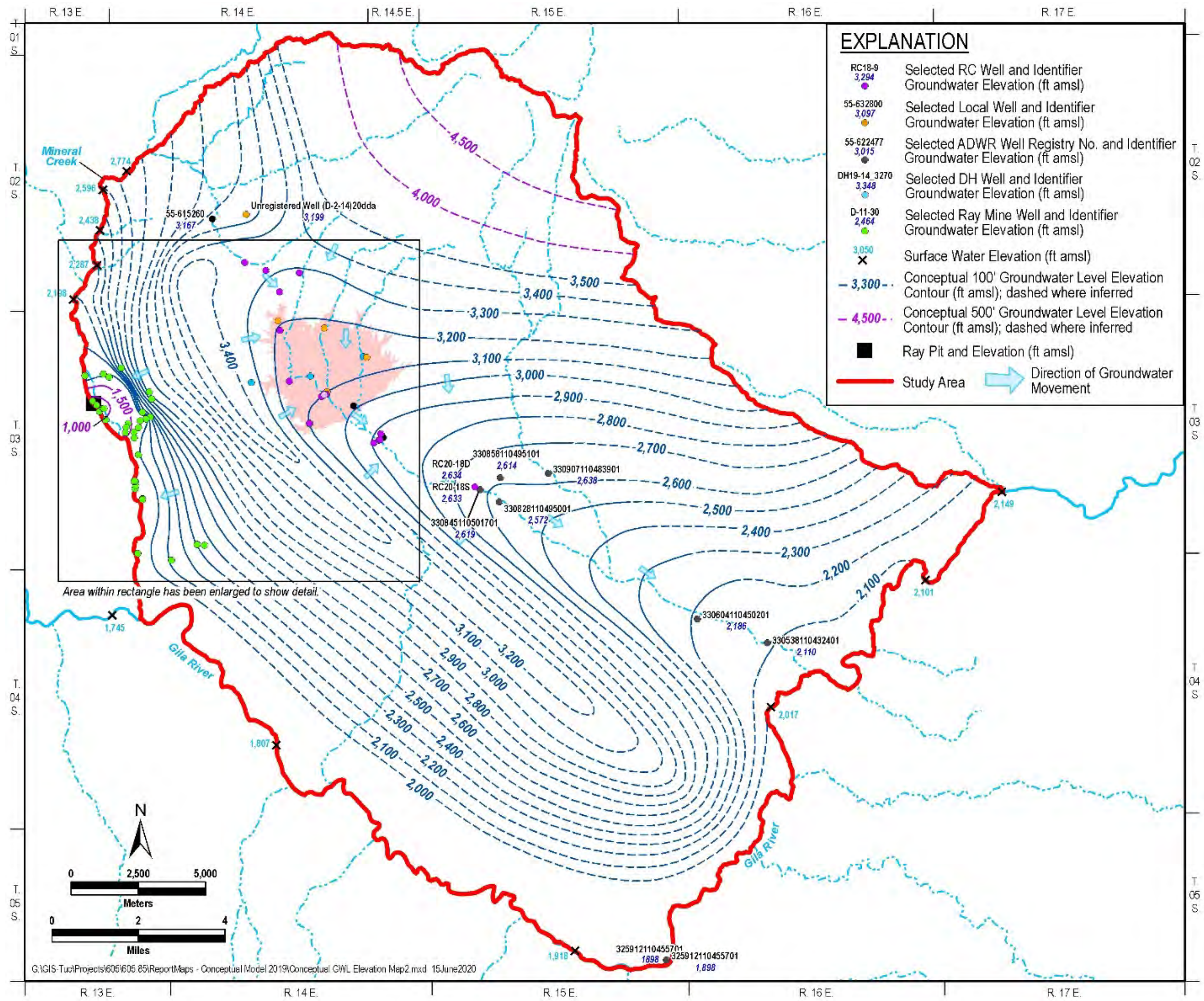

Figure 5-1. Groundwater Elevation Contours in the Skunk Camp Study Area

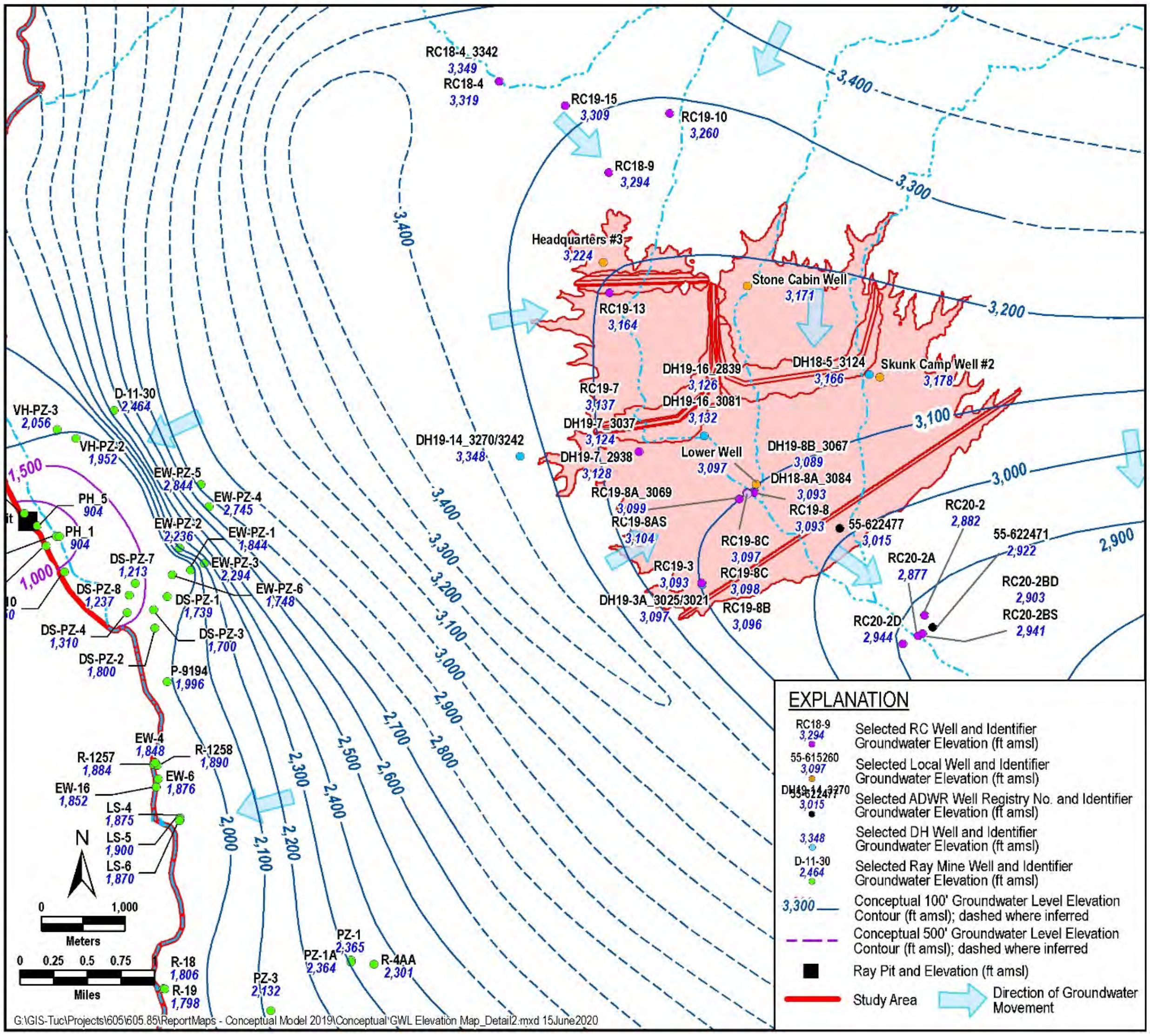

Figure 5-2. Groundwater Elevation Detail Contours in the Skunk Camp Study Area

5.2 Depth to Groundwater

Depth to groundwater level measured in private and site investigation wells near the proposed Skunk Camp TSF ranges from about 70 to 560 ft bls. The shallowest measured water levels occur near the center of the basin beneath the alluvial channels, and the deepest water level occurs at RC19-10 northeast of the proposed TSF.

5.3 Direction of Groundwater Movement

Contouring of available water level data indicate that the direction of groundwater movement in Dripping Spring valley follows the general trend of land surface topography from upland areas in the Pinal Mountains, Mescal Mountains, and Dripping Spring Mountains, toward the Gila River to the southeast and south (Figure 5-1). In the in the vicinity of the proposed Skunk Camp TSF groundwater follows topography southeastward along the Dripping Spring Wash toward the Gila River. Groundwater within the Mineral Creek watershed moves west toward Mineral Creek.

5.4 Hydraulic Gradient

5.4.1 Horizontal Hydraulic Gradients

Preliminary horizontal gradients were calculated for selected well pairs in Dripping Spring basin. In the north part of the basin, the computed gradient between RC18-4 and the RC19-8 series wells is about 0.014. Between the RC19-8 series wells and RC20-2A the gradient steepens to 0.025. The gradient drops to about 0.016 between the well RC20-2A and 3 miles downgradient at GWSI 330828110495001. It remains relatively constant at about 0.015 between GWSI 330828110495001 and GWSI 330604110450201. Below this location, the gradient again flattens to about 0.008 between GWSI 330604110450201 and GWSI 330538110432401 (Figure 5-1).

5.4.2 Vertical Hydraulic Gradients

Selected vertical hydraulic gradients were calculated for well pairs, annular piezometer installations and completed wells, and for grouted-in piezometer installations. Preliminary results are described below. Additional data are needed to determine gradients at some of the monitoring sites.

At the north end of the proposed TSF, a vertical gradient was calculated between the water level in well RC19-15 and the annular piezometer installed above the well screen. At RC19-15, completed in Tcg, the pore pressure equivalent groundwater elevation of 3,339 ft amsl, measured using the annular piezometer (installed at 3,294 ft amsl) is 28 ft higher than the groundwater elevation of 3,311 ft amsl, measured in the well (screen interval 3,126 – 2,746 ft amsl), indicating a downward gradient of 0.08 (Plate 1).

In the center of the proposed TSF, an upward vertical gradient was calculated at dual completion well RC19-8A shallow and deep (RC19-8AS and RC19-8AD), completed in the Tcg (Plate 1). The groundwater elevation of 3,104 ft amsl measured at RC19-8AS (screen interval 2,949 – 2,909 ft amsl) is 3 ft lower than the groundwater elevation of 3,107 ft amsl measured at RC19-8AD (screen interval 2,801 – 2,781 ft amsl), indicating an upward gradient of 0.02 in the center of the valley. At DH19-8B, a similar upward gradient was observed between the piezometers installed at 2,609 ft amsl and 2,943 ft amsl (Plate 1).

At RC19-3 and DH19-3A, located on the west side of the valley near the southwest toe of the proposed TSF, all monitoring points show downward gradients of 0.01 to 0.02. This includes well RC19-3, completed in Tcg, and screened from 2,750 – 2,610 ft amsl, and the annular piezometer installed at 2,856 ft amsl; and three grouted-in piezometers at DH19-3A installed at 3,021, 2,732, and 2,437 ft amsl (Plate 1). DH19-3A_3021 and DH19-3A_2732 are installed in Tcg, and DH19-3A_2437 is installed in an underlying Paleozoic limestone.

The downward gradients in the sites distal from the wash suggest that water recharged in the higher elevations flows downward and towards Dripping Spring Wash. As water moves closer to the wash upward gradients dominate as water in the Tcg discharges towards the alluvium.

6 HYDROCHEMISTRY

Hydrochemical sampling was initiated by RC to characterize groundwater and surface water in the area of the proposed TSF and throughout the Skunk Camp study area. The principal goals of the hydrochemical sampling program include:

- Establishing a baseline hydrochemistry for groundwater, surface water, and springs in the vicinity of and downstream of the proposed TSF; and
- Characterizing groundwater systems to support the conceptual hydrogeologic model including identifying principal sources of groundwater recharge and pathways for groundwater discharge to/from groundwater systems in the study area.

Samples were collected for common and trace constituents, routine parameters, radiological constituents, stable isotopes, and radioisotopes. Hydrochemical data for the Skunk Camp site was submitted in the Skunk Camp Data Submittal (M&A, 2020a).

In this report, as with previous reports by M&A (e.g. 2010, 2012, 2013, 2016b), hydrochemistry data are presented in a series of graphs to highlight and compare chemical and isotopic characteristics of each sample, and ultimately each component of the groundwater, springs, and surface water features. These graphs are used as a basis to identify distinct populations, evaluate degree of spatial or temporal variability, and allow for interpretation of the hydrochemistry data to support refinement of the conceptual model of the groundwater and surface water systems. Groundwater and surface water sampling locations are shown on Plate 2. The results of the hydrochemical sampling program are presented in the following sections, including major ion chemistry and water type, and isotopic data.

6.1 Quality Assurance and Quality Control

Hydrochemistry data are carefully tracked and documented through an extensive quality assurance/quality control (QA/QC) review. Once review is complete, verified chemical data are stored in a relational database designed to facilitate accurate and understandable data export and reporting. A detailed description of the QA/QC process is provided in M&A, 2017. The purpose of this process is to establish a reliable, high quality body of chemical data. Verification of sample documentation ensures that data are associated with the correct sample. Verification of laboratory chemical results provides confidence that the quality, integrity, and usability of the data are maintained. Database management procedures provide users of the database with a systematic way to store, modify, extract, and manage RC data. These procedures provide a clear, auditable trail linking data from original field and laboratory sources to import into the RC database.

6.2 Common Constituents

Common constituents (calcium, magnesium, sodium, potassium, chloride, bicarbonate, and sulfate) represent most of the dissolved ionic chemical species in natural waters. Two different graphical representations of the relative abundance of these ionic species are used to identify water samples with similar compositions:

6.2.1 Stiff Diagrams

Stiff diagrams show proportions of common ions for a suite of samples, preferably taken at the same time, that are shown as distinctly-shaped diagrams on a map to help evaluate spatial variability of water composition; the relative size of the diagram is indicative of the total dissolved solids (TDS) content of each sample. Stiff diagrams of the most recent representative sample for each location are shown on Plate 2.

6.2.2 Trilinear Diagrams

Trilinear (Piper) diagrams show relative proportions of major cations and anions for all samples simultaneously so that distinct groupings and mixing relationships, if present, can be identified and compared.

Figure 6-1 is a trilinear diagram showing spring, surface water and groundwater data for the Skunk Camp study area. Figure 6-2 shows the compositions of all groundwater samples within the study area, with well development samples highlighted. Results and interpretation of these data are presented in Section 6-4.

6.3 Isotopes

Environmental isotopes are widely used as a tool to characterize differences between distinct water sources, relative ages, and aquifer conditions. Both stable and radioisotopes are analyzed to characterize groundwater, surface water and spring samples within the Skunk Camp study area.

6.3.1 Radioisotopes (^{14}C and ^{3}H)

Tritium (^{3}H) and carbon-14 (^{14}C) are used to estimate recharge rates and residence times of groundwater. ^{3}H data provide information regarding the presence or absence of modern-day recharge. ^{3}H activities less than 0.8 indicate sub-modern recharge, or recharge occurring prior to 1952; tritium activities above 0.8 indicate that modern precipitation makes up at least some part of the sample (Clark and Fritz, 2000). Higher ^{14}C activities (i.e., larger percent modern carbon [pmC] values) indicate groundwaters with shorter residence times. Estimates of mean groundwater residence times are approximate as many processes within the aquifer can potentially affect the ^{14}C activity (see Appendix E of M&A, 2010, for a detailed explanation of calculation of groundwater ages from ^{14}C activities and associated uncertainties). Despite the limitations of the method, ^{14}C data provide valuable qualitative information regarding the approximate residence time distribution of groundwater as well as identification of areas of active recharge.

Radioisotope compositions of samples within the Skunk Camp study area are shown on Figure 6-3. ^{3}H values less than the detection limit are plotted at zero. Results and interpretation of these data are presented in Section 6.4.

6.3.2 Stable Isotopes of Water ($\partial^{18}O$ and $\partial^{2}H$)

Stable isotopes of oxygen and hydrogen in water ($\partial^{18}O$ and $\partial^{2}H$) are frequently used in hydrologic studies to 'fingerprint' sources of water. Different water sources often have unique isotopic signatures due to fractionation of these isotopes during processes such as evaporation and precipitation (Clark and Fritz, 2000). In general, lighter (more negative) stable isotope values are associated with cooler, wetter climate conditions such as winter precipitation, high elevation precipitation, or even an entirely different climate regime such as the late Pleistocene time when conditions were generally colder and wetter. Heavier (less negative) stable isotope compositions are typical of warmer conditions such as summer precipitation or precipitation at lower elevations. The Global Meteoric Water Line (GMWL), based on the stable isotope composition of global precipitation, is plotted on all stable isotope figures as a reference line (Craig, 1961). Samples that trend to the right of the reference line can be interpreted as having an evaporative signature, which can occur in the atmosphere and terrestrially (for a complete explanation of the processes governing these interpretations see Clark and Fritz, 2000).

Stable isotope compositions of samples from surface waters and springs are shown on Figure 6-4. Results and interpretation of these data are presented in Section 6.4.

6.3.3 Stable Isotopes of Sulfate ($\partial^{34}S$)

Stable isotopes of sulfur and oxygen in dissolved sulfate ($\partial^{34}S_{SO4}$ and $\partial^{18}O_{SO4}$) can be used to 'fingerprint' sources of dissolved sulfate in water samples (Clark and Fritz, 2000). Depleted $\partial^{34}S$ values are often associated with dryfall sulfur particles, such as would be deposited on the surface by smelter operations that occurred in Superior between 1924 and 1971 (Bassett et al., 1994) or by other on-going smelter operations in the area. $\partial^{34}S$ values may also reflect the heterogeneity of local geology, including presence of sulfide, pyrite, or evaporite minerals (for a complete explanation of the processes governing these interpretations see Clark and Fritz, 2000).

Stable isotope compositions of dissolved sulfate in samples from groundwater, surface water, and springs in the Skunk Camp study area are shown on Figure 6-5. Results and interpretation of these data are presented in Section 6.4.

6.4 Hydrochemical Interpretation

The following sections present an interpretation of the hydrochemical data in the context of the evaluation at the Skunk Camp study area.

6.4.1 Common Ion Composition

6.4.1.1 Springs and Surface Water

Spring and surface water samples in the Skunk Camp study area are grouped into two categories based on sub-basin: spring samples from the Dripping Spring watershed and samples from the Gila River below Dripping Spring Wash are plotted in green; spring and surface water samples from the upper Mineral Creek watershed are plotted in blue (Plate 2 and Figures 6-1, 6-3, 6-4, 6-5).

Spring samples from Dripping Spring watershed have a calcium-magnesium-bicarbonate water type (Plate 1 and Figure 6-1), with TDS concentrations ranging from 384 milligrams per liter (mg/L) at Stone Cabin Spring to 842 mg/L at Stone Cabin Box Spring. Chimney Spring and Woodchopper Spring have slightly higher sulfate content. Generally, springs in the study area have relatively homogeneous chemical composition, similar to local groundwater but with less variable sodium-potassium content (Figure 6-1).

Samples collected from the Gila River below Dripping Spring Wash are distinct from springs in the study area, having a sodium-potassium-chloride-bicarbonate water type (Plate 1 and Figure 6-1). TDS concentrations range from 422 – 702 mg/L.

The chemical composition of surface waters in the Mineral Creek watershed has been described in detail by M&A (2016b). Perennial surface water flow in the Mineral Creek watershed is comprised of calcium-magnesium-bicarbonate water type, supported by groundwater discharge from the eastern part of the Mineral Creek watershed at Government Springs, mixed with a more sulfate-rich chemical composition from Lyons Fork (LF 0.2 C). Discharge from the Apache Leap Tuff (ALT) aquifer at MC 3.4 W has distinctly lower sulfate and higher sodium content (M&A 2016b). Sump Spring has higher magnesium content than other sites in the Mineral Creek watershed.

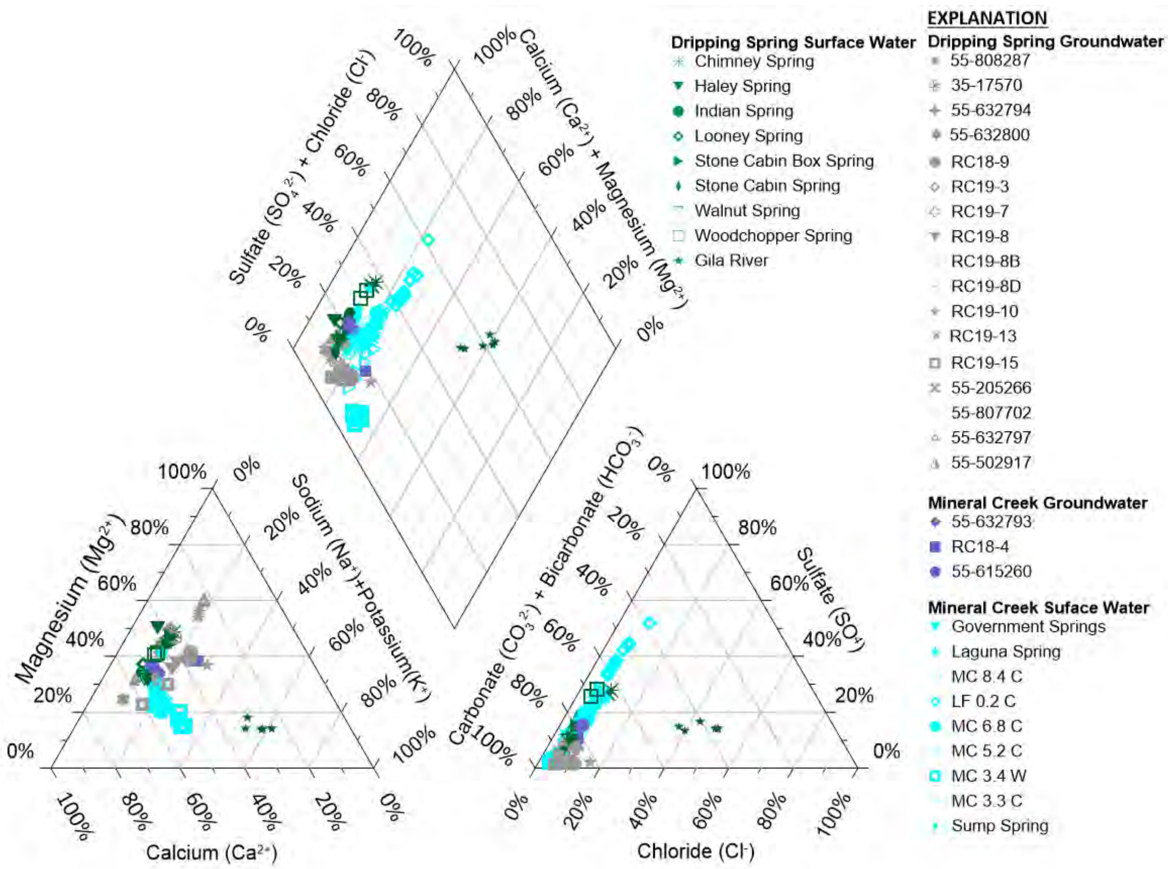

Figure 6-1. Trilinear Diagram of Common Ion Composition of Surface Water, Spring, and Groundwater Samples

6.4.1.2 Groundwater

At the time of preparation of this report, groundwater quality in the Dripping Spring Basin has been reported from 11 local wells and 11 new monitoring wells installed in 2018-2019, located in the Dripping Spring and Mineral Creek groundwater basins as shown on Plate 2.

The chemical compositions of groundwater samples from the Dripping Spring and Mineral Creek groundwater basins are presented in Plate 2 and Figure 6-1 and Figure 6-2. Most of the groundwater samples have a calcium-magnesium-bicarbonate water type. Two samples, RC18-4 and RC19-10, have increased sodium-potassium and chloride content (Figure 6-2). These samples are from wells with relatively low hydraulic conductivity, making them difficult to fully develop. The use of sodium bentonite during the well construction process could account for the increased sodium-potassium and chloride content in these samples. TDS of groundwater samples ranges from 207 mg/L at 55-807702 to 453 mg/L at 55-632793. The common ion composition of groundwater samples from Mineral Creek and Dripping Spring groundwater basins do not appear to be distinct, although samples from the Mineral Creek basin have slightly higher sulfate content than many of the groundwater samples from the Dripping Spring basin (Figure 6-2).

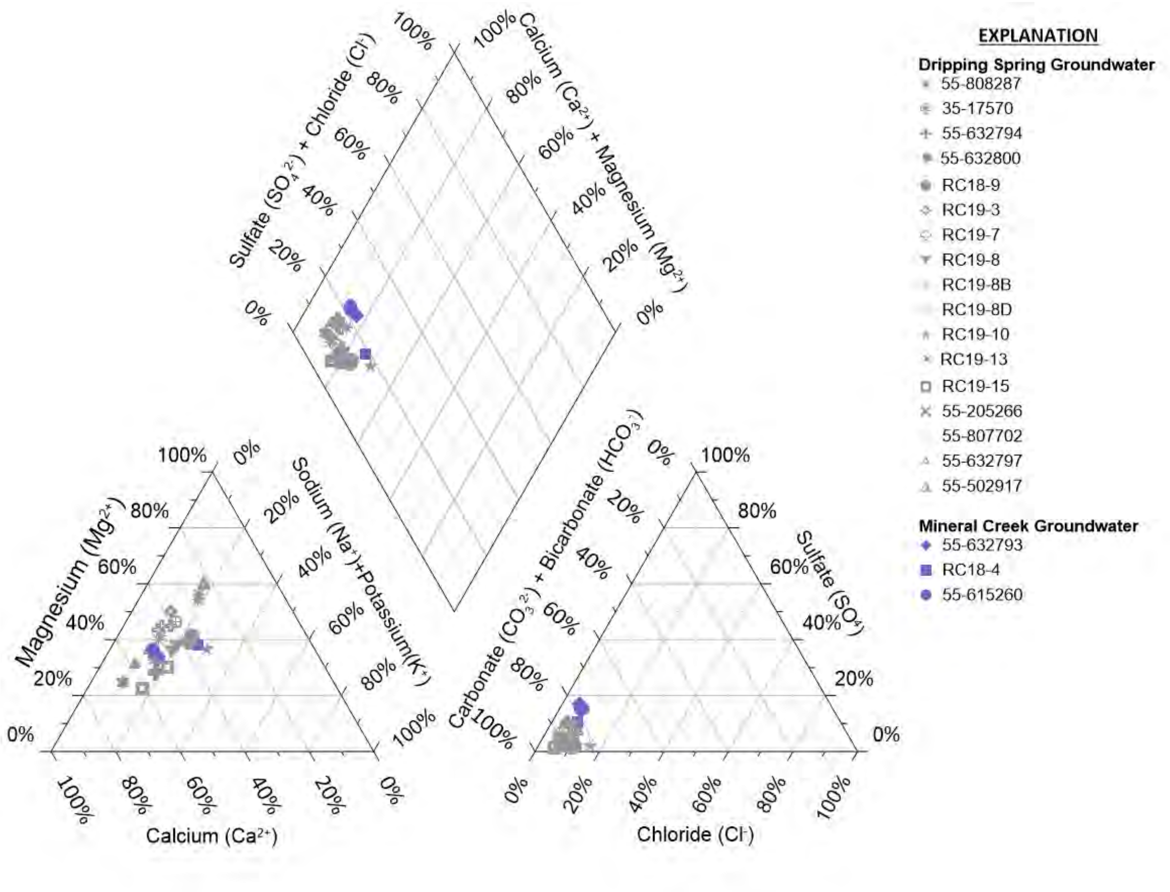

Figure 6-2. Trilinear Diagram of Common Ion Composition of Groundwater Samples

6.4.2 Isotopic Composition

6.4.2.1 Springs and Surface Water

Samples from springs in the Dripping Spring watershed all have active ^3H and relatively high ^{14}C activities, suggesting that these waters are recharged on modern to sub-modern timescales (Figure 6-3). Woodchopper Spring, Chimney Spring, Walnut Spring, and Stone Cabin Spring have lower ^{14}C and ^3H values, indicating these may be supported by mixing of slightly older groundwater with a modern source such as precipitation runoff or a shallow groundwater system. Looney Spring and Stone Cabin Box Spring have relatively high ^{14}C and ^3H, consistent with recharge from modern precipitation. The Gila River has the highest ^3H and ^{14}C activities of all, likely because the Gila is largely supported by seasonal precipitation.

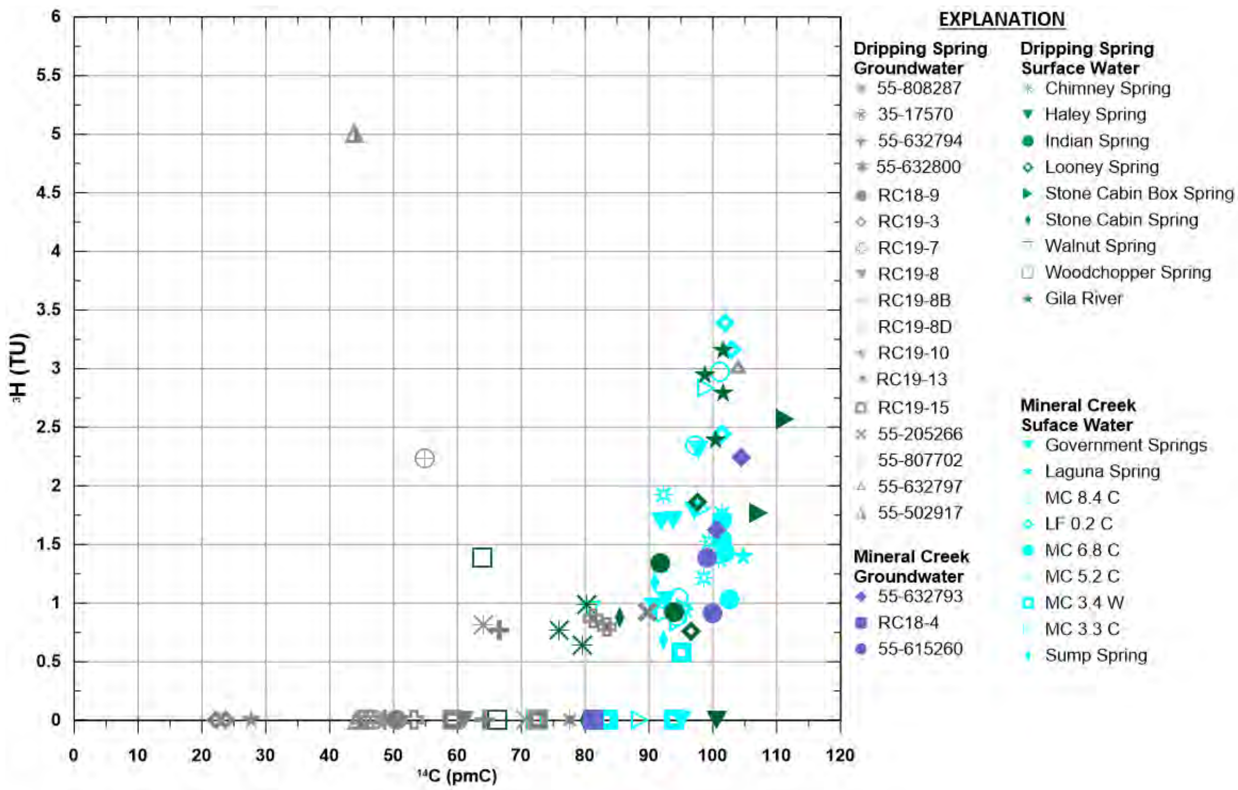

Figure 6-3. ^{3}H Versus ^{14}C in Surface Water, Springs, and Groundwater

Isotope data from surface water and spring samples located in Mineral Creek watershed are generally comprised of modern – sub-modern recharge (Figure 6-3), with some older groundwater contributed by the ALT aquifer (e.g., MC 3.4 W). The isotope data support the mixing model developed based on the chemical composition of these samples. A complete assessment of these data is provided by M&A (2016b).

Spring samples from Dripping Spring watershed have relatively diverse stable isotope ($\partial^{18}O$ and $\partial^{2}H$) content (Figure 6-4). Stone Cabin Box Spring, Chimney Spring, and Looney Spring plot below and to the right of the GMWL, indicative of significant evapoconcentration in the water sampled from these springs. These samples were collected during the summer when warm conditions lead to increased evaporation rates, particularly at sites where water is in contact with the atmosphere. Woodchopper Spring, Walnut Spring, and Stone Cabin Spring plot farther to the left near the GMWL. Continued seasonal sampling may offer additional insights into the relative contributions of groundwater and surface water at these springs, which often varies predictably with seasonal precipitation patterns at sites with larger surface water inputs.

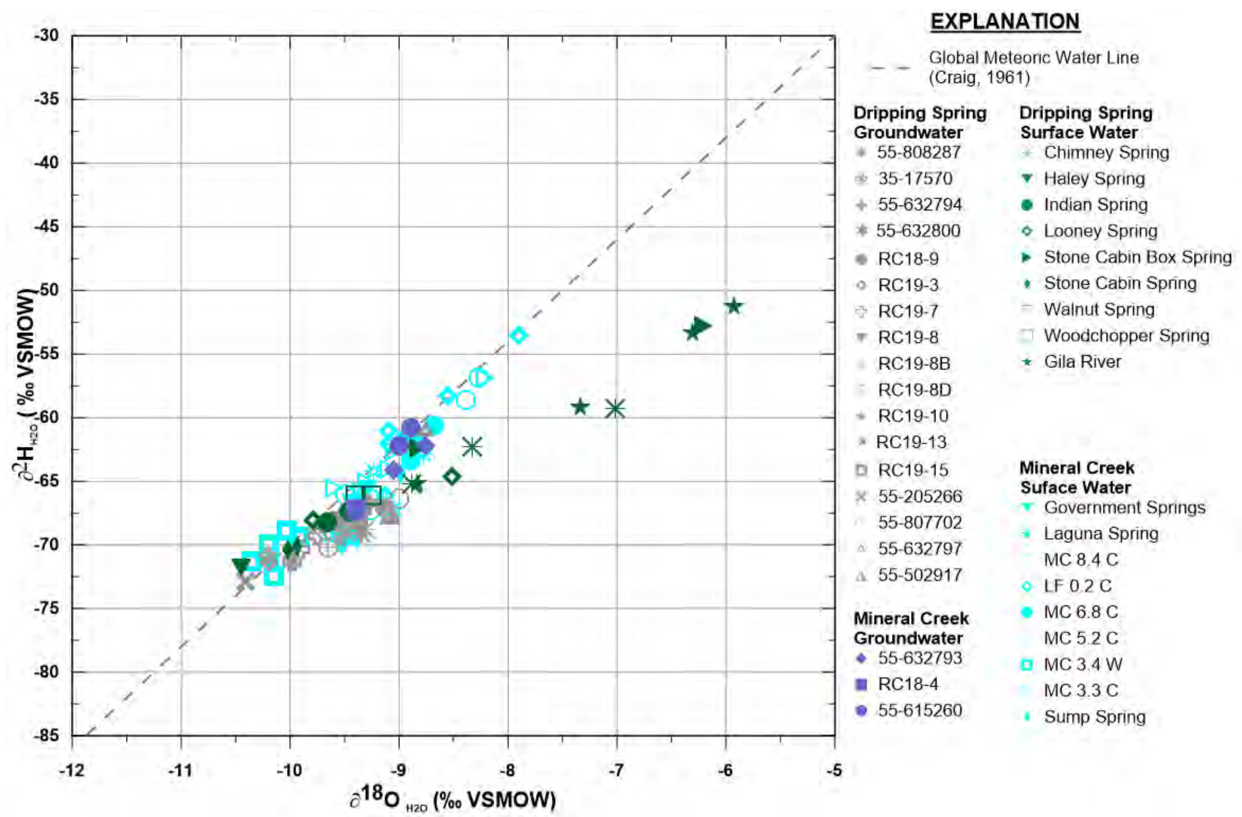

Figure 6-4. δ^2H Versus $\delta^{18}O$ Composition of Surface Water, Springs, and Groundwater

Stable isotope data from the Gila River plot below the GMWL (Figure 6-4), likely due to evapoconcentration through interaction with the atmosphere. Samples collected during summer months plot farthest to the right. Stable isotopes of Mineral Creek watershed samples have been discussed in detail by M&A (2016b); Mineral Creek surface water and spring samples are principally supported by groundwater discharge.

The sulfate/chloride mass balance of surface water and spring samples from Dripping Spring watershed displays low variability; however, the $\partial^{34}S_{SO4}$ content is more variable (Figure 6-5).

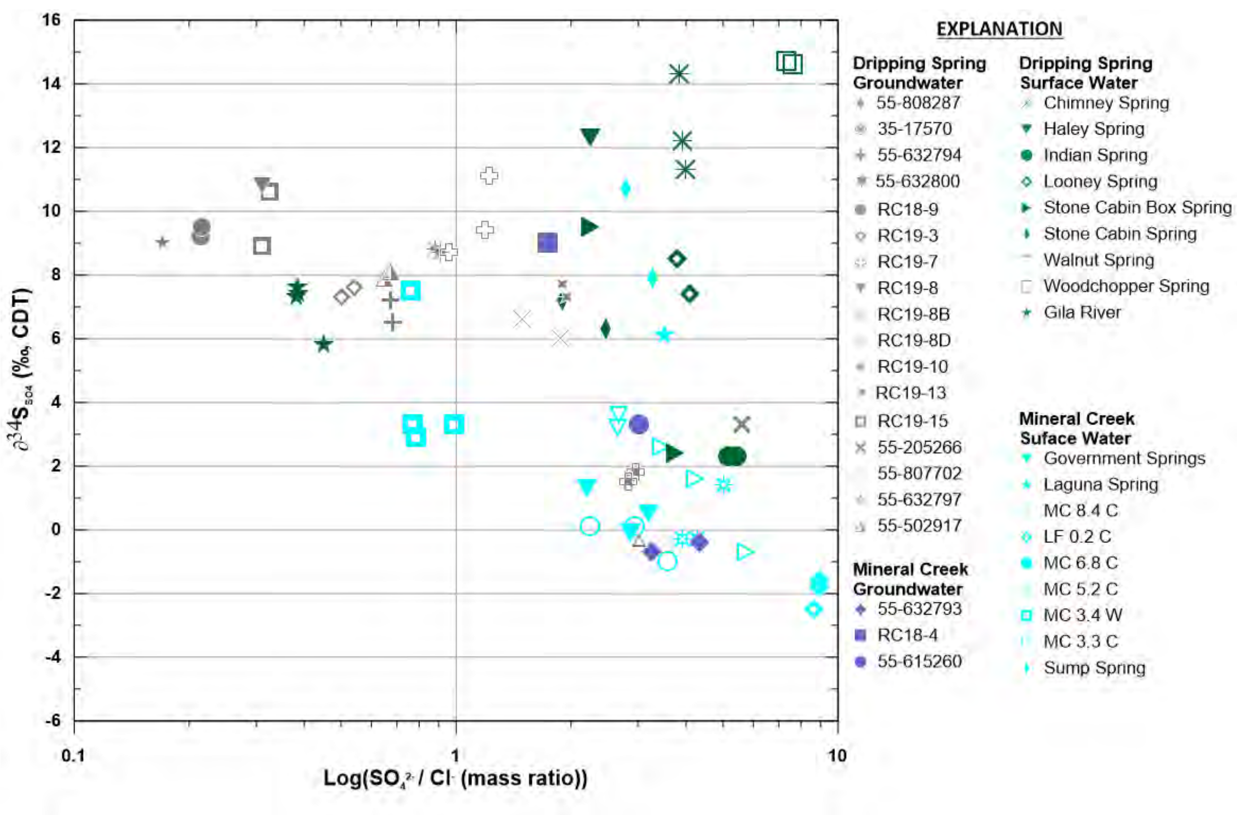

Figure 6-5. Stable Isotopes of Sulfate (δ³⁴S Composition) versus Sulfate/Chloride Mass Ratio in Surface Water, Springs, and Groundwater

Woodchopper Spring and Chimney Spring have high $\partial^{34}S_{SO4}$ content; Stone Cabin Box Spring, Looney Spring, and Stone Cabin Spring have moderate $\partial^{34}S_{SO4}$ content comparable to that of some of the Dripping Spring groundwater samples; Indian Spring and Walnut Spring have lower $\partial^{34}S_{SO4}$ content more similar to that of samples from Mineral Creek watershed. Samples from the Gila River below Dripping Spring Wash have moderate $\partial^{34}S_{SO4}$ content and a lower sulfate/chloride mass balance (Figure 6-5). The sulfate/chloride mass balance and $\partial^{34}S_{SO4}$ content of Mineral Creek surface water and spring samples represent distinct groundwater sources as described by M&A (2016b). Sump Spring has much higher $\partial^{34}S_{SO4}$ content than other Mineral Creek surface water and spring samples, and more closely resembles other springs from Dripping Spring watershed. This is likely due to differences in sulfate sources, possibly related to local geological conditions.

Taken together, the isotope data suggest that Woodchopper, Walnut, Indian, and Stone Cabin Springs are supported predominately by a mix of sub-modern groundwater and modern precipitation runoff and/or shallow modern groundwater, while Stone Cabin Box, Looney, and

Chimney Springs appear to have more recent runoff and/or shallow groundwater with shorter residence times. The Gila River samples also have the characteristics of modern precipitation runoff. Mineral Creek surface water flow is comprised of mixing of distinct groundwater sources (M&A 2016b). The differences in $\partial^{34}S_{SO4}$ content and sulfate/chloride mass balance are likely attributed to local geologic conditions, although dry deposition of sulfate can have a seasonal impact on $\partial^{34}S_{SO4}$ content (e.g., M&A 2013, 2016b).

6.4.2.2 Groundwater

Data collected to date on ^{3}H and ^{14}C activities indicate that water at 55-632797, 55-632793, and 55-615260 is comprised of modern to sub-modern recharge (Figure 6-3), of similar age to samples collected from springs in Dripping Spring watershed. Water sampled from 55-632794 and 35-17570 has active ^{3}H and lower ^{14}C activities, suggesting a slightly older relative age, similar to samples from Woodchopper Spring, Walnut Spring, and Stone Cabin Spring. Samples from RC19-8B, RC19-15, RC19-7, RC18-9, RC19-13, 55-808287, 55-807702, RC19-10 and RC19-3 have no detectible ^{3}H and lower ^{14}C activities, suggesting that these sites have little to no mixing with modern waters and recharge occurs on sub-modern timescales. RC19-3 and RC19-10 have the oldest relative age in the dataset, with a ^{14}C activity of less than 30 pmC (Figure 6-3). These sites are furthest from both Dripping Spring Wash and the Dripping Spring Fault, indicating that waters closer to the fault and wash are in a zone of more active mixing. Two sites, RC19-8D and 55-502917, have low ^{14}C activities and relatively high ^{3}H activities. These wells are both relatively shallow and drilled beneath the alluvium. The presence of both ^{3}H and lower ^{14}C is likely an indication that there is mixing of relatively old water, consistent with the upward vertical gradients beneath Dripping Spring Wash and modern precipitation recharged through the alluvial channels (Figure 6-3).

Stable isotope data of groundwater samples plot along the GMWL (Figure 6-4), with little to no evidence of evaporation. The samples that plot to the extreme lower left are RC19-3, RC19-7, RC19-8D, and RC19-8B. In general, based on the ^{3}H and ^{14}C data, these sites appear to have longer residence times. RC19-8D, which had active ^{3}H, appears to be an exception. Samples plotting further to the upper right along the GMWL (55-632797, 55-632793, and 55-615260) are associated with shorter residence times based on ^{3}H and ^{14}C activities. The correlation of longer residence times with more depleted stable isotope data is frequently observed (e.g., M&A 2016b, 2013, 2012, and 2010). Data that plot on the lower left are associated with cooler temperatures, suggesting waters were recharged during the winter months or during a cooler era, while warmer conditions are associated with data that plot to the upper right (for a description of the processes governing isotope fractionation see Clark & Fritz 2000).

The $\partial^{34}S_{SO4}$ content of groundwater samples from Mineral Creek groundwater basin is similar to that of surface water and springs in the Mineral Creek watershed, excluding samples for MC

3.4C which discharges from ALT (Figure 6-5). This is likely a result of the geologic makeup of the groundwater basin and supports the current conceptual model that surface water flow in Mineral Creek is supported principally by local groundwater (M&A 2016b).

The $\partial^{34}S_{SO4}$ content of groundwater samples from Dripping Spring groundwater basin is more variable (Figure 6-5). 35-17570 and 55-632797 have a similar signature to that of Mineral Creek groundwater samples. Other groundwater samples from Dripping Spring basin have higher $\partial^{34}S_{SO4}$ content and a lower sulfate/chloride mass ratio. The differences likely reflect local geologic conditions.

6.5 Spatial Distribution of Select Constituents

Concentrations of select constituents of concern (antimony, cadmium, copper, fluoride, nickel, selenium, sulfate, thallium, TDS, and zinc) have been mapped and are presented in Appendix A. These maps show the most recent available sample for each groundwater, surface water, and spring sampling location. Data were compared with applicable water quality standards, the most stringent of which are indicated for surface water and groundwater, respectively, in Table 6-1.

Water quality standards are exceeded for dissolved selenium (Figure A-8) and TDS (Figure A-13). The Arizona Aquatic and Wildlife - Warm Water Chronic standard for dissolved selenium is 0.002 mg/L (Arizona Administrative Code, 2016) and is exceeded at one spring sampling location (Looney Spring). Nine surface water and spring sampling locations had one or more samples with TDS concentrations that exceeded the Environmental Protection Agency's (EPA) Secondary Maximum Contaminant Level (SMCL) of 500 mg/L. SMCLs are not enforced by the EPA; instead they are "established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL (EPA, 2019)."

Table 6-1. Applicable Water Quality Standards for Groundwater and Surface Water

Constituent	Most Stringent Standard (applicable to)	Limit (mg/L)	Observed Exceedances
Antimony, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.006	None
Antimony, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.03	None
Antimony, Total Recoverable	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.006	None
Antimony, Total Recoverable	AZ Fish Consumption (Surface water & springs)	0.64	None
Cadmium, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.005	None
Cadmium, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.0032	None
Cadmium, Total Recoverable	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.005	None
Cadmium, Total Recoverable	AZ Fish Consumption (Surface water & springs)	0.084	None
Copper, Dissolved	AZ Full Body Contact & EPA Maximum Contaminant Standard (Groundwater)	1.3	None
Copper, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.014	None
Copper, Total Recoverable	AZ Full Body Contact & EPA Maximum Contaminant Standard (Groundwater)	1.3	None
Copper, Total Recoverable	AZ Agricultural Livestock Watering (Surface water & springs)	0.5	None
Fluoride, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	4	None
Fluoride, Dissolved	AZ Full Body Contact (Surface water & springs)	140	None
Fluoride, Total	AZ Numeric Aquifer Water Quality Standard (Groundwater)	4	None
Fluoride, Total	AZ Full Body Contact (Surface water & springs)	140	None
Nickel, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.14	None
Nickel, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.079	None
Nickel, Total Recoverable	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.14	None
Nickel, Total Recoverable	AZ Fish Consumption (Surface water & springs)	4.6	None
Selenium, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.05	None
Selenium, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.002	None
Selenium, Total Recoverable	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.05	None
Selenium, Total Recoverable	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.002	None
Sulfate, Dissolved	EPA Secondary Maximum Contaminant Standard (Groundwater, Surface water & Springs)	250	None
Sulfate, Total	EPA Secondary Maximum Contaminant Standard (Groundwater, Surface water & Springs)	250	None
Thallium, Dissolved	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.002	None
Thallium, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.15	None
Thallium, Total Recoverable	AZ Numeric Aquifer Water Quality Standard (Groundwater)	0.002	None
Thallium, Total Recoverable	AZ Fish Consumption (Surface water & springs)	0.0072	None
Total Dissolved Solids (Laboratory)	EPA Secondary Maximum Contaminant Standard (Groundwater, Surface water & springs)	500	7
Zinc, Dissolved	EPA Secondary Maximum Contaminant Standard (Groundwater)	5	None
Zinc, Dissolved	AZ Aquatic and Wildlife - Warm Water Chronic (Surface water & springs)	0.18	None
Zinc, Total Recoverable	EPA Secondary Maximum Contaminant Standard (Groundwater)	5	None
Zinc, Total Recoverable	AZ Fish Consumption (Surface water & springs)	5.106	None

7 WATER BALANCE

This section summarizes the data sources, methodology, and results of the water balance analysis that was completed for the Skunk Camp study area. The values of each water budget component are approximations based on best available information and professional interpretations. The water budgets summarized herein are estimates of the current annual inflows and outflows for the Skunk Camp study area (Figure 1-1). The results of this water balance are intended to support the numerical groundwater flow and transport model.

A basin water balance involves determination of water sources and discharges to estimate basin inflow and outflow volumes during a specific time period. Water budgets are described by the basic mathematical relationship:

[Inflows] – [Outflows] = [Storage Change]

A change in storage occurs when inflows are not equal to outflows during a specific time period. Changes in inflows and outflows through time generally result in the change of storage over time.

Based on limited activity in the Skunk Camp study area and several assumptions about water use, which are discussed in detail below, a simplified water budget was generated representing current conditions. Groundwater inflows consist solely of groundwater recharge from precipitation. Groundwater outflows are comprised of groundwater evapotranspiration from perennial vegetation and subflow to the Gila River and Mineral Creek. West of the dripping springs mountains, there is significant activity associated with the Ray Mine, Winkelman, and Kearny including pit dewatering, groundwater pumping, and groundwater recharge from tailings piles and likely other storage facilities. Information about these inflows and outflows are neither readily available nor pertinent to the development of a TSF in Dripping Spring wash. Further, at this scale, inflows and outflows associated with the Ray Mine are likely overshadowed by the large volumes of water flowing down the Gila River and are therefore not included in this water balance. The system is assumed to be at or near equilibrium; there is no change in storage. The methods and assumptions for estimating each water budget component are described in the following sections.

7.1 Model Domain Boundaries

The water balance generated herein represents a regional system that is defined by boundaries selected based on the hydrogeologic setting (Figure 2-2). The conceptual model domain defined by these boundaries falls within the Middle Gila watershed and is comprised of two smaller watersheds, Mineral Creek and Dripping Spring Wash. Although the TSF lies entirely inside the

Dripping Spring Wash watershed, the boundaries as defined encompass other areas of hydrologic interest including Mineral Creek and the Ray Mine pit.

Mineral Creek forms the northwest boundary of the domain and is demarcated by the perennial stretch of Mineral Creek that eventually becomes Little Box Lake just upstream from Ray Mine. Downstream of Little Box Lake the model boundary follows the historical streamline of Mineral Creek. The boundary follows the historical trace of Mineral Creek passing through the middle of the Ray Mine and meeting back up with the original stream channel just upstream from its confluence with the Gila River upstream of Kelvin, Arizona. There is a pit lake at the bottom of the Ray Mine pit that is maintained at a constant elevation. The discharge from Big Box Dam, which forms Little Box Lake, is routed through the Ray Mine via a lined concrete tunnel and channel back into its original channel. From the confluence of Mineral Creek and the Gila River the boundary of domain is delineated upstream along the Gila River to the confluence with Mescal Creek at the edge of the Mescal Mountains. At this point the boundary follows the topographic high represented by the Mescal Mountains and Pinal Mountains that is assumed to serve as a groundwater divide for the Dripping Spring Wash and Mineral Creek watersheds.

7.2 Inflows

Inflows to the water budget are represented solely by recharge from precipitation. Due to the groundwater divide of the Pinal and Mescal Mountains it is assumed that little to no underflow enters the study area from adjacent basins. Underflow into or out of the domain from basins along the Gila River is assumed to minimal and constrained by the presence of the Gila River. Similar conditions are also assumed to exist along Mineral Creek with underflow being negligible. Inflow attributed to water stored in Little Box Lake is considered minimal.

Wastewater treatment plants are present in the towns of Winkelman and Kearny however the systems are assumed to interact with water from the Gila River and not considered as part of the water budget.

7.2.1 Recharge

Recharge derives from precipitation and associated surface runoff that infiltrates at the surface and percolates downward to recharge the water table. Recharge is difficult to measure directly, particularly across large areas with variable topography and surface geology. Research has been previously conducted by others to develop practical methods of quantifying recharge in the semi-arid and arid areas of the southwestern United States. The following equation was developed by Anderson and others (1992) to quantify recharge to alluvial basins across the south-central portions of Arizona:

$$\log Q_{rech} = -1.40 + 0.98 logP$$

Q is the recharge rate in inches per year (in/yr) and P is annual precipitation in excess of 8 in/yr. The use of the 8 in/yr precipitation threshold effectively accounts for precipitation lost to evapotranspiration and soil-moisture storage (Anderson and others, 1992).

Average annual precipitation for the study area was estimated using Parameter-elevation Relationships on Independent Slopes Model (PRISM) (PRISM Climate Group, 2017). PRISM is a physiographic based model that provides spatially continuous estimates of rainfall distributed based on land surface topography and precipitation measured at rainfall gaging stations. Annual estimates of precipitation are provided by PRISM on a 4-kilometer scale (approximately 1.5 miles). Estimates of average precipitation for the 30-year period between 1981 and 2010 are available on both the four kilometer and 800-m scale (approximately 0.5 mile). For the Skunk Camp study area, the annual average precipitation between 1981 and 2010 was 18.48 in/yr or 255,846 acre-feet; and between 2008 and 2017 it was 15.75 in/yr, which is equivalent to 217,982 acre-feet. To account for the recent decline in precipitation and recharge the average precipitation between 1981 and 2010 at the 800 m resolution was decreased by 15% and a value of 15.71 in/yr was assumed for this analysis. Applying Anderson's (1992) methodology, the annual recharge rate from precipitation is 0.29 in/yr, or 1.88% of precipitation. Given the study area of 166,000 acres, this translates to 4,012 acre-feet of annual recharge.

This recharge does not occur uniformly; its spatial variability corresponds to the PRISM distribution of precipitation. Figure 7-1 depicts the distribution of recharge in the study area based on PRISM and Anderson (1992). In reality, a portion of the recharge is likely concentrated along stream drainages (Meixner and others, 2016).

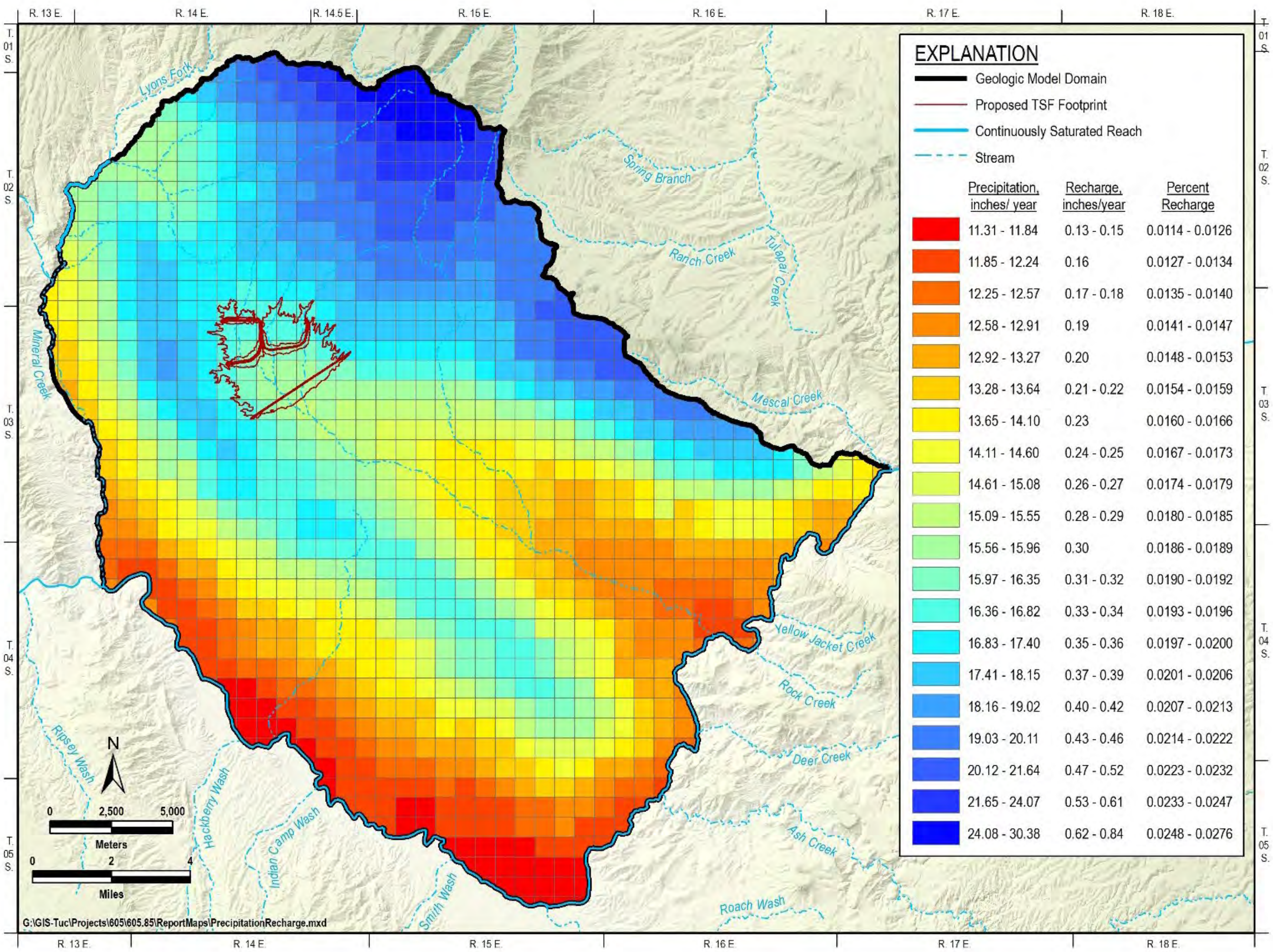

Figure 7-1. Recharge

7.3 Outflows

Groundwater leaves the model domain through groundwater evapotranspiration and groundwater discharge to streams. The main discharge point for groundwater in the Dripping Spring Wash is the Gila River at the southern edge of the domain. Water in the Mineral Creek watershed leaves via the Ray Mine pit, is discharged into Mineral Creek, or is discharged into the Gila River. The other main pathway for groundwater to leave the model domain is through evapotranspiration of deep-rooted perennial riparian vegetation. The methods used to estimate each of these components are described below. Estimated values for each component are summarized in Table 7-2.

7.3.1 Groundwater Discharge

Numerous groundwater seeps and springs have been cataloged within the Skunk Camp study area (M&A, 2020). In general, the volume of groundwater discharged via springs and seeps is negligible relative to the fluxes of groundwater lost via other mechanisms, such as groundwater discharge to surface water and evapotranspiration of groundwater. Any groundwater discharged to seeps and streams within the study is presumed to be included in the groundwater evapotranspiration component of the water budget.

7.3.2 Groundwater Evapotranspiration

Evapotranspiration encompasses both evaporation and transpiration and is the process by which water returns to the atmosphere from the land surface and near subsurface. Evapotranspiration occurs across the landscape wherever vegetation or soil moisture are present. This is largely a vadose zone process; in this region of Arizona most plants do not access groundwater from beneath the water table. However, along stream drainages and riparian areas where groundwater is relatively close to the surface, trees and shrubs draw water from beneath the water table, resulting in groundwater evapotranspiration (GET).

Locations having the potential for GET can be identified on remotely sensed images using the Normalized Difference Vegetation Index (NDVI), a metric for quantifying extent of vegetation based on greenness. NDVI values can range from -1 to 1, however typical values range from 0.025 (bare soil) to 0.5 (dense green-leaf vegetation) (Holben, 1986). Areas with long-term high NDVI values especially during dry summer months indicate vegetation that is established and active during of the warmest and driest part of the year and likely dependent upon groundwater.

Images of NDVI at a resolution of 30 m for the study area are available from the Earth Engine Evapotranspiration Flux (EEFlux), an on-line Landsat-image-based evapotranspiration calculator (https://eeflux-level1.appspot.com/). Average NDVI values for the month of June in the study area were calculate using images between 2008 and 2017, excluding 2012 due to errors with the sensor. Locations with higher NDVI values during this time were identified as possible areas with groundwater dependent vegetation. Field observations were used to verify the locations of the perennial groundwater dependent vegetation based on the type of the vegetation.

Through the field verification process, it was determined that the NDVI values for groundwater dependent vegetation are largely elevation dependent. As the elevation increased, the NDVI value for vegetation that was determined to be groundwater dependent also tended to increase. For this reason, the threshold NDVI value used for determining GET location changed as a function of elevation. The NDVI threshold values used are shown in Table 7-1. Locations above 4,500 ft amsl were not considered as locations with groundwater dependent vegetation.

Table 7-1. NDVI Thresholds based on elevation for GET

Elevation (ft amsl)	NDVI Threshold Value
0 – 3,000	0.37
3,000 – 3,500	0.40
3,500 – 4,000	0.45
4,000 – 4,500	0.52

The locations identified to have potentially high GET are shown in Figure 7-2. The figure shows the maximum and minimum extent of potential GET; it does not show GET rates.

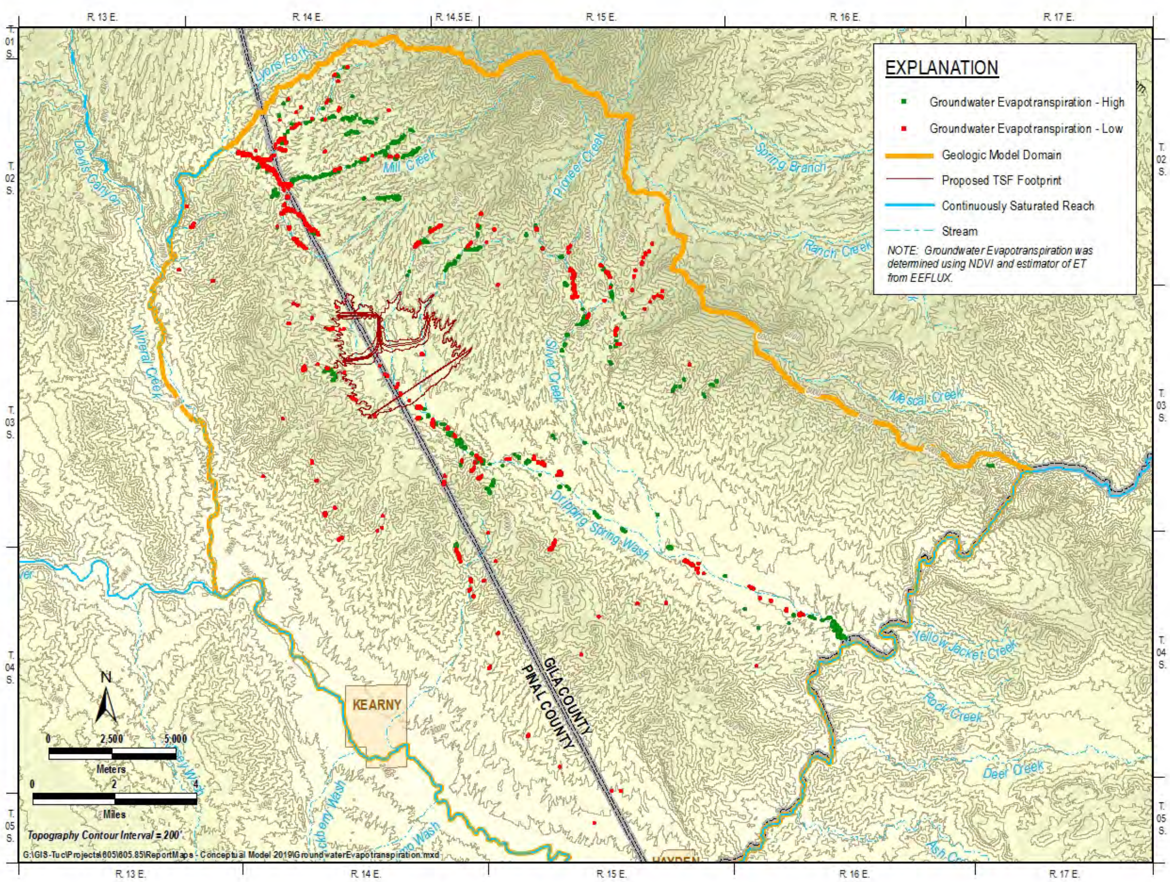

Figure 7-2. Potential Groundwater Evapotranspiration Locations

Estimates of GET were determined using actual evapotranspiration (ETa) data available from the Google Earth Engine Evapotranspiration Flux (EEFlux) website. EEFlux is based on the METRIC (Mapping Evapotranspiration at high Resolution with Internalized Calibration) model developed by the University of Idaho, which can calculate evapotranspiration on a daily temporal basis. EEFlux-reported ETa values are based on an evapotranspiration rate calculated using a surface energy balance method and a reference ET based on the Penman-Monteith equation (Penman, 1948; Monteith, 1965).

An average annual ETa rate of 2 millimeters per day (mm/d) was calculated for the GET locations shown in Figure 7-2 as the average of the high ETa in June and low ETa in January for the period 2008 to 2017. The maximum and minimum GET rates for the model domain were 1,263 acre-feet per year (AF/yr) and 644 AF/yr, respectively, for an annual average of 955 AF/yr.

7.3.3 Groundwater Withdrawals

Groundwater withdrawals in the basin are limited because of low population numbers and minimal agricultural and ranching activities. Review of the ADWR well registry database indicates that there are 107 exempt registered wells and 39 non-exempt registered wells in the model area. Assuming individual user rates of 0.5 AF/yr and 1.0 AF/yr for exempt and non-exempt wells, respectively; the total annual groundwater withdrawal rate is 90 AF/yr. This estimate is considered reasonable based on an ADWR 2009 Water Atlas estimate of 150 AF/yr for groundwater withdrawals in the entire Dripping Spring groundwater basin, which also includes the Reed Basin, south of the Gila River.

It is believed that most of the pumped groundwater returns to the groundwater system through septic tanks or is included in GET estimate; therefore, net groundwater withdrawals are considered to be zero.

7.4 Water Balance Summary

The water balance for the Skunk Camp conceptual model domain is summarized in Table 7-2.

Table 7-2. Summary of Water Budget Components

	AF/year
INFLOW	
Recharge	4,012
OUTFLOW	
Groundwater Evapotranspiration	955
Groundwater Discharge	3,057

8 SUMMARY

This report presents a regional hydrogeologic conceptual model for the proposed Skunk Camp TSF site. Overall, this conceptual model report largely confirms and expounds on the same geology and geologic units and general hydrogeologic units and setting as described in the DEIS.

The Skunk Camp study area includes all or part of the Dripping Spring Wash-Gila River and the Mineral Creek-Gila River watersheds in Pinal and Gila Counties, approximately 3 miles east of the ASARCO Ray open pit mining complex. The proposed TSF facility is located entirely within the Dripping Spring watershed, which is drained by Dripping Spring Wash, which discharges into the Gila River approximately 12 miles upstream from its confluence with the San Pedro River at the town of Winkleman.

The Dripping Spring Valley is composed of Tertiary basin-fill deposits with Holocene alluvium along the active stream channels. The valley is flanked by bedrock mountain blocks with older rock units ranging in age from Tertiary to Precambrian. Much of the proposed TSF facility is located on outcrops of variably weathered Tcg.

Groundwater levels indicate that the gradient beneath Dripping Spring Wash is from the northwest to the southeast, towards the Gila River. Groundwater gradients along Mineral Creek and on the western side of the Dripping Springs Mountains indicate that groundwater discharges towards the Gila River and Mineral Creek. ASARCO's Ray Mine is a local groundwater sink.

Vertical gradients are downward in the uplands closer to the mountains and upward near the valley bottom beneath Dripping Spring Wash. While the alluvium is not observed to be continuously saturated in the vicinity of the TSF, regional water levels are maintained near the base of the alluvium and the alluvium is further filled with water in response to infiltrated runoff during wet seasons. This suggests that the alluvium has an important role in facilitating drainage of the basin during periods of excess water.

Geochemical analyses further support this conceptualization. Water sampled from the alluvium and shallow Tcg beneath Dripping Springs Wash show a mixture of high tritium recent runoff and older groundwater with reduced carbon-14. Groundwater at depth closer to the mountain front is the oldest sampled at site supporting the idea that water at depth follows long slow flow paths towards the center of the valley.

The measured hydraulic conductivity of the Tertiary Gila Conglomerate in the TSF area ranges from 7.30 $x10^{-7}$ to 1.60 $x10^{-3}$ with a geometric mean value of 1.69 $x10^{-4}$ cm/sec. The hydraulic conductivity of the Tcg is notably lower in the eastern portion of the TSF footprint suggesting that the hydraulic conductivities in the western portion of the TSF footprint may be in influenced by the fault where the bulk of the investigations were focused, which tends to result in lower hydraulic conductivity values.

In comparison to the rock units, the hydraulic conductivity of the quaternary alluvial deposits is higher, approximately on the order of $1x10^{-2}$ cm/sec. Although the alluvial deposits are typically observed to be unsaturated, they represent relatively more conductive pathways for groundwater movement. This further supports the conceptualization that the alluvium has a role in draining both recent recharge and long-term groundwater discharge.

Hydraulic conductivity testing conducted in the mountain block units surrounding the Dripping Spring Valley is limited. Hydraulic conductivities of units that make up part of the Dripping Spring, Pinal, and Mescal mountains range over more than four orders of magnitude. However, the bulk hydraulic conductivity of the unit is expected to be controlled by the prevalence of diabase and connected fractures to the extent that they exist.

The Dripping Springs Fault is a dominant structural feature in the basin and appears to have some role in controlling groundwater flow. The fault was encountered during well drilling at well RC20-2D in the Bolsa Quartzite, outside the TSF footprint. Testing at the well indicated that the hydraulic conductivity of the well is $1.1x10^{-3}$ cm/sec which is higher than the adjacent Tcg by approximately 1 order of magnitude. Within the Tcg, the fault was not observed directly, however, the hydraulic conductivities in the western portion of the TSF footprint, more proximal to the fault, are higher than hydraulic conductivities in the eastern portion of the TSF. The spatial distribution of the hydraulic conductivity in the Tcg suggests the fault may influence hydraulics within the Tcg.

Groundwater recharge from precipitation is estimated to be on the order of 1.5-3% of annual precipitation. Recharge does not occur uniformly throughout the study area; rather it is assumed that recharge rates are higher in upland areas where precipitation is greater.

A groundwater balance for the basin was conducted and shows that precipitation-derived recharge is the only input to the groundwater system in the model domain. Outflows from the basin include groundwater evapotranspiration (23%) and groundwater discharge (77%). Although groundwater pumping occurs in the Dripping Spring Watershed, it is minimal and assumed to be returned to the groundwater flow system via septic tanks or lost to evapotranspiration; therefore, it is not included in the water budget.

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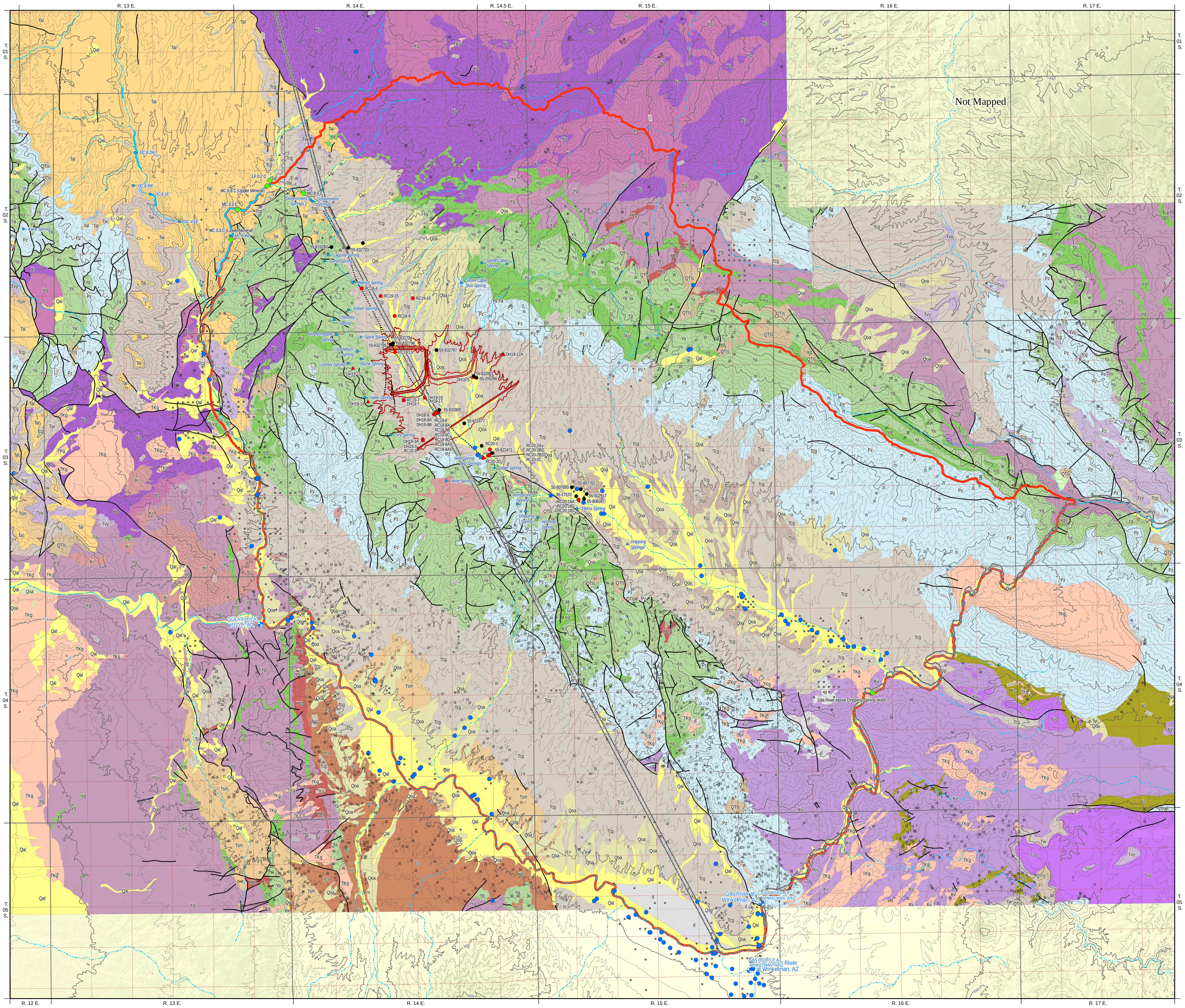
10 ACRONYMS & ABBREVIATIONS

ADWR ....Arizona Department of Water Resources
AF/yr ....acre-feet per year
cfs ....cubic feet per second
cm/sec ....centimeters per second
DEIS...........................Draft Environmental Impact Statement
EEFlux ....Earth Engine Evapotranspiration Flux
EPA ....Environmental Protection Agency
ETa ....actual evapotranspiration
ft amsl.........................feet above mean sea level
ft bls ....feet below land surface
GET ....groundwater evapotranspiration
GMWL ....Global Meteoric Water Line
gpm ....gallons per minute
GWSI ....ADWR Groundwater Site Inventory
HGUs ....hydrogeological units
in/yr ....inches per year
KCBCL ....KCB Consultants Ltd.
METRIC ....Mapping Evapotranspiration at Resolution with Internalized Calibration
mg/L ....milligrams per liter
mm/d ....millimeters per day
NVDI..........................Normalized Difference Vegetation Index
OBI.............................optical borehole image
pmC ....percent modern carbon
PRISM........................Parameter-elevation Relationships on Independent Slopes Model
QA/QC ....quality assurance/quality control
SMCL.........................Secondary Maximum Contaminant Level
TDS ....total dissolved solids
TSF.............................tailings storage facility
USFS ....United States Forest Service
USGS ....United States Geological Survey
δ..................................delta; represents the ratio of heavier and lighter isotopes



Geology modified from Richard, 1998; Spencer & others, 1998; and Krieger, 1974

EXPLANATION

SITE INVESTIGATION LOCATIONS

- Diamond Drill Hole
- Rotary
- Private Well
- ADWR Well
- GWSI Well
- USGS Stream Gage
- Site Investigation Spring
- Other Spring (ALRIS)
- Sonde Location
- Surface Water Sampling Location

- Geologic Model Domain
- Proposed TSF Footprint
- Continuously Saturated Reach
- Stream
- Fault; dotted where concealed (AZGS)
- Strike and Dip

GEOLOGIC UNITS

- d — Disturbed Surficial Deposits
- Qal — Alluvium
- Qoa — Older Alluvium
- QTls — Talus, Colluvium and Landslide Deposits
- Tcg — Conglomerate - Gila Group
- Tss — Lake Deposits - Gila Group
- Tvy — Younger Tertiary Volcanic Rocks
- Tal — Apache Leap Tuff
- Tvo — Older Tertiary Volcanic Rocks (Undifferentiated)
- Tw — Whitetail Formation
- Tsm — San Manuel Formation, Undivided
- Tc — Cloudburst Formation
- TKg — Tertiary to Cretaceous Intrusive Rocks
- Kv — Cretaceous Volcanic Rocks
- Ki — Cretaceous Instrusive Rocks
- Ks — Cretaceous Sedimentary Rocks
- Pz — Paleozoic Sedimentary Rocks
- Yd — Younger Precambrian Diabase
- Ya — Younger Precambrian Apache Group, undivided
- Yg — Younger Precambrian Intrusive Rocks
- Xg — Older Precambrian Granite
- Xi — Older Precambrian Intrusive Rocks
- Xp — Pinal Schist

N

Topography Contour Interval = 200'

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Miles

RESOLUTION COPPER

GEOLOGIC FEATURES AND MONITORING LOCATIONS

MONTGOMERY & ASSOCIATES

Water Resource Consultants

2020

Plate 1

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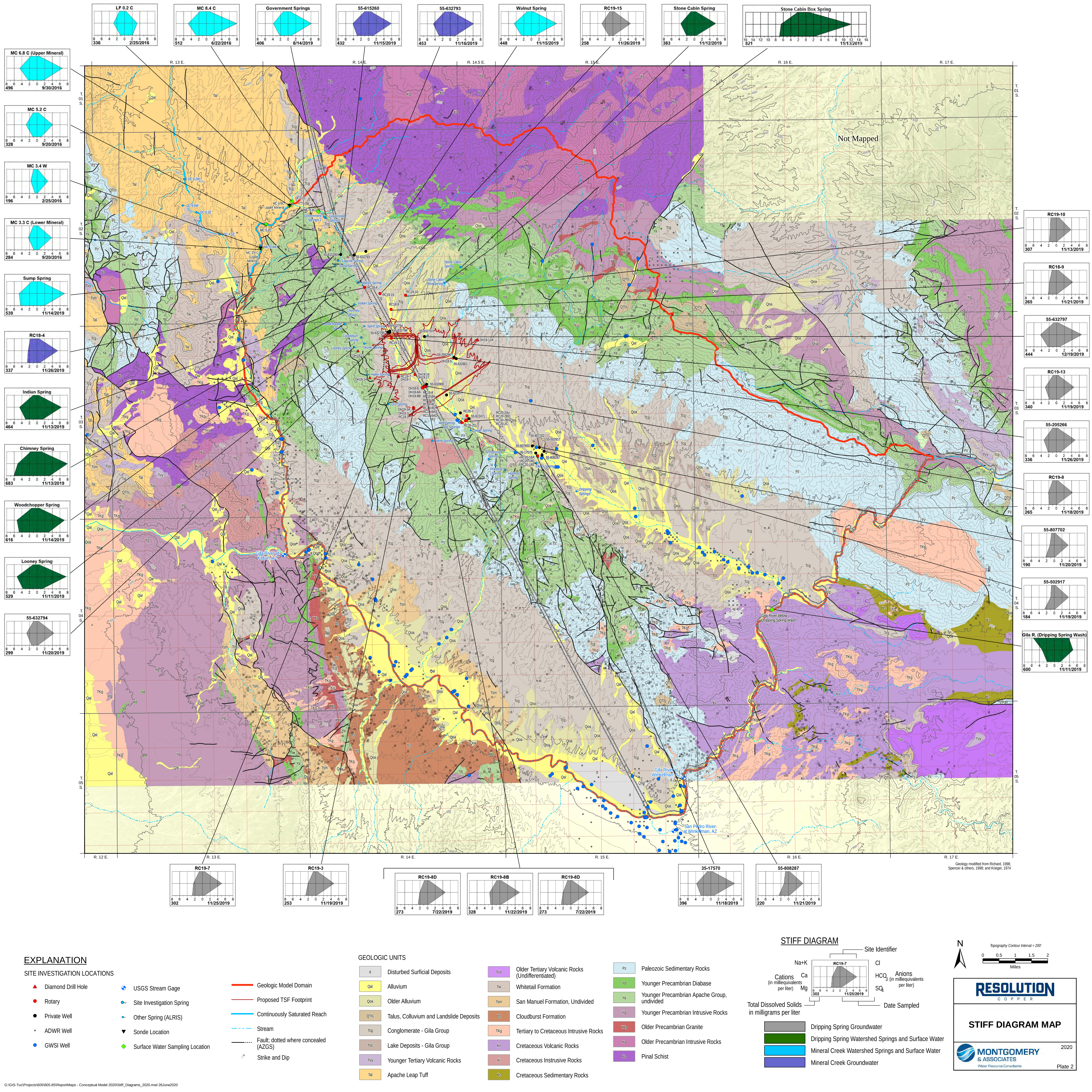

LF 0.2 C
336 2/25/2016
MC 8.4 C
512 6/22/2016
Government Springs
406 8/14/2019
55-615260
432 11/15/2019
55-632793
453 11/16/2019
Walnut Spring
448 11/15/2019
RC19-15
258 11/26/2019
Stone Cabin Spring
383 11/12/2019
Stone Cabin Box Spring
821 11/13/2019
MC 6.8 C (Upper Mineral)
496 9/30/2016
MC 5.2 C
328 9/20/2016
MC 3.4 W
196 2/25/2016
MC 3.3 C (Lower Mineral)
284 9/20/2016
Sump Spring
539 11/14/2019
RC18-4
337 11/26/2019
Indian Spring
464 11/13/2019
Chimney Spring
683 11/13/2019
Woodchopper Spring
616 11/14/2019
Looney Spring
529 11/11/2019
55-632794
299 11/20/2019
RC19-10
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RC18-9
265 11/21/2019
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RC19-8
265 11/18/2019
55-807702
190 11/20/2019
55-502917
184 11/19/2019
Gila R. (Dripping Spring Wash)
600 11/1/2019
RC19-7
302 11/25/2019
RC19-3
253 11/19/2019
RC19-8D
273 7/22/2019
RC19-8B
328 11/22/2019
RC19-8D
273 7/22/2019
35-17570
396 11/18/2019
55-808287
220 11/21/2019
Not Mapped
Geology modified from Richard, 1998; Spencer & others, 1998; and Krieger, 1974
EXPLANATION
SITE INVESTIGATION LOCATIONS
Diamond Drill Hole
Rotary
Private Well
ADWR Well
GWSI Well
USGS Stream Gage
Site Investigation Spring
Other Spring (ALRIS)
Sonde Location
Surface Water Sampling Location
Geologic Model Domain
Proposed TSF Footprint
Continuously Saturated Reach
Stream
Fault; dotted where concealed (AZGS)
Strike and Dip
GEOLOGIC UNITS
Disturbed Surficial Deposits
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Older Alluvium
Talus, Colluvium and Landslide Deposits
Conglomerate - Gila Group
Lake Deposits - Gila Group
Younger Tertiary Volcanic Rocks
Apache Leap Tuff
Older Tertiary Volcanic Rocks (Undifferentiated)
Whitetail Formation
San Manuel Formation, Undivided
Cloudburst Formation
Tertiary to Cretaceous Intrusive Rocks
Cretaceous Volcanic Rocks
Cretaceous Instrusive Rocks
Cretaceous Sedimentary Rocks
Paleozoic Sedimentary Rocks
Younger Precambrian Diabase
Younger Precambrian Apache Group, undivided
Younger Precambrian Intrusive Rocks
Older Precambrian Granite
Older Precambrian Intrusive Rocks
Pinal Schist
STIFF DIAGRAM
Site Identifier
Cations (in milliequivalents per liter)
Na+K
Ca
Mg
Anions (in milliequivalents per liter)
Cl
HCO_3
SO_4
Total Dissolved Solids in milligrams per liter
Date Sampled
Dripping Spring Groundwater
Dripping Spring Watershed Springs and Surface Water
Mineral Creek Watershed Springs and Surface Water
Mineral Creek Groundwater
Topography Contour Interval = 200'
Miles
RESOLUTION COPPER
STIFF DIAGRAM MAP
MONTGOMERY & ASSOCIATES
Water Resource Consultants
2020
Plate 2
G:\GIS-Tuc\Projects\605\605.85\ReportMaps - Conceptual Model 2020\Stiff_Diagrams_2020.mxd 26June2020

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Appendix A

Spatial Distributions of Select Constituents of Concern

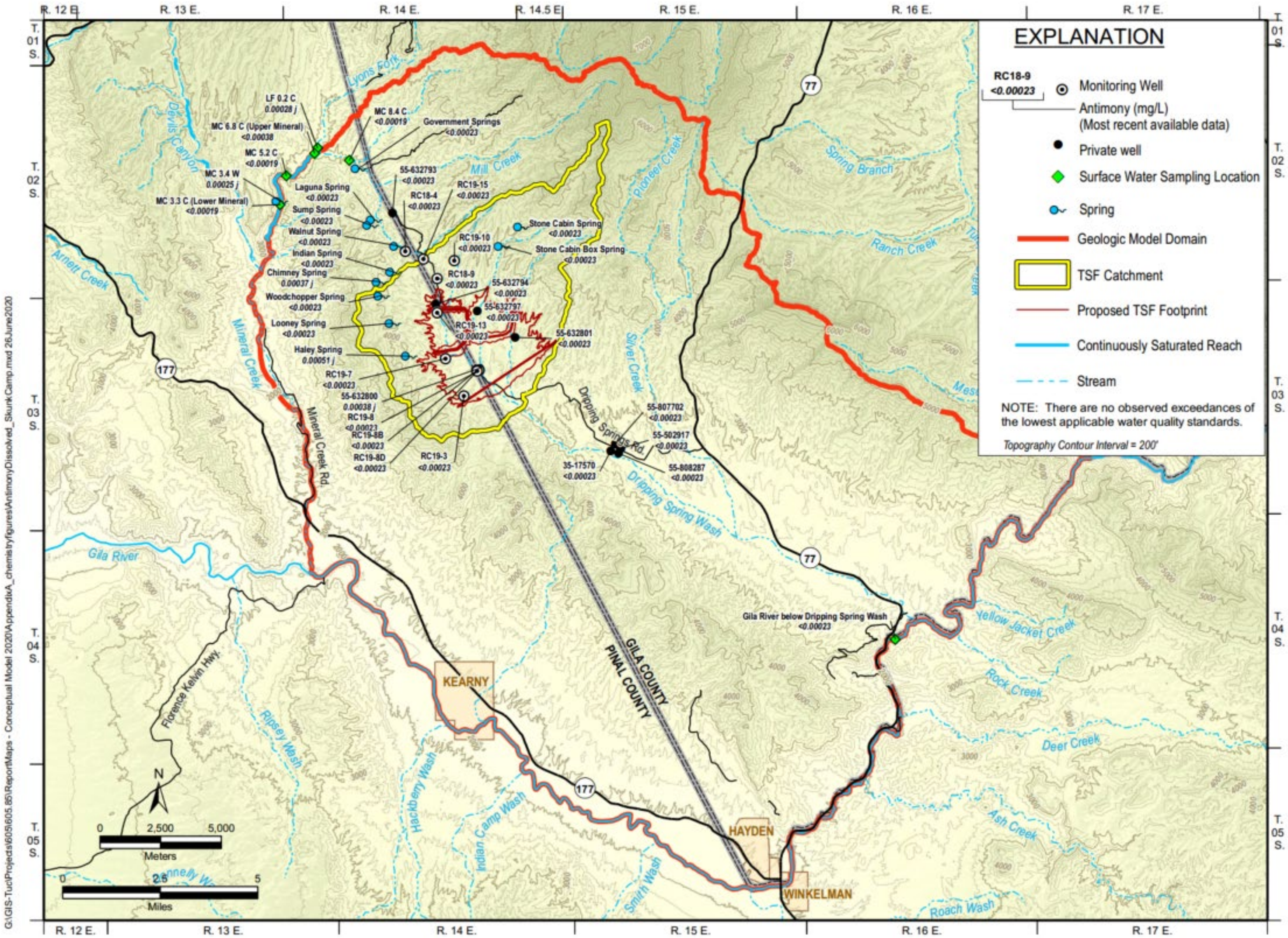

Figure A-1. Concentration of Dissolved Antimony

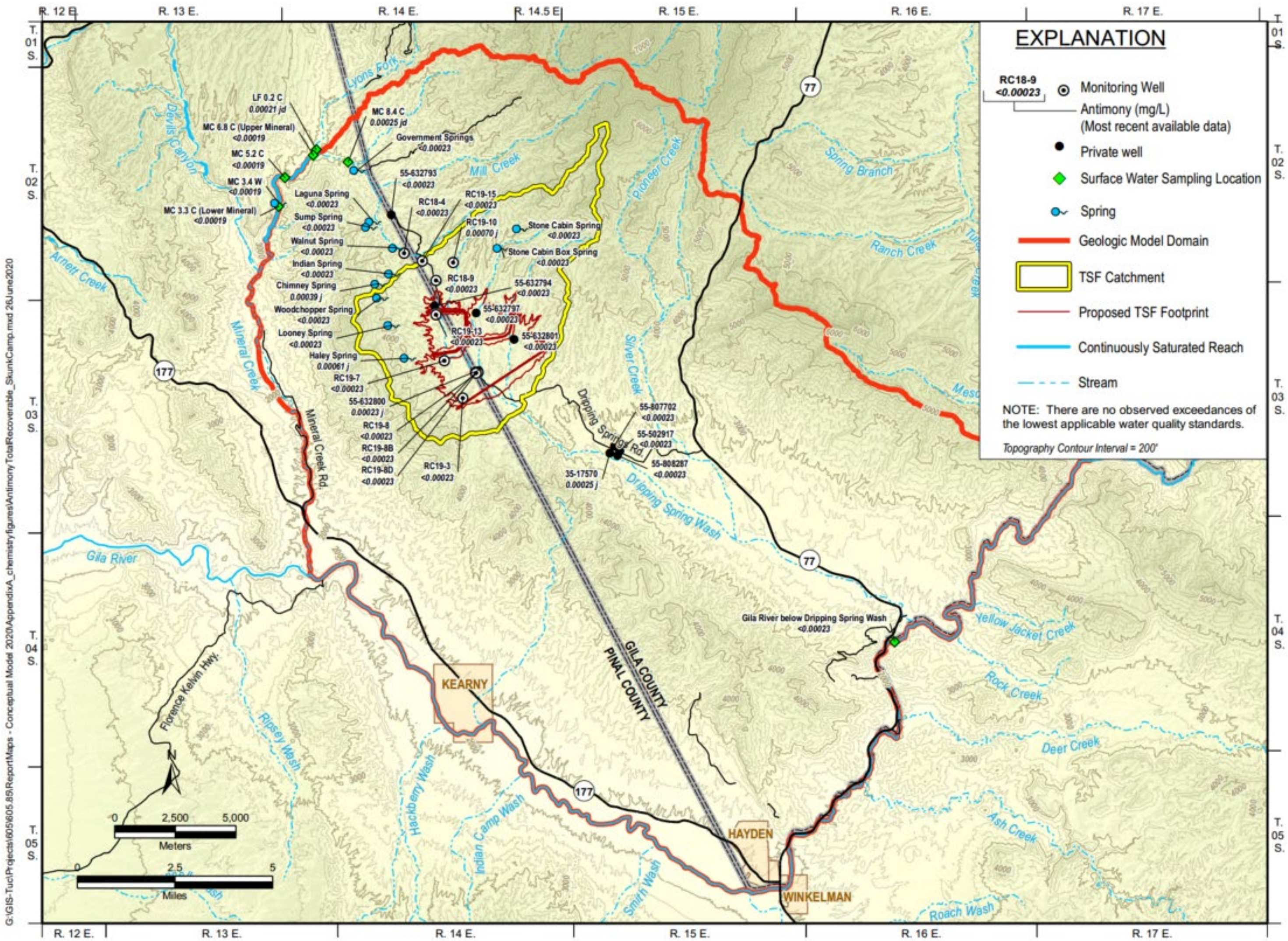

Figure A-2. Concentration of Total Recoverable Antimony

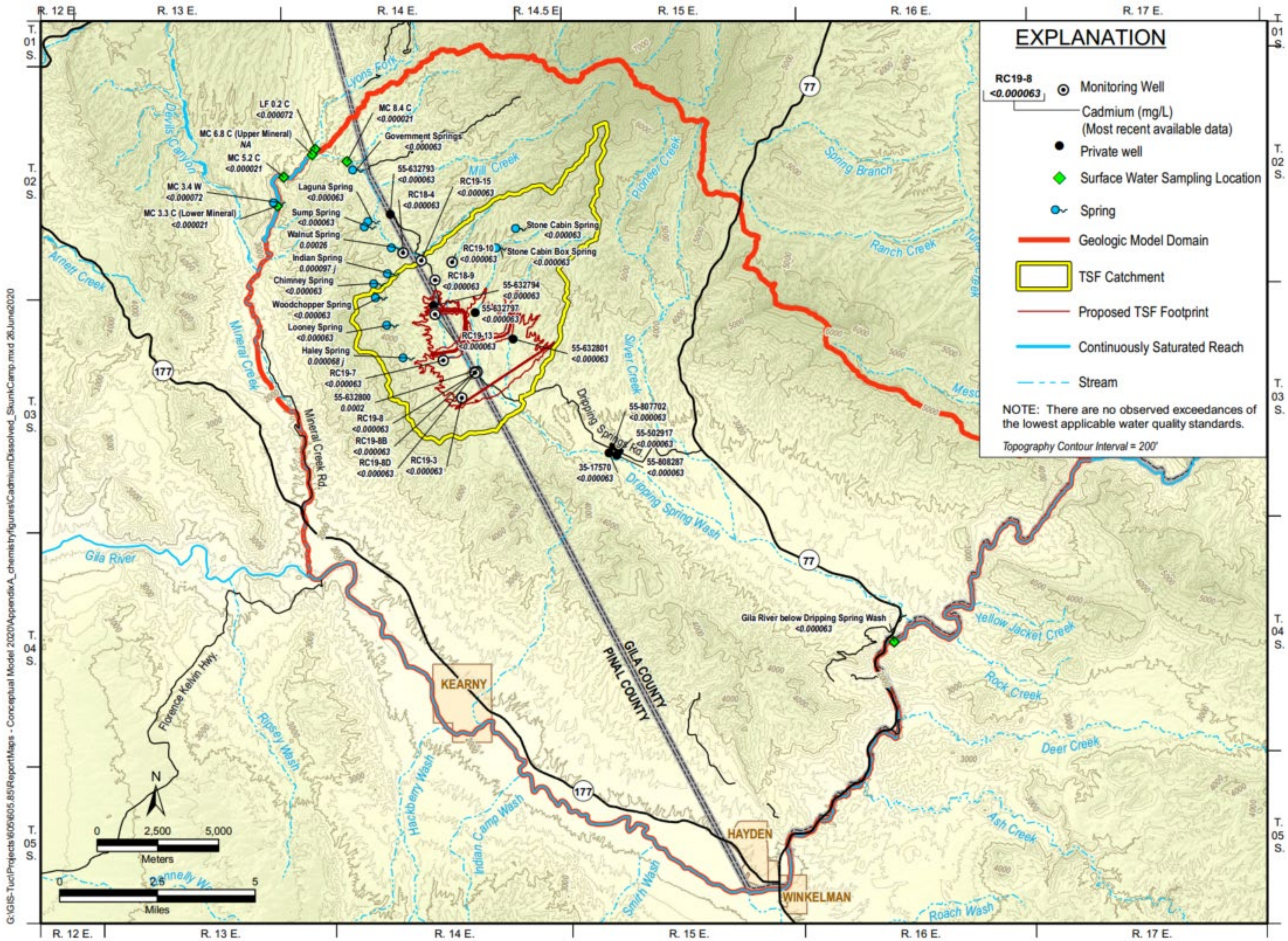

Figure A-3. Concentration of Dissolved Cadmium

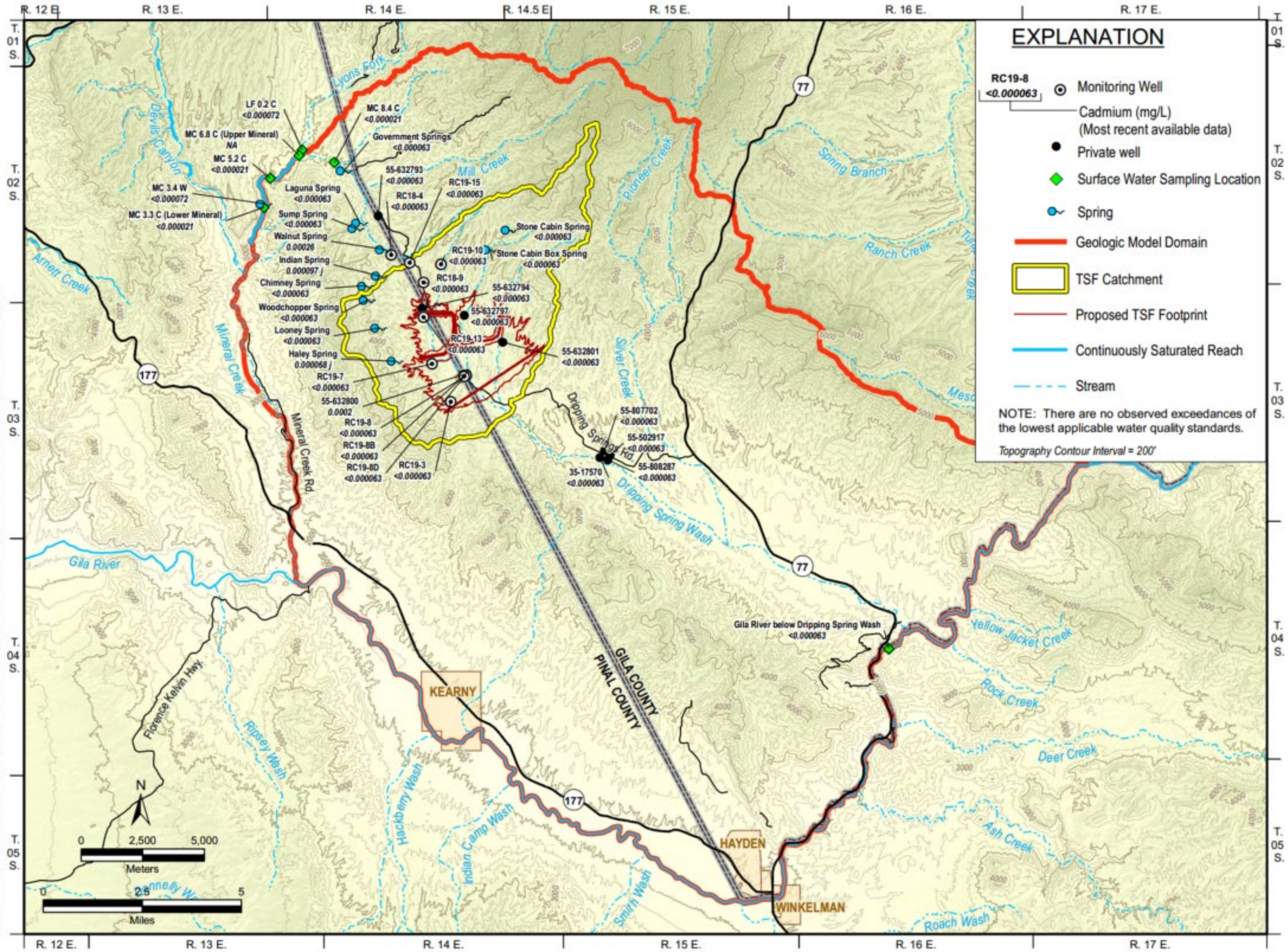

Figure A-4. Concentration of Total Recoverable Cadmium

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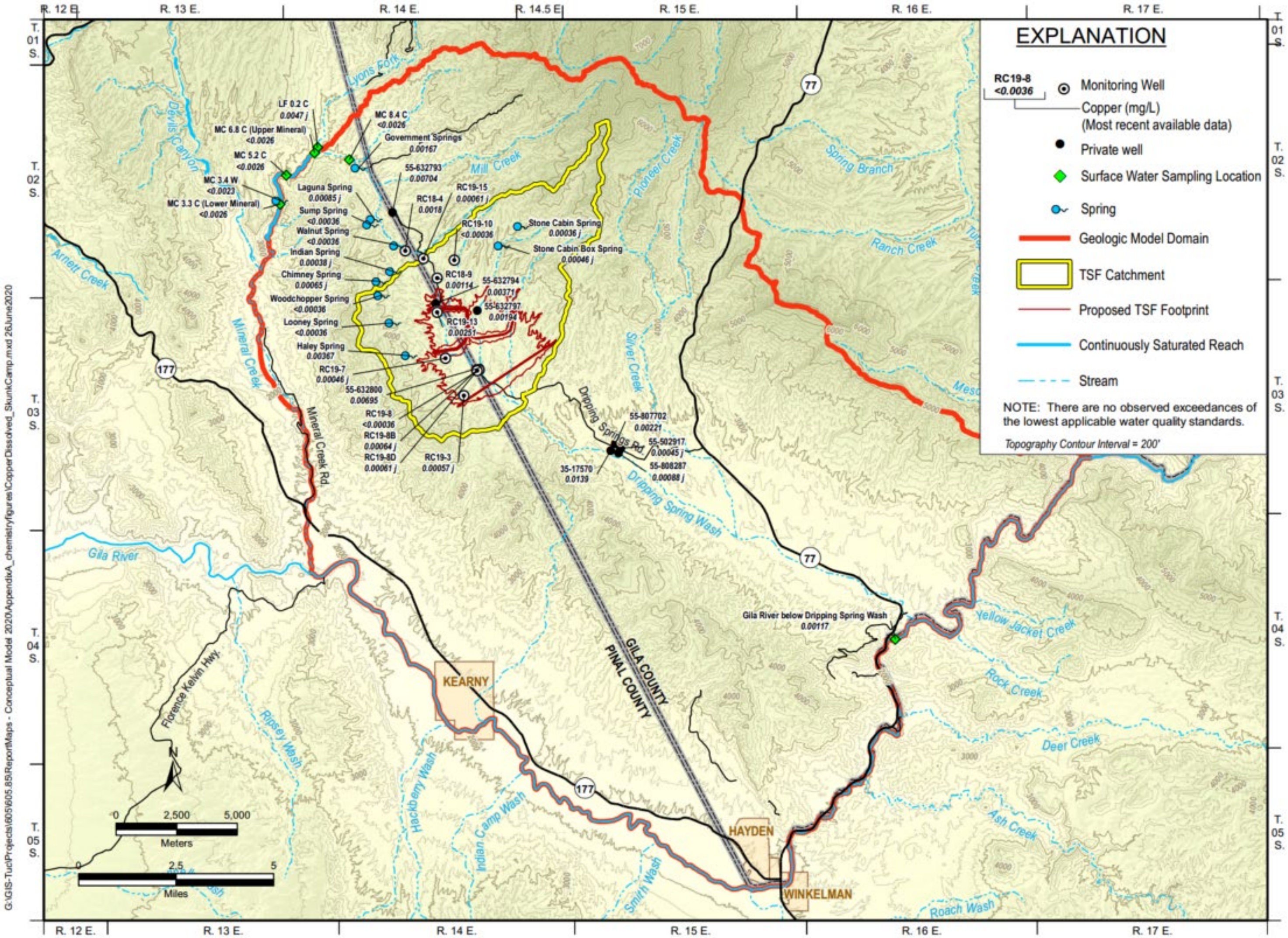

Figure A-5. Concentration of Dissolved Copper

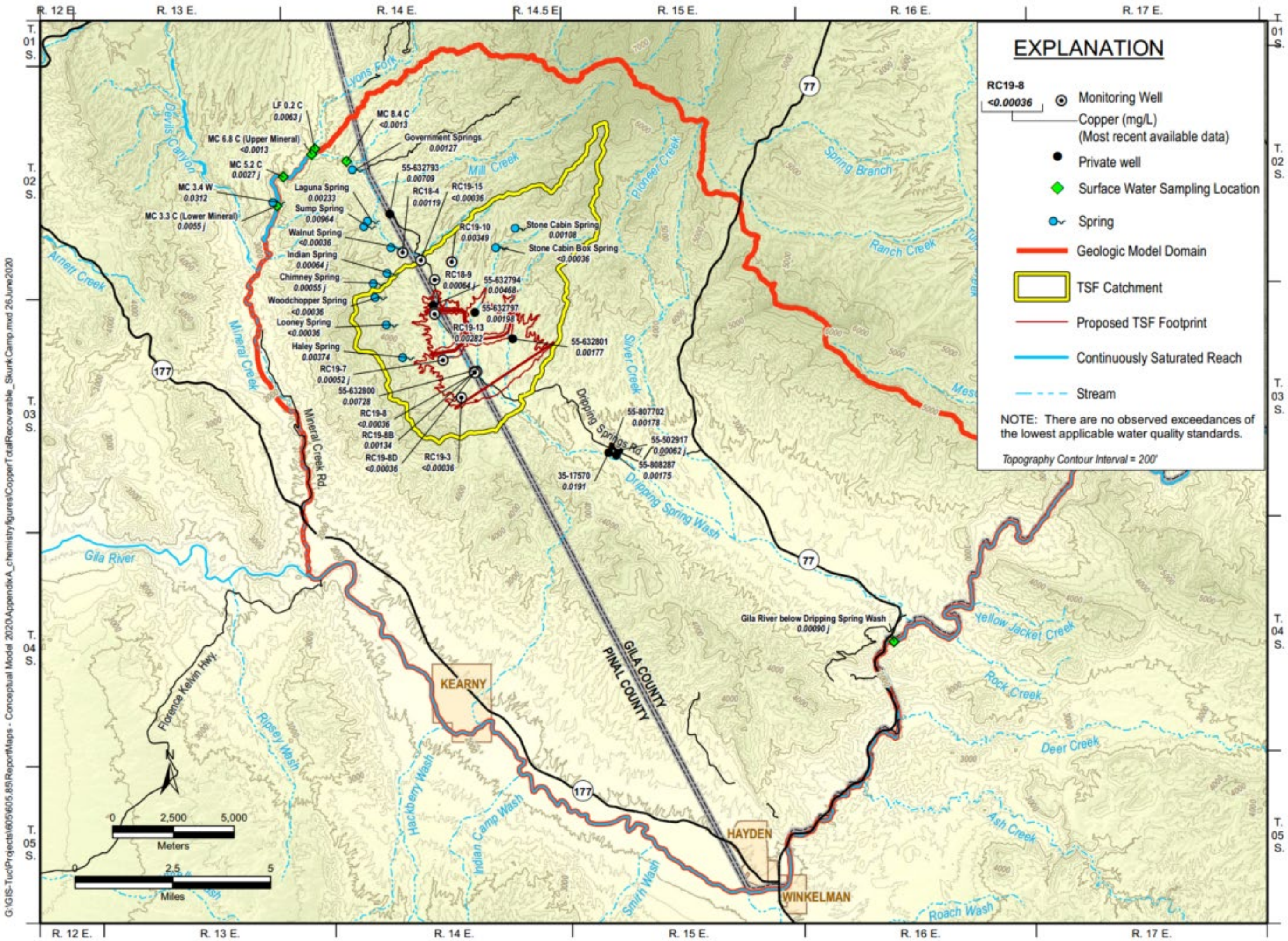

Figure A-6. Concentration of Total Recoverable Copper

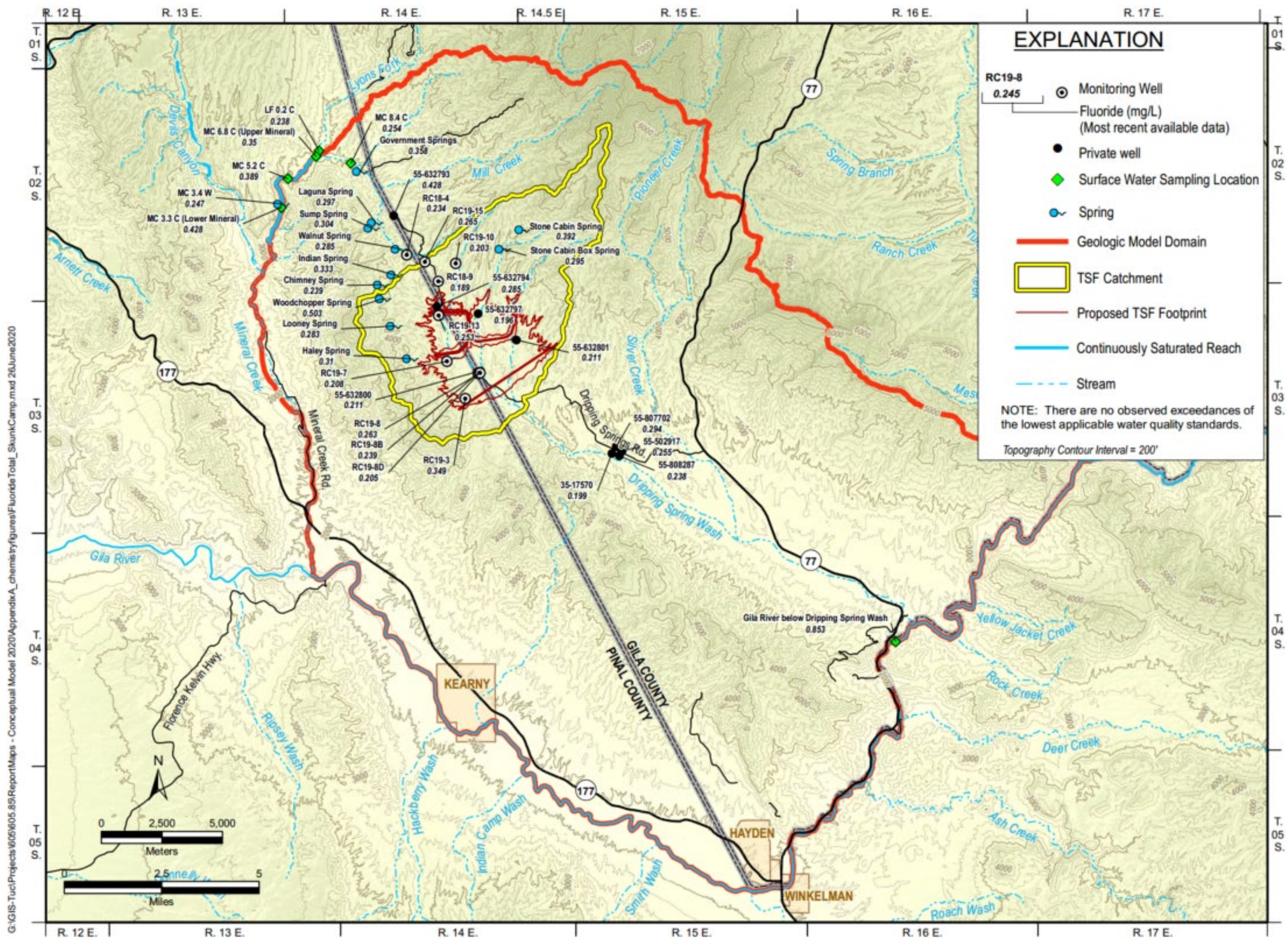

Figure A-7. Concentration of Total Fluoride

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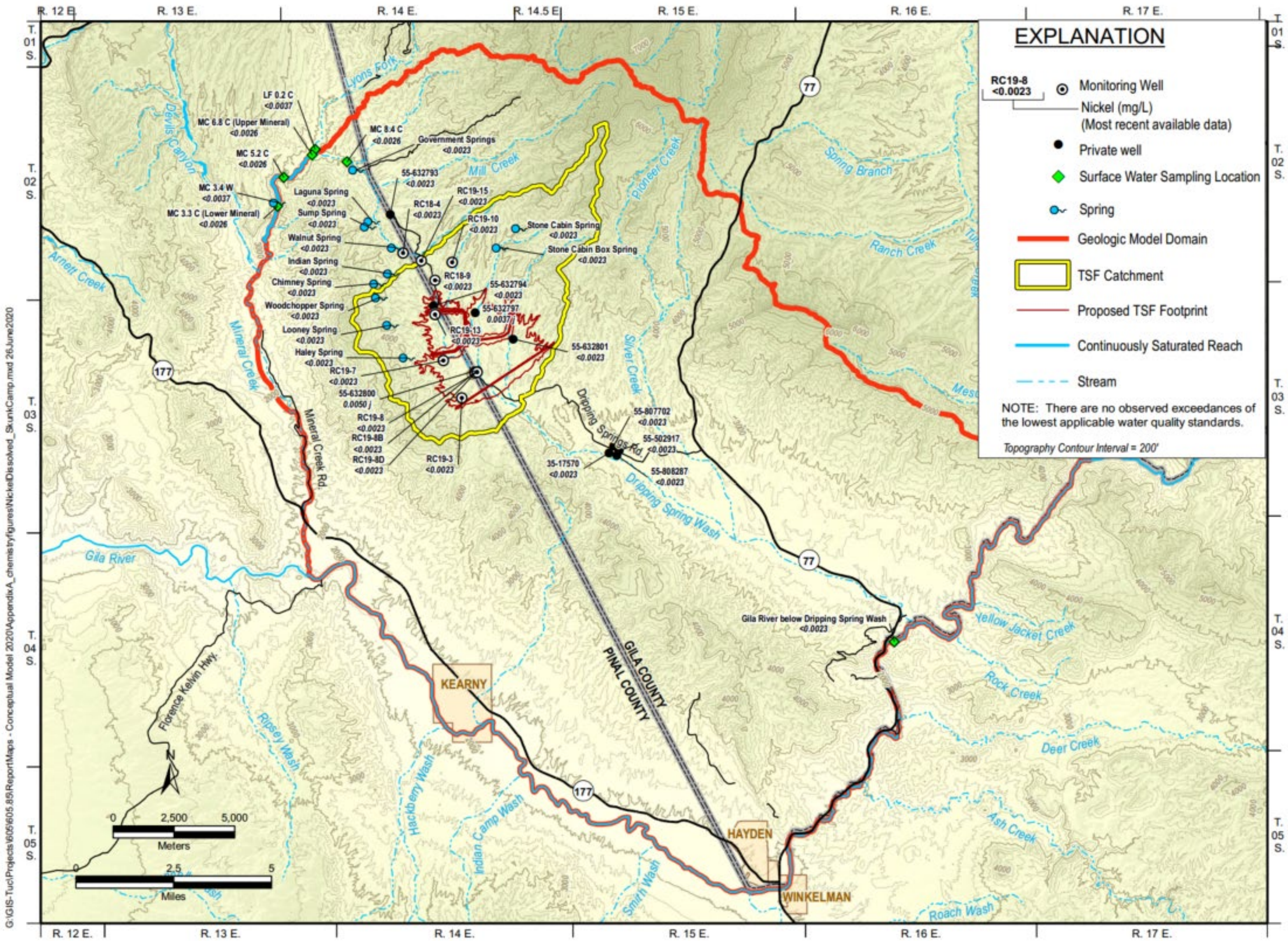

Figure A 8. Concentration of Dissolved Nickel

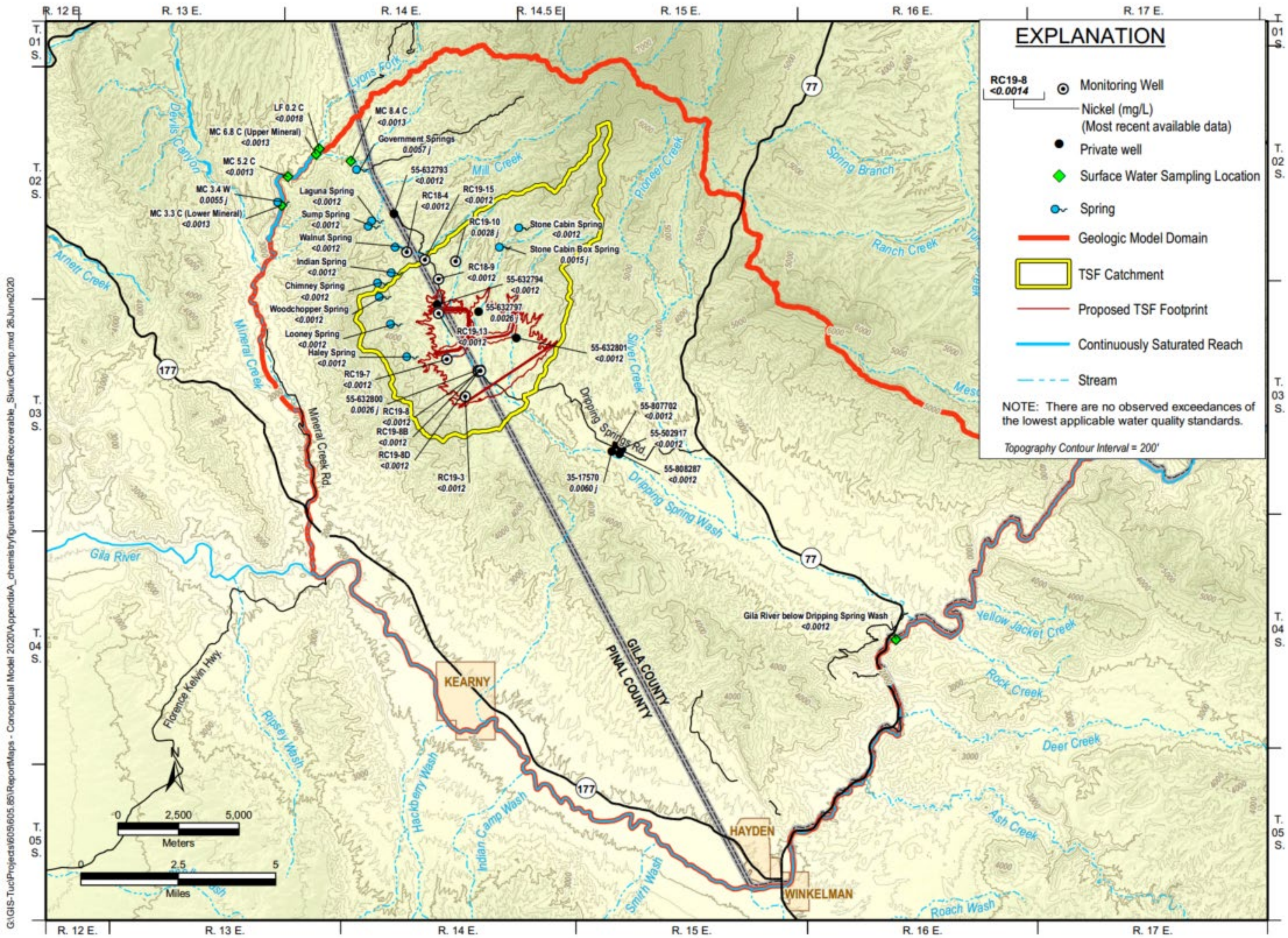

Figure A-9. Concentration of Total Recoverable Nickel

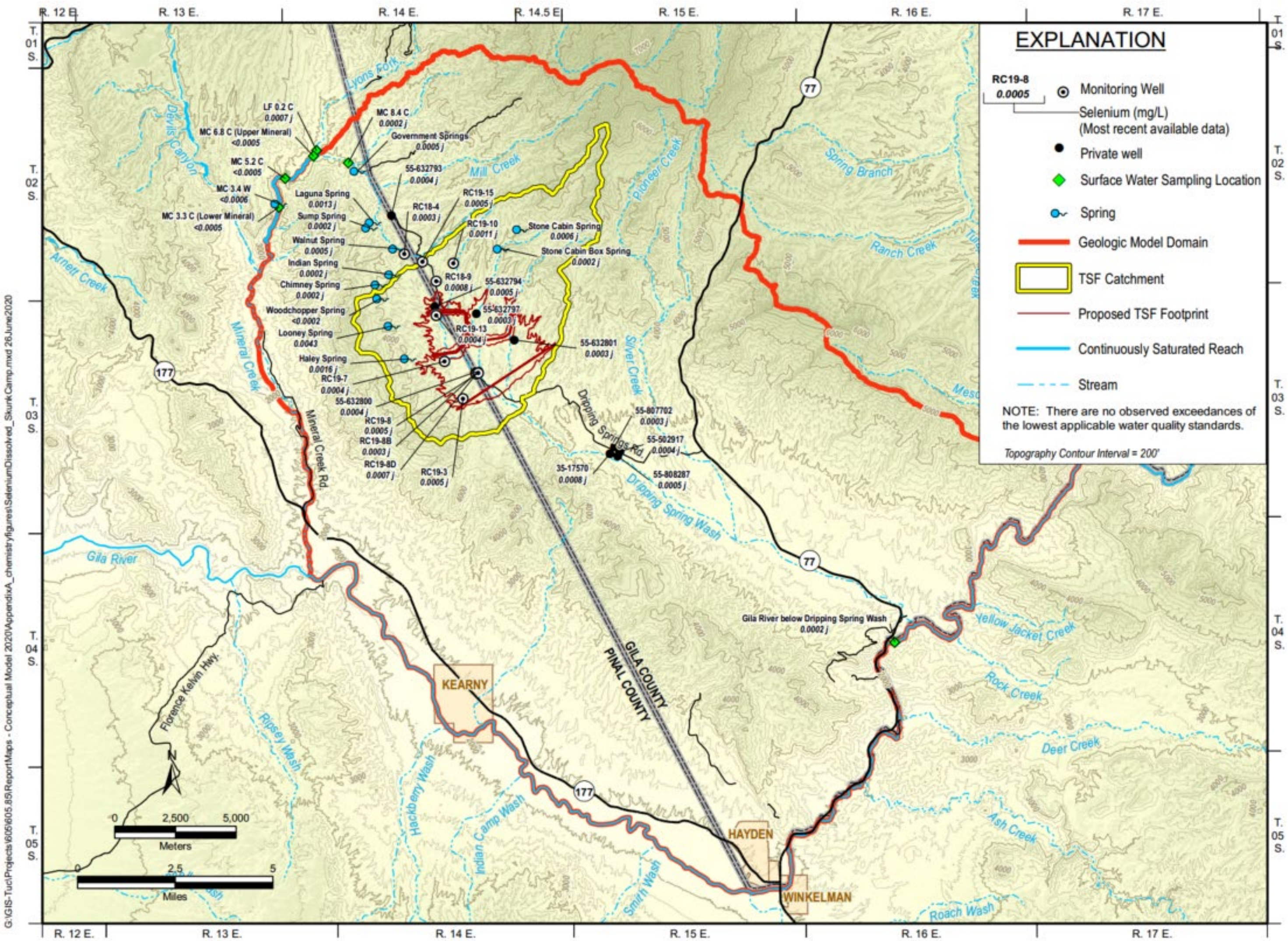

Figure A-10. Concentration of Dissolved Selenium

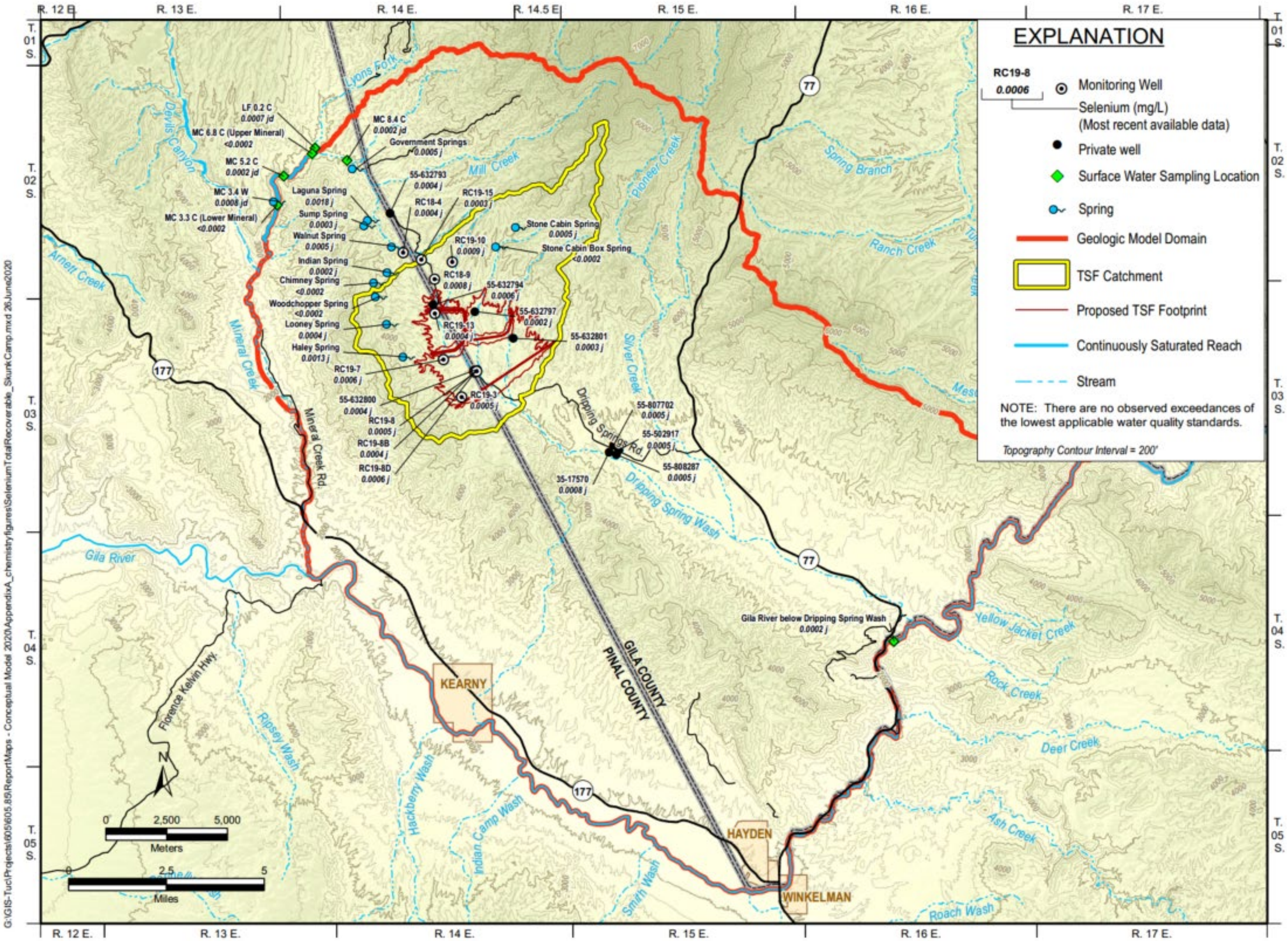

Figure A-11. Concentration of Total Recoverable Selenium

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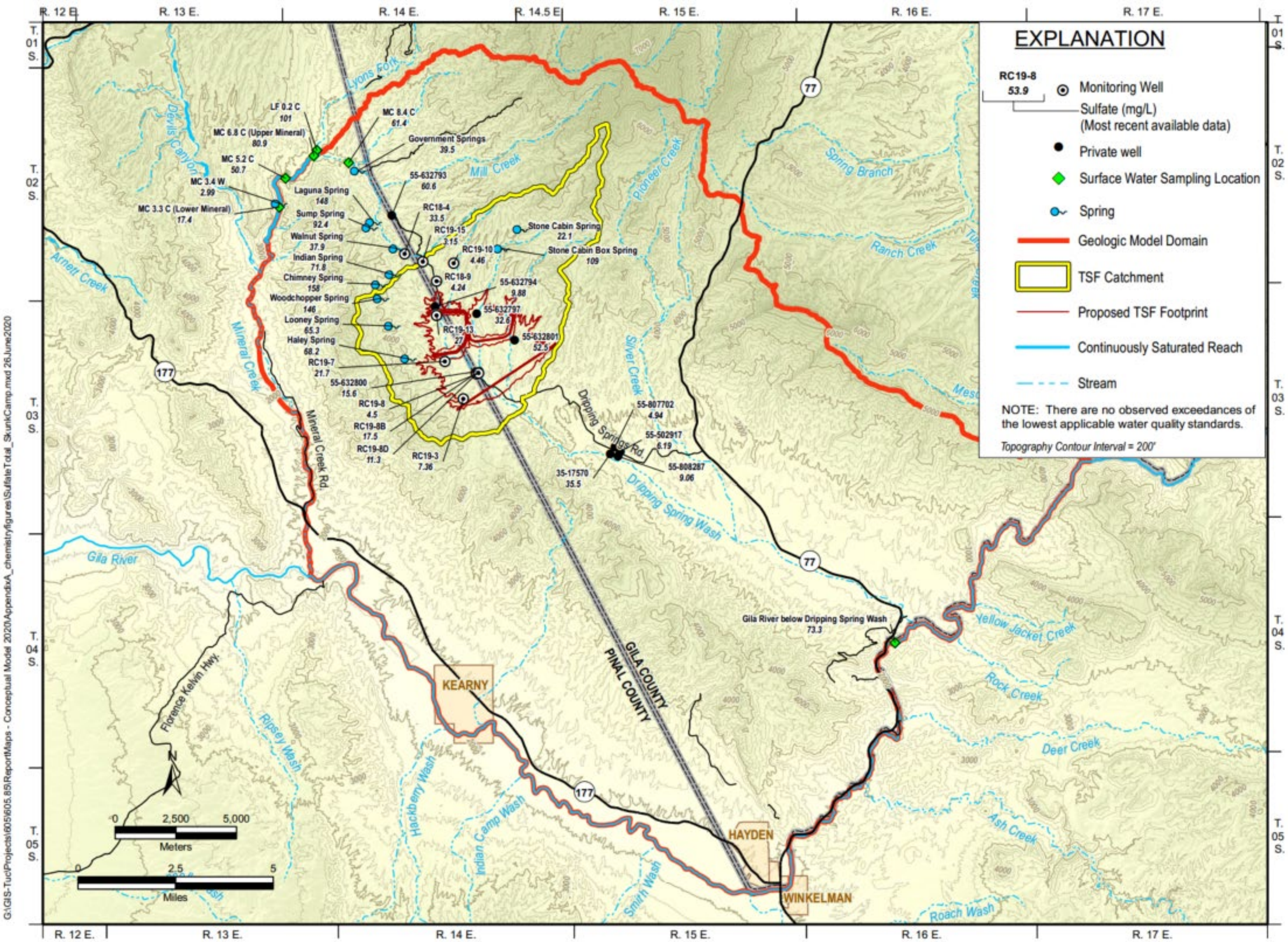

Figure A-12. Concentration of Total Sulfate

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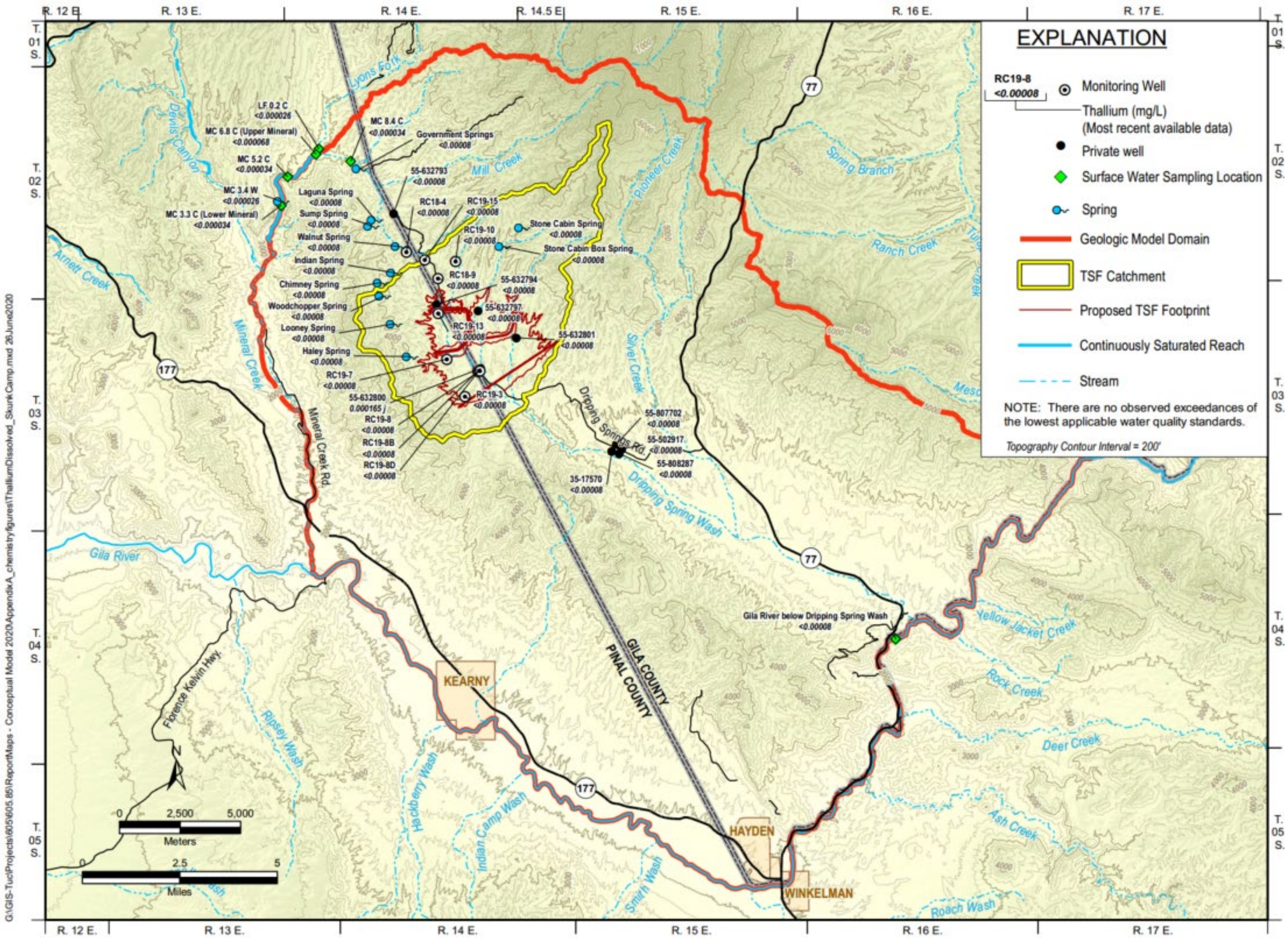

Figure A-13. Concentration of Dissolved Thallium

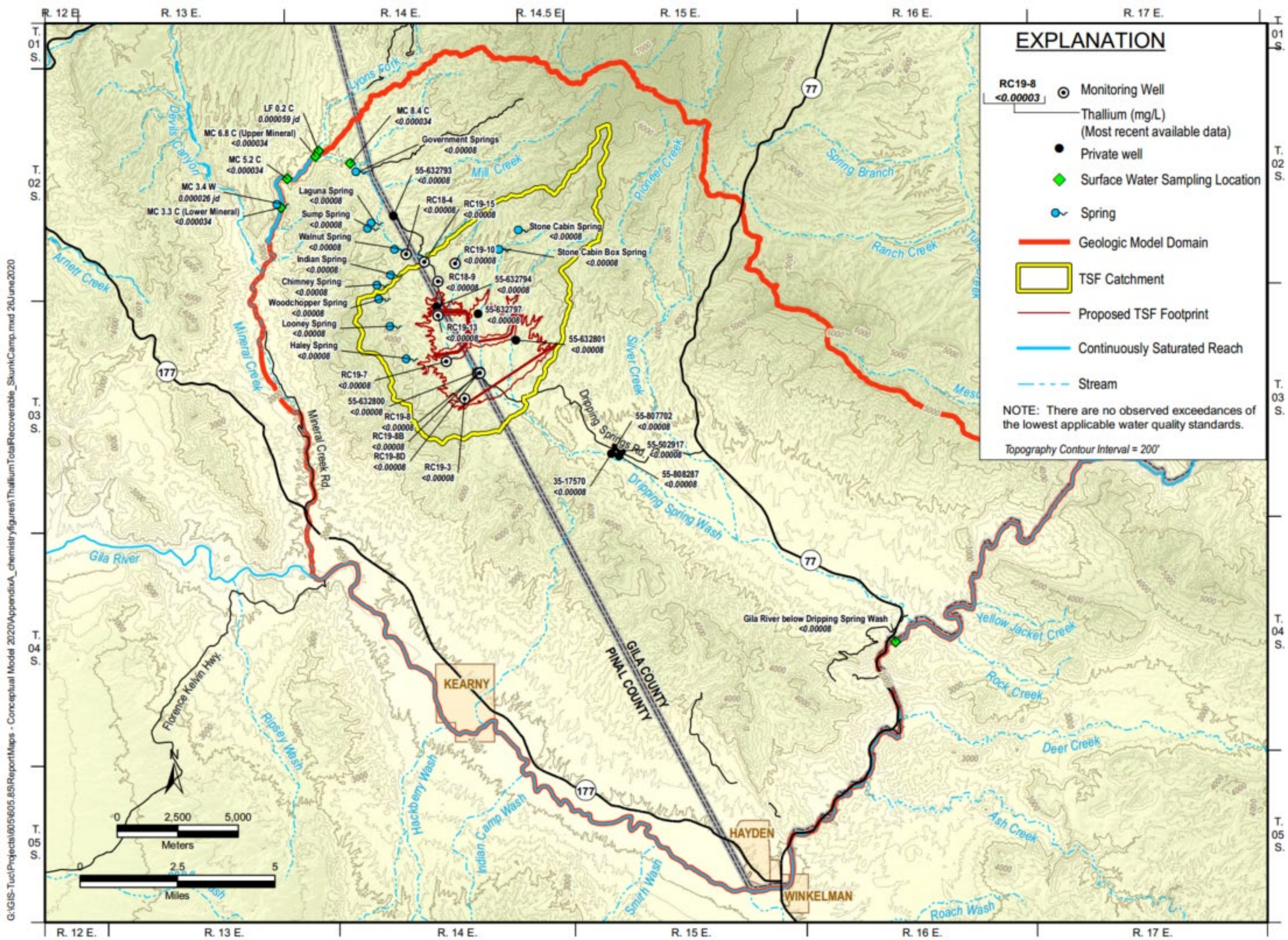

Figure A-14. Concentration of Total Recoverable Thallium

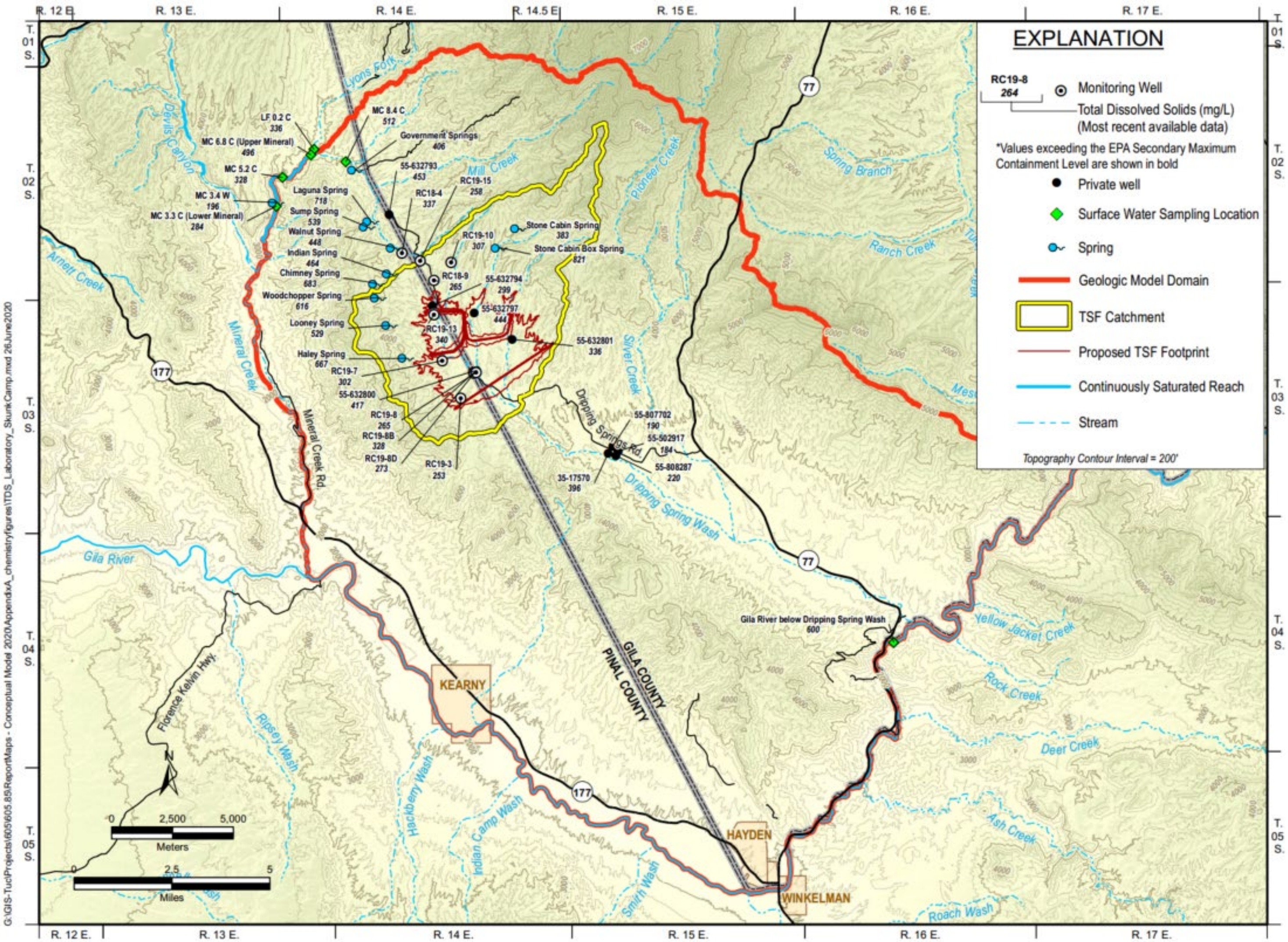

Figure A-15. Concentration of Laboratory TDS

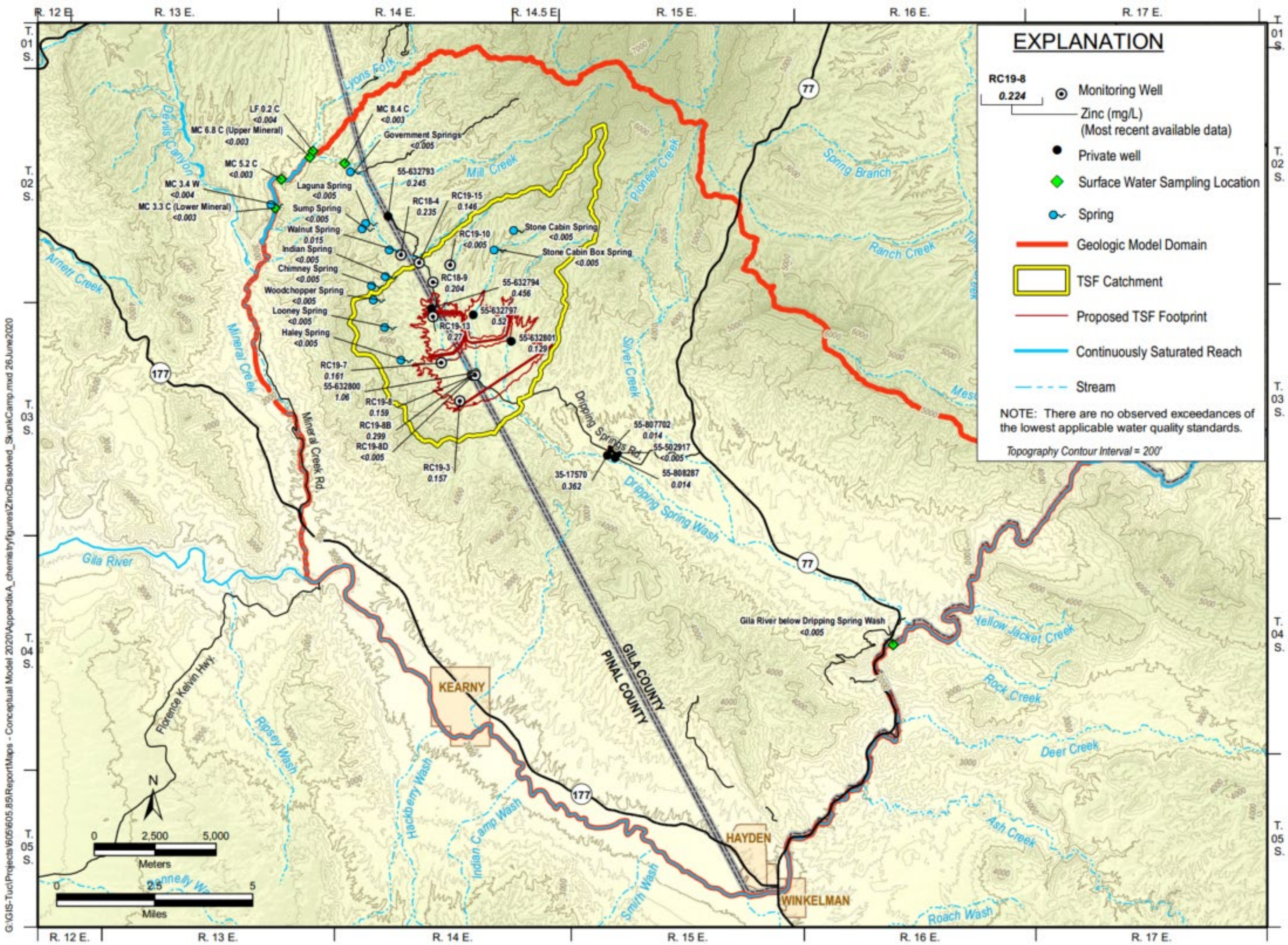

Figure A-16. Concentration of Dissolved Zinc

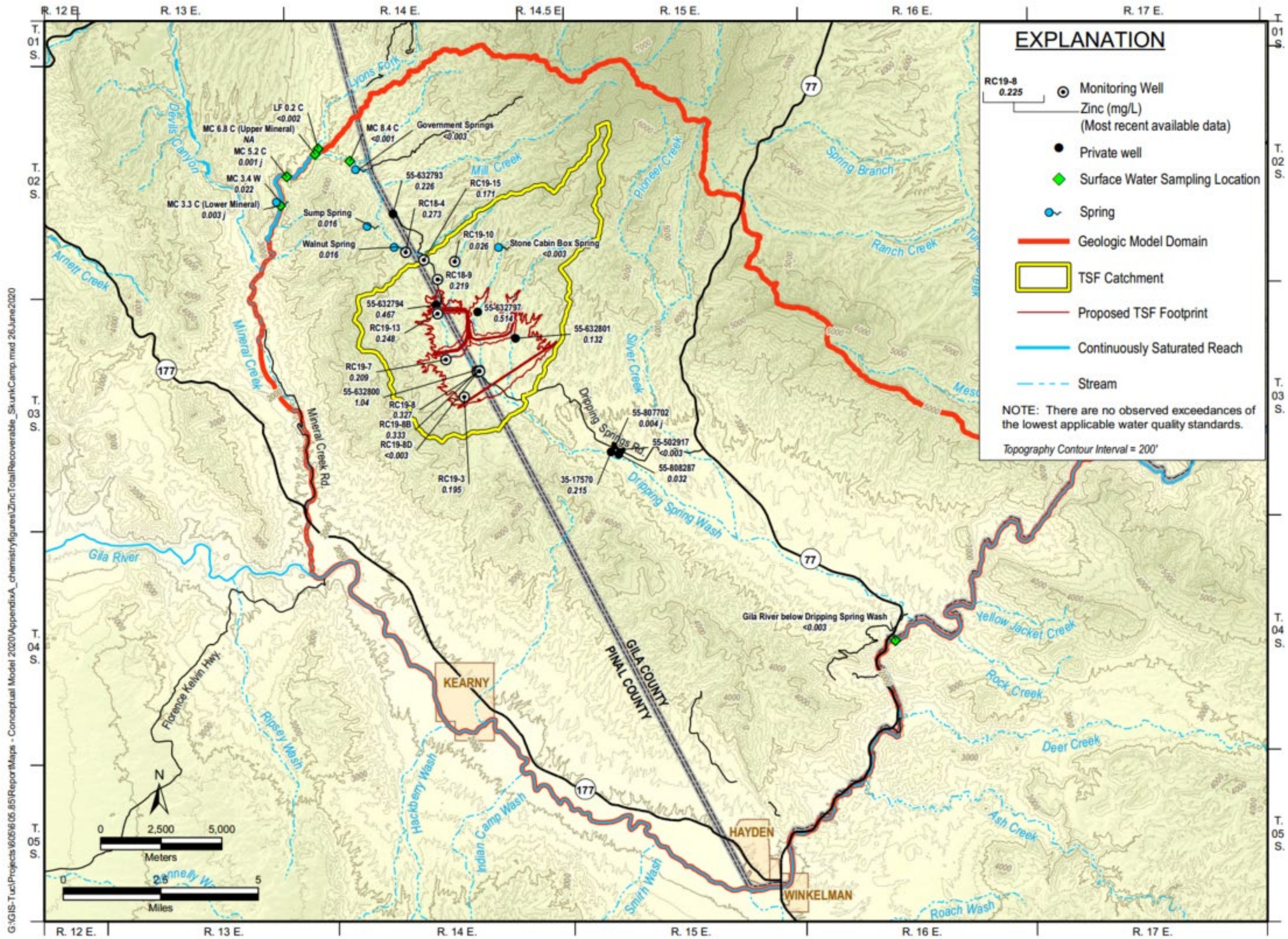

Figure A-17. Concentration of Total Recoverable Zinc

Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: Response to Water Work Group Action Item WR-30 - Part 2

From: Peacey, Victoria (RC) <Victoria.Peacey@riotinto.com>
Sent: Monday, June 29, 2020 4:28 PM
To: Rasmussen, Mary C -FS <mary.rasmussen@usda.gov>
Cc: Donna Morey <dmorey@swca.com>; Chris Garrett <cgarrett@swca.com>
Subject: Response to Water Work Group Action Item WR-30 - Part 2

EXTERNAL: This email originated from outside SWCA. Please use caution when replying.

Hello Mary,

As a follow-up to the submittal on Friday and as part 2 of the Water Working group Action Item WR-30 "*Submittal of Skunk Camp conceptual and predictive modeling reports*" please see the link below to the report for your review and consideration:

- **Conceptual Hydrogeologic Model: Skunk Camp Tailings Storage Facility Alternative, prepared by M&A (June 2020).**

https://cloudshare.elmontgomery.com/s/WHPwC8PwotknJeM

PW: SC_CM_4RCC

I checked the link and it works, but let me know if you have any issues.

Best,

Vicky Peacey
Senior Manager Permitting and Approvals

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