CONCEPTUAL MODEL OF GROUNDWATER FLOW IN THE ANIMAS UPLIFT AND PALOMAS BASIN COPPER FLAT PROJECT SIERRA COUNTY, NEW MEXICO

prepared by

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prepared for

New Mexico Copper Corporation,
a wholly owned subsidiary of THEMAC Resources Group, Ltd.
2425 San Pedro NE
Albuquerque, New Mexico 87110

May 22, 2012

EXHIBIT
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CONCEPTUAL MODEL OF GROUNDWATER FLOW IN THE ANIMAS UPLIFT AND PALOMAS BASIN COPPER FLAT PROJECT, SIERRA COUNTY, NEW MEXICO

1.0 INTRODUCTION

This report presents the current conceptual model of the hydrogeological system in the area of the Copper Flat Project (Project) near Truth or Consequences, New Mexico. The Project location is shown on Figure 1.1.

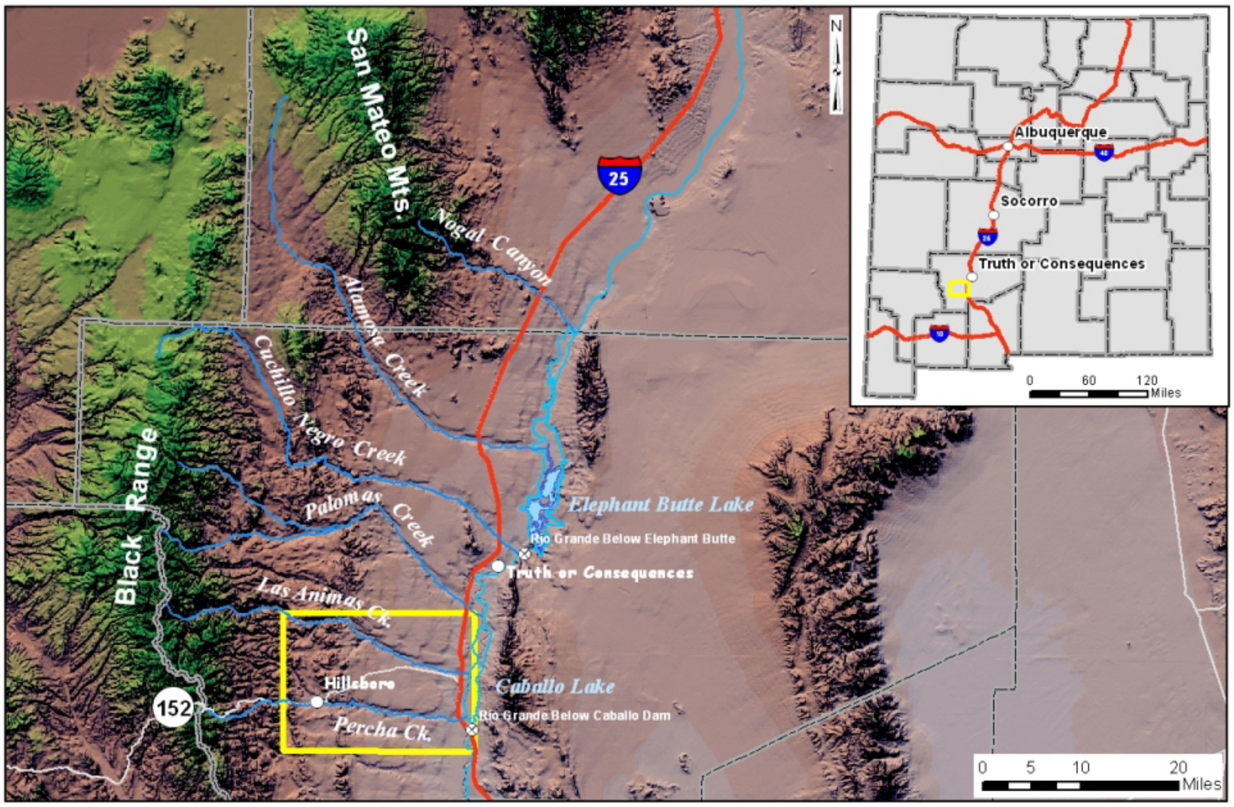


Figure 1.1. Copper Flat Project location.

The purpose of the conceptual model is to describe the hydrologic and hydrogeologic systems in which the mine water-supply wells and the Project facilities including open pit, tailings impoundment, and waste rock deposit are set.

The conceptual model is based on previous studies by Shomaker (1993), Adrian Brown Consultants (1996), Bureau of Land Management (BLM, 1999), Raugust (2003), and NMCC Baseline Data Report (INTERA, 2012), and ongoing investigations. It will provide the framework for development of a numerical hydrologic/hydrogeologic model, which will in turn provide a more precise quantitative framework in which to evaluate the effects of Project development.

2.0 CLIMATE AND METEOROLOGY

Precipitation and evaporation in the study area are examined using data from regional meteorological stations. The station at Hillsboro, New Mexico, has a long record (with at least partial data from 1893), is located nearby (about 4 miles from the Copper Flat open pit), and at a similar elevation (5,270 feet above mean sea level (ft amsl)) as the Copper Flat Mine site. Locations of the Hillsboro station and other meteorological stations along the east side of the Black Range are shown on Figure 2.1.

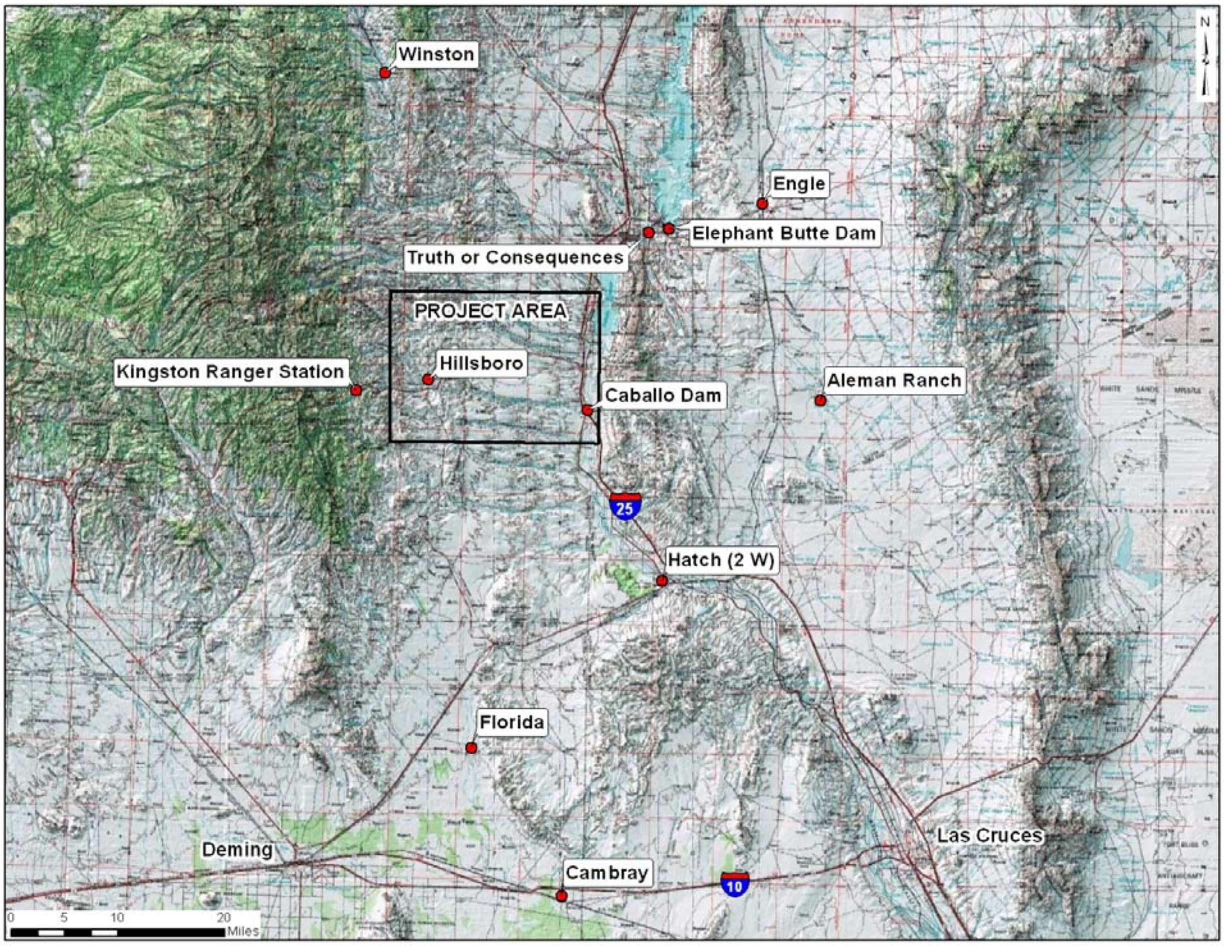


Figure 2.1. Locations of meteorological stations surrounding Project area.

2.1 Annual Precipitation

The range of variability between wet and dry climatic conditions is seen in the annual precipitation recorded at Hillsboro from 1925 through 2010, shown on Figure 2.2. Annual precipitation ranges from about 5 to about 20 inches per year (in./yr) and averages about 12.5 inches. Copper Flat weather station recorded 4.82 inches precipitation between October 2010 and September 2011, signifying extreme drought conditions during this period.

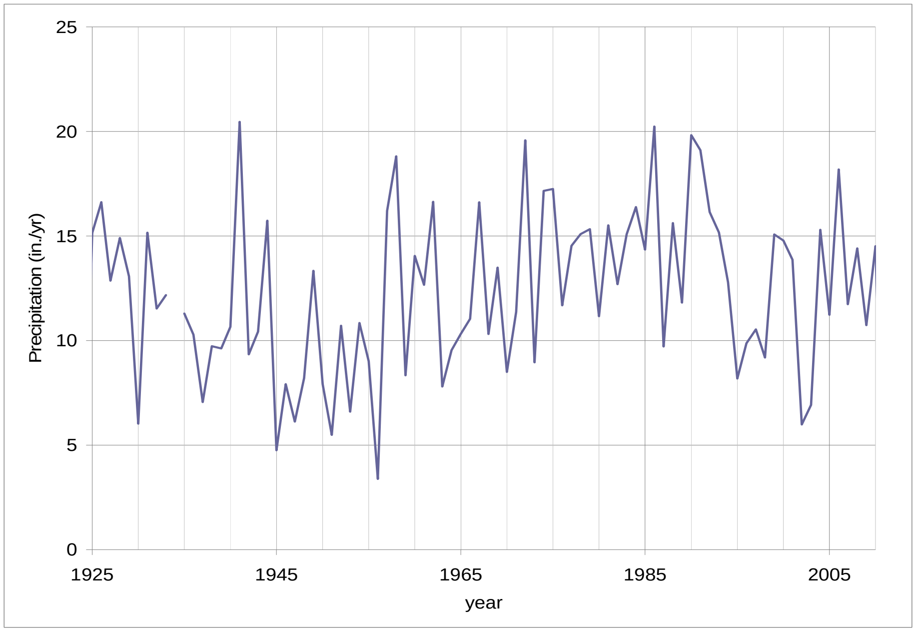


Figure 2.2. Recorded annual precipitation at Hillsboro meteorological station.

2.2 Precipitation Events

The frequency and magnitude of rainfall-runoff events are examined in the statistical distribution of daily precipitation at Hillsboro, shown on Figure 2.3. Daily precipitation of 1 inch or more occurs, on average, twice per year. Storm events of magnitude 2 inches can be expected to occur every 5 years, and the 100-year storm event is about 3.5 inches.

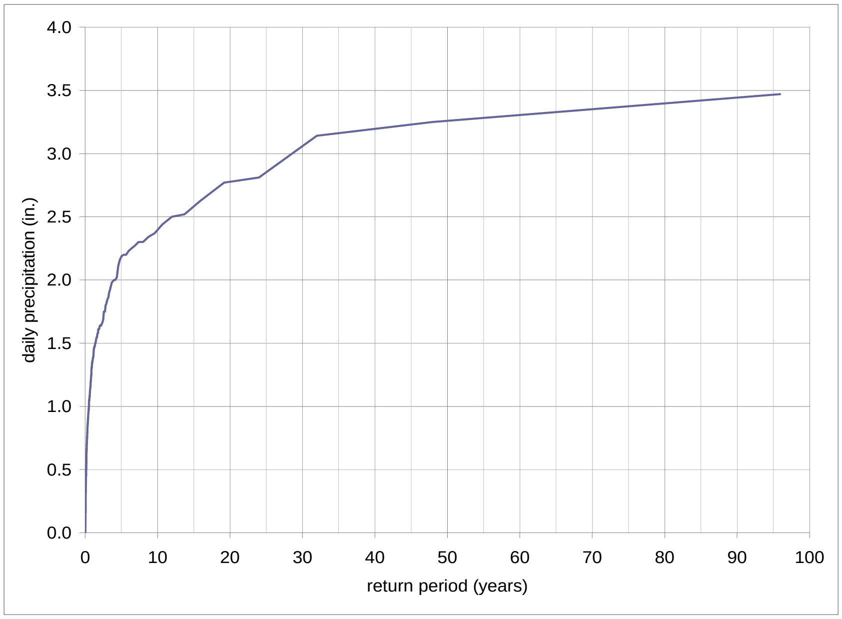


Figure 2.3. Distribution of daily precipitation at Hillsboro meteorological station.

2.3 Precipitation and Elevation

Precipitation is known to increase with elevation, and the bulk of surface-water runoff and groundwater recharge in the study area is generated by precipitation on the higher elevations of the Percha Creek and Las Animas Creek watersheds. Mean annual precipitation was compared to elevation for meteorological stations east of the Black Range as shown on Figure 2.4. The best-fit linear relationship estimates about 8.6 in./yr mean annual precipitation at elevation 4,000 ft amsl and about 26.2 in./yr at elevation 10,000 ft amsl, approximately the maximum in the study area.

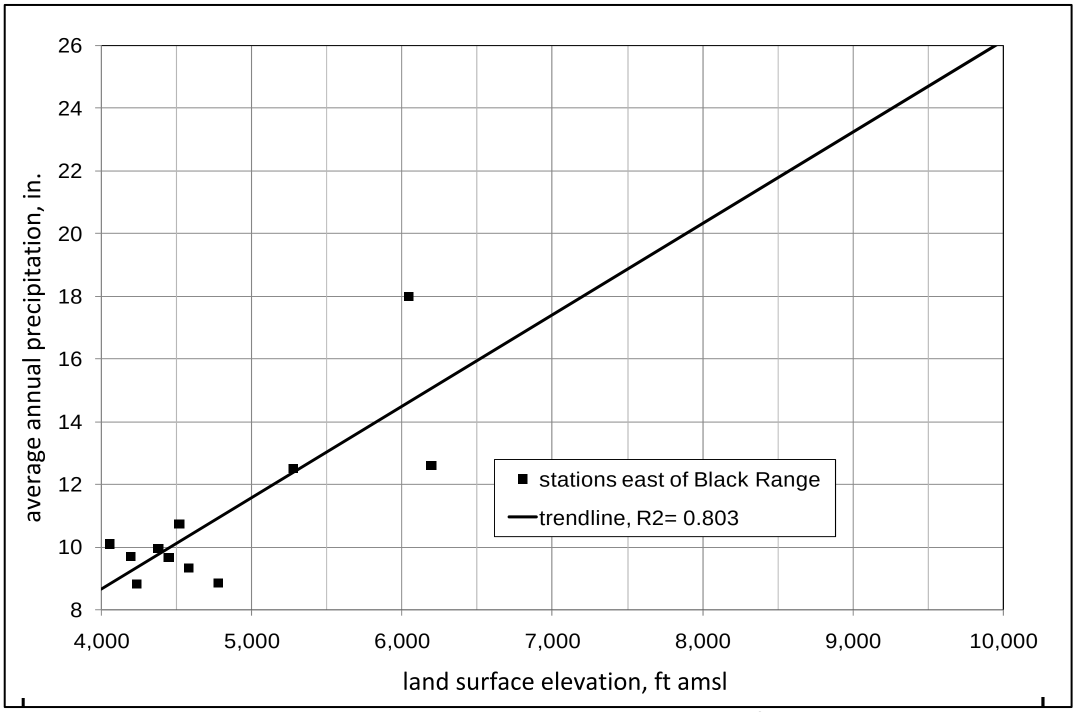


Figure 2.4. Mean annual precipitation versus elevation of meteorological station.

2.4 Potential Evapotranspiration

Potential evapotranspiration (ET), or the maximum evaporation and plant transpiration that could be expected assuming full availability of water, is commonly estimated using the Penman-Monteith equations (Monteith, 1965) which relate maximum ET (ET_0) to meteorological parameters including temperature, relative humidity and wind speed, and to geographical parameters (latitude and time of year) for a given reference crop.

Annual ET_0 computed from results at Hillsboro meteorological station is shown on Figure 2.5 to be about 60 in./yr. This compares well to previous estimates (SRK, 1997) of 65 in./yr of potential evaporation, and the baseline data collected at Copper Flat (62.5 inches net evaporation between October 2010 and September 2011). Actual ET, or actual evaporation from an open water surface, is less, depending on sun and wind exposure, ground conditions, and availability of water.

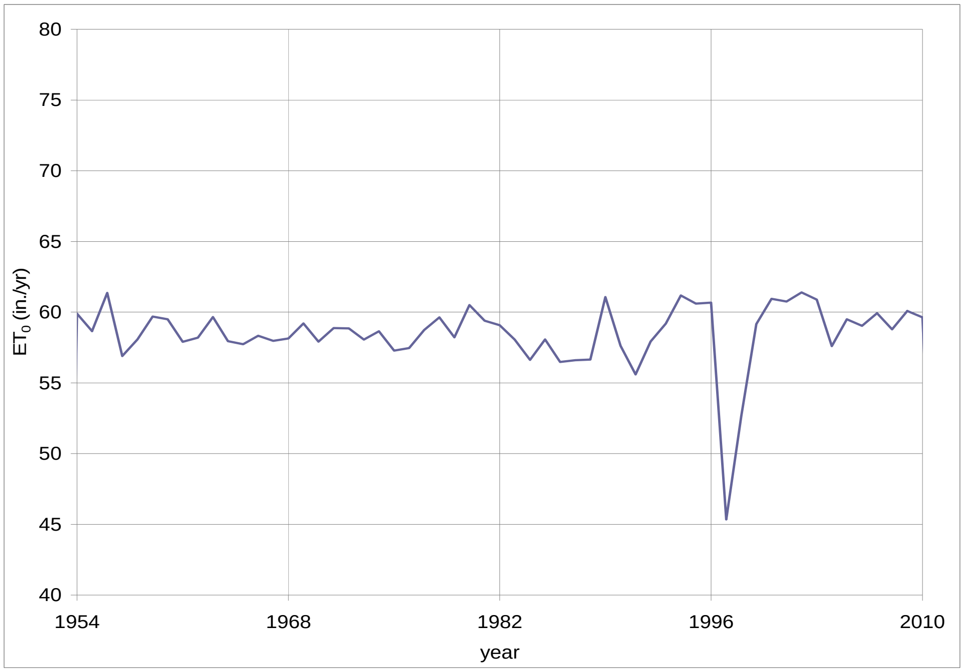


Figure 2.5. Penman-Monteith evapotranspiration (ET_0) from Hillsboro meteorological station.

Evaporation in the study area increases at lower elevations. An estimate of reservoir evaporation along the Rio Grande (Middle Rio Grande Endangered Species Collaborative, 2003) is:

$$\text{evaporation} = 135.8 \text{ in.} - (0.0135 \text{ in./ft amsl}) * Z$$

where,

Z is elevation in feet above mean sea level.

Estimated average evaporation, precipitation (Fig. 2.4) and net evaporation for Caballo Lake and the Copper Flat open pit are presented in Table 2.1.

Table 2.1. Estimated average total and net reservoir evaporation

location	elevation (ft amsl)	mean annual precipitation (in.)	annual reservoir evaporation (in.)	net evaporation (in./yr)
Caballo Lake	4,200	9.2	79.1[1]	69.9
Copper Flat open pit	5,440	12.8	62.4	49.5

[1] Equivalent to 74% of pan evaporation measured at Caballo (WRCC)

3.0 HYDROLOGY AND WATER BALANCE

Topographic basins of the study area are shown on Figure 3.1 and include Las Animas Creek and Percha Creek watersheds as well as the Grayback and Greenhorn arroyo drainages. Part of the original Grayback Arroyo watershed now drains to the Copper Flat pit.

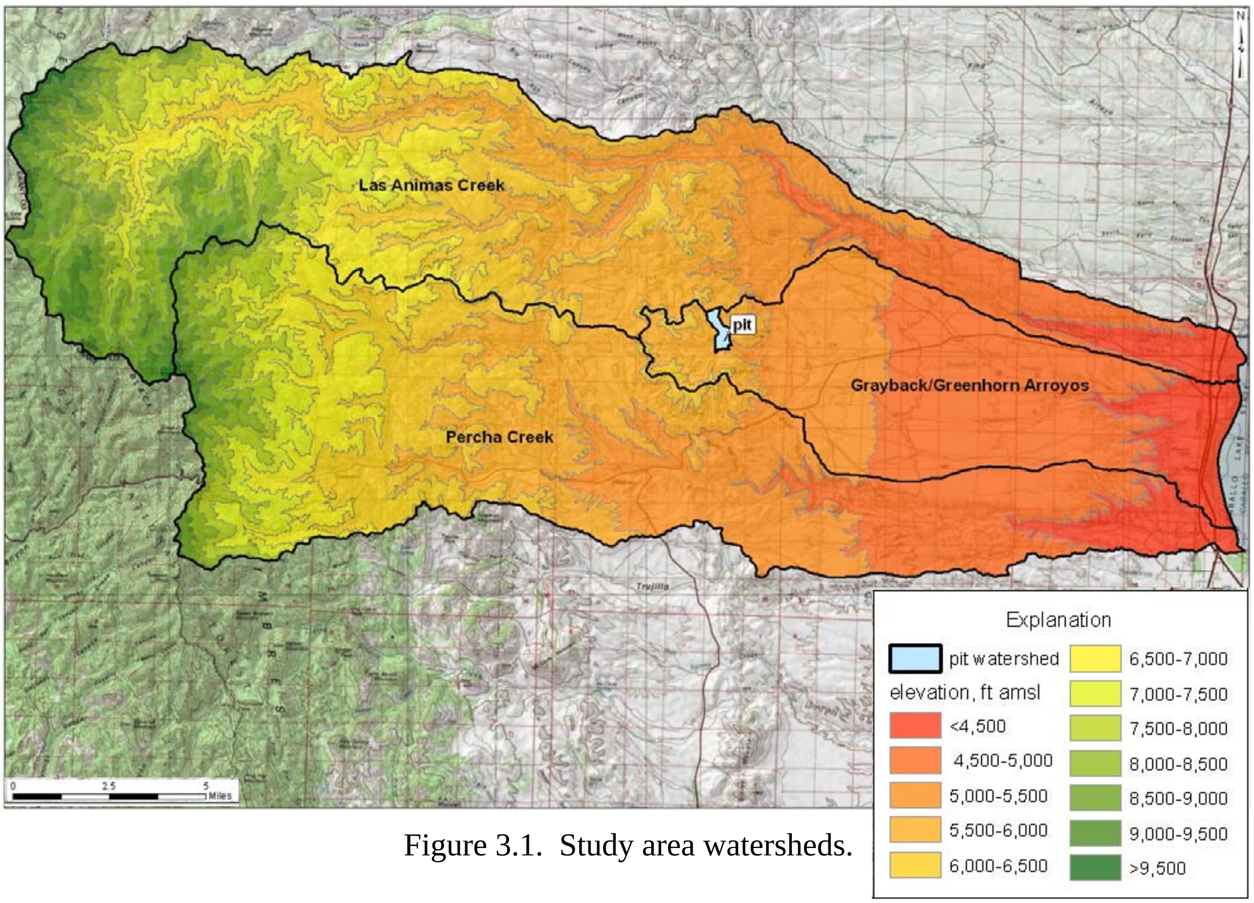


Figure 3.1. Study area watersheds.

3.1 Watershed Area and Precipitation

The areas of each of the watersheds within defined elevation bands are listed on Table 3.1. The mean annual precipitation (Fig. 2.4) estimated for the midpoint of each band is presented on Table 3.2, along with the estimated total annual volume of precipitation for each watershed.

Table 3.1. Study area watershed areas and hypsometry

elevation range (ft amsl)	Las Animas Creek	Percha Creek	Grayback / Greenhorn Arroyos	open pit
	area (acres)			
<4,500	2,888	3,576	4,539	
4,500-5,000	7,030	11,035	17,095	
5,000-5,500	8,412	12,614	9,708	230
5,500-6,000	14,539	14,072	2,864	
6,000-6,500	12,369	13,030	635	
6,500-7,000	10,279	8,219		
7,000-7,500	6,507	5,355		
7,500-8,000	5,808	4,159		
8,000-8,500	6,160	3,021		
8,500-9,000	6,362	1,749		
>9,000	3,305	509		
total	**83,659**	**77,339**	**34,840**	**230**

ft amsl - feet above mean sea level

Table 3.2. Study area precipitation by watershed and elevation

midpoint elevation (ft amsl)	precipitation (in./yr)	Las Animas Creek	Percha Creek	Grayback / Greenhorn Arroyos	open pit
		precipitation (ac-ft/yr)			
4,350	9.7	2,326	2,880	3,655	
4,750	10.8	6,345	9,961	15,431	
5,250	12.3	8,617	12,921	9,944	236
5,750	13.8	16,661	16,126	3,282	
6,250	15.2	15,679	16,516	804	
6,750	16.7	14,279	11,417		
7,250	18.1	9,832	8,091		
7,750	19.6	9,482	6,790		
8,250	21.0	10,805	5,298		
8,750	22.5	11,933	3,280		
9,500	24.7	6,802	1,048		
total		**112,760**	**94,328**	**33,116**	**236**

ft amsl - feet above mean sea level
in./yr - inches per year
ac-ft/yr - acre-feet per year

3.2 Runoff and Groundwater Recharge

Groundwater recharge has, in some studies, been estimated using the method of Maxey and Eakin (1949), in which estimated mean annual precipitation, a function of elevation, is correlated with an independent estimate of discharge. The result is a set of recharge factors, defined as the proportion of precipitation that becomes runoff or recharge (excess precipitation), for a given level of mean annual precipitation.

Some example sets of recharge factors are presented in Table 3.3. These include the formulation of Bennett and Finch (2002) used to estimate recharge in the trans-Pecos region of Texas, that was subsequently used to estimate recharge to the Salt Basin in New Mexico and Texas (JSAI, 2010) and the Davis Mountains/Salt Basin in Texas (LBG-Guyton, 2004). Another example is that of Maxey and Eakin (1949), which studied dry, closed basins in southern Nevada, estimating discharge as playa ET. This example was modified by McDonald-Morrissey (1998) in BLM (2000), in a study of wetter, exorheic basins along the Carlin Trend in northern Nevada that estimated discharge from gaged surface flows and as ET from vegetated areas.

Table 3.3. Published recharge factors

midpoint elevation (ft amsl)	precipitation (in./yr)	portion of precipitation that becomes runoff and/or recharge		
		Bennett and Finch (2002)	Maxey - Eakin (1949)	BLM (2000)
4,350	9.7	0.00	0.03	0.03
4,750	10.8	0.00	0.03	0.03
5,250	12.3	0.00	0.07	0.07
5,750	13.8	0.02	0.07	0.07
6,250	15.2	0.03	0.15	0.3
6,750	16.7	0.04	0.15	0.3
7,250	18.1	0.05	0.15	0.3
7,750	19.6	0.07	0.15	0.3
8,250	21.0	0.08	0.25	0.45
8,750	22.5	0.09	0.25	0.45
9,500	24.7	0.11	0.25	0.45

Actual runoff and recharge are influenced by site-specific conditions including topography and surface geology. However in the absence of an independent estimate of discharge, the previously published recharge factors may indicate a potential range of basin water yield. Table 3.4 presents the estimates of runoff and groundwater recharge for the study area corresponding to the recharge factors presented in Table 3.3.

Table 3.4. Study-area runoff and groundwater recharge, estimated assuming published parameters

runoff + recharge (acre-feet per year)	Bennett and Finch (2002)	Maxey - Eakin (1949)	BLM (2000)
Las Animas Creek	5,149	16,805	30,104
Percha Creek	2,920	11,247	19,595
Grayback / Greenhorn Arroyos	96	1,619	1,740
open pit	1	16	16
total	**8,166**	**29,688**	**51,455**

3.3 Water Balance

Discharge from the study area occurs mainly as discharge to Caballo Lake and the Rio Grande, and as ET discharge from riparian and irrigated areas along Las Animas and Percha Creeks. Evaporation and ET for Caballo Lake and for the study area watersheds are estimated on Table 3.5.

In Table 3.5, ET from irrigated crops or riparian vegetation was estimated at 3 ft/yr. Net evaporation for Caballo Lake, estimated at 70 in./yr (Table 2.1), was rounded down to account for runoff from the east side of the lake. Net evaporation and ET for North Caballo Lake and Rio Grande riparian area were estimated as the average of net combined Caballo evaporation and riparian ET rate.

Table 3.5. Estimated evaporation and ET

	area (ac)	net evaporation / groundwater ET rate (ft/yr)	net evaporation / groundwater ET rate (ac-ft/yr)
Caballo Lake (water surface at 4,200 ft amsl)	6,344	5	31,719
North Caballo Lake / Rio Grande riparian area	5,214	4	20,858
Animas Creek irrigated / riparian area	1,421	3	4,262
Percha Creek irrigated / riparian area	280	3	839
Copper Flat open pit	5	4	20
total			**57,698**

The Caballo Lake discharge components, totaling 52,577 acre-feet per year (ac-ft/yr) in Table 3.5, are provided in part by direct contribution from the Rio Grande. Based on average daily discharge below Elephant Butte dam (U.S. Geological Survey (USGS) gage No. 08361000) and below Caballo dam (USGS gage No. 08362500) from 1938 through 2010, an average of 12,364 ac-ft/yr more water is released from Elephant Butte than from Caballo.

Another part of the remaining Caballo Lake discharge (40,213 ac-ft/yr) is provided by contributions from the Palomas Creek (catchment area 233,942 ac) and Cuchillo Creek (catchment area 235,493 ac) basins north of the study area. Assuming water yield proportional to catchment area (Table 3.1), Palomas and Cuchillo Creeks basins would be expected to produce about 71 percent of the total, with the study area basins contributing the remainder (about 11,850 ac-ft/yr).

Based on this estimate of total discharge (runoff + groundwater discharge) to the Rio Grande / Caballo Lake system and on the discharge estimates in Table 3.5, an estimated water balance for the study area is presented in Table 3.6.

Table 3.6. Estimated water balance

runoff and recharge	
Animas Creek	10,709
Percha Creek	6,074
Grayback and Greenhorn Arroyos	201
Copper Flat open pit	1
total	**16,984**
discharge	
Animas Creek irrigated and riparian area	4,262
Percha Creek irrigated and riparian area	839
discharge to Rio Grande and Caballo Reservoir	11,850
Copper Flat open pit	20
total	**16,971**

The initial water balance in Table 3.6 may be compared with the water balance of the Upper Mimbres Basin, located on the opposite side of the Black Range from the study area, with a similar distribution of elevations. The average yield of the 300,000-acre basin above Faywood gaging station is estimated (based on gaged flows) at 26,700 ac-ft/yr (White, 1930). Assuming the same per-acre water yield for the study area would result in an estimate of 17,450 ac-ft/yr, similar to the estimate given in Table 3.6.

The estimated water balance will be further refined based on results of 2011 Las Animas Creek and Percha Creek seepage studies, of pit-area monitoring and hydraulic testing, and possibly on results of numerical model development.

4.0 GEOLOGY AND HYDROGEOLOGY

The hydrogeologic study area is shown on Figure 4.1, along with the larger area of the study area (surface) watersheds. Although most of the precipitation that recharges the groundwater system originates in the upper part of the watersheds, the most significant groundwater systems are found downstream from the Black Range mountain block.

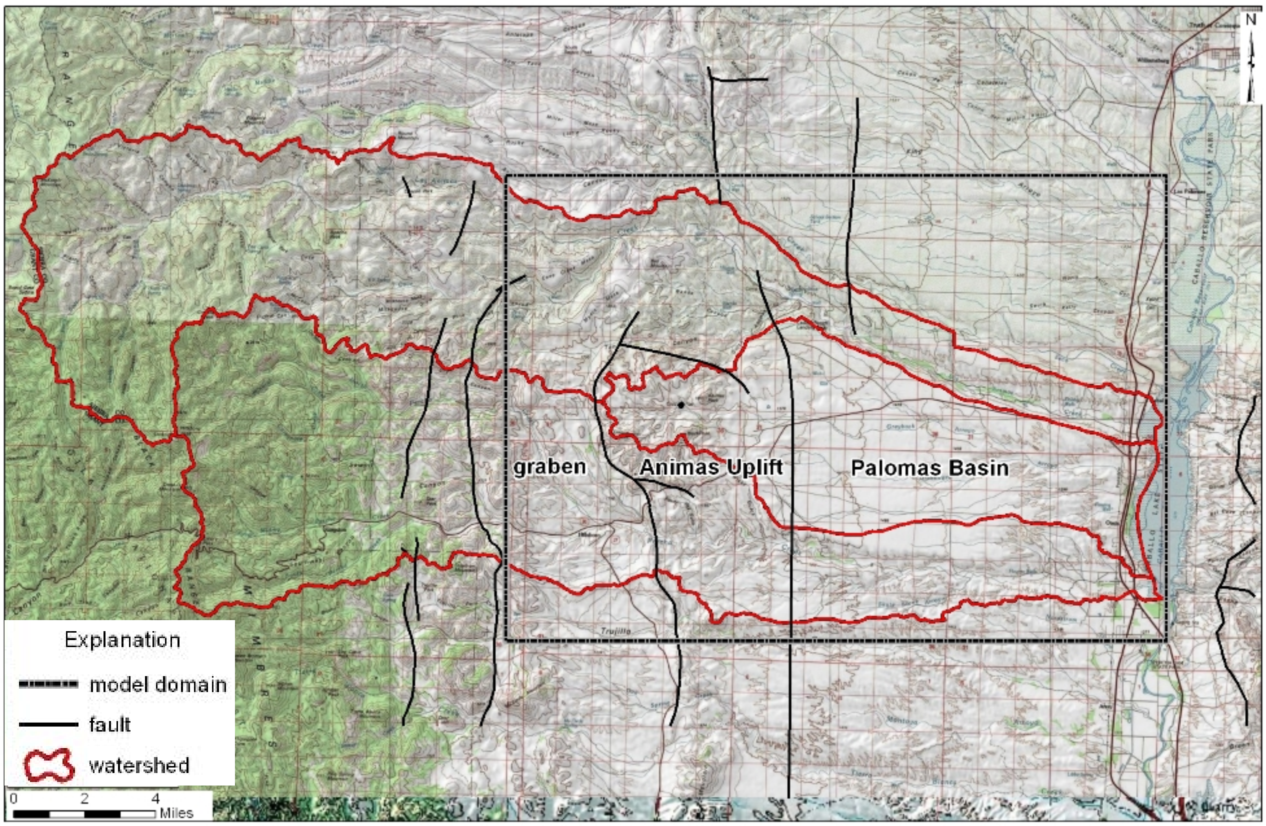


Figure 4.1. Hydrogeologic zones.

The study area consists of three major hydrogeologic zones (Fig. 4.1), shown in west-east cross-section on Figure 4.2. The three zones are 1) The Animas Uplift, in which the ore body is located, 2) the graben east of the Black Range and west of the Animas Uplift, and 3) the Palomas Basin, a sediment-filled basin east of the Animas Uplift in which the mine water supply wells are located.

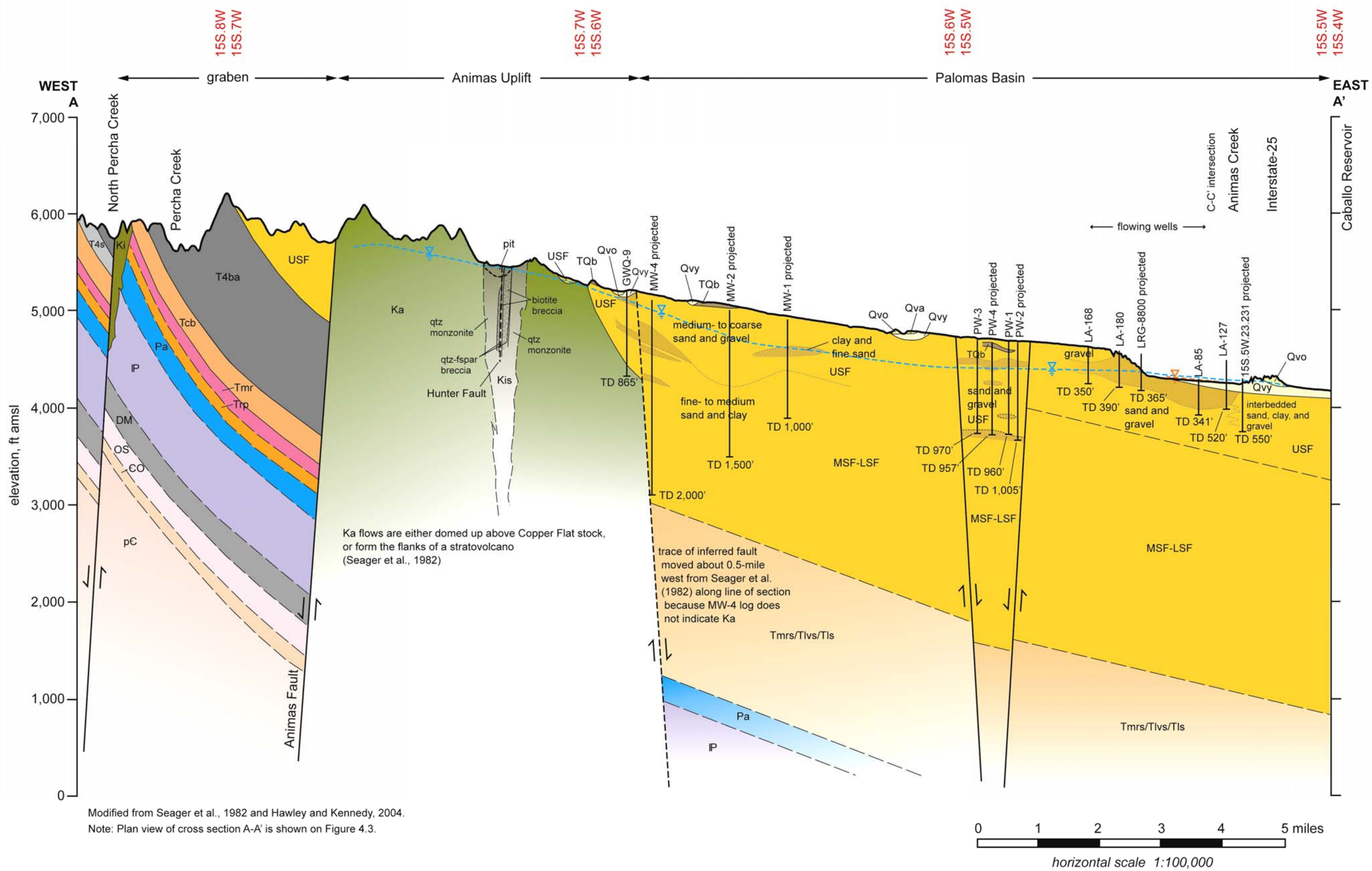


Figure 4.2. Hydrogeologic zones, west-to-east cross-section.

The Animas Uplift contains the Copper Flat open pit, excavated in 1982 by Quintana Minerals, which the New Mexico Copper Corporation (NMCC) proposes to expand. The Quintana pit was excavated to a maximum depth corresponding to elevation 5,400 ft amsl. The current water level in the pit is about 5,440 ft. The pre-mining groundwater level (without lake evaporation) was about 5,450 ft. The main part of the other Project facilities, including waste rock and tailings storage facilities, would be located on the Animas Uplift.

The graben between the Black Range and the Animas Uplift drains to the Warm Springs valley. Potential effects to groundwater levels and spring discharge within the graben will be evaluated.

The Palomas (geologic) Basin lies within the Lower Rio Grande Underground Water (administrative) Basin. The Project water-supply wells are located within the basin on a mesa adjacent to Animas Creek (Fig. 4.1), and will be the main source of groundwater drawdown and surface-flow depletion from the Project. Parts of the waste rock and tailings storage facilities would also be located overlying the western margin of the Palomas Basin.

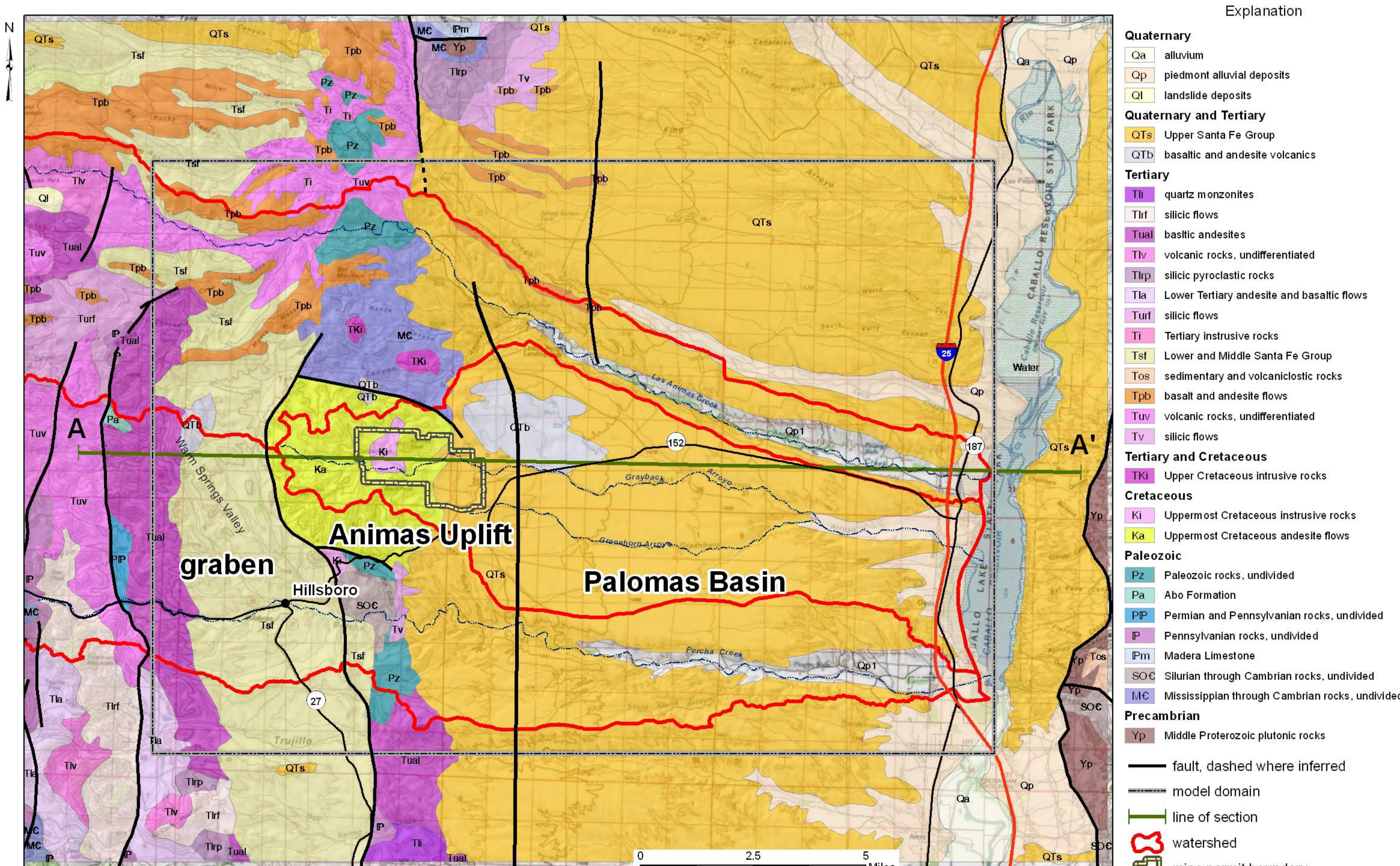
4.1 Geology

The geologic description is adapted from Shomaker (1993), who cites Harley (1934), Hedlund (1975), Dunn (1982), and Seager et al. (1982). The geologic map of the study area is presented on Figure 4.3. Three major geologic subdivisions (Figs. 4.1 and 4.2), the Animas Uplift, the graben east of the Black Range, and the Palomas Basin, are described below.

4.1.1 Animas Uplift

The Animas Uplift is an upthrown block, ranging from less than 2 to about 4 miles wide, bounded by north-south trending faults (Fig. 4.1). The Copper Flat ore body is located within a nearly circular remnant of a Cretaceous-age andesite volcano about 4 miles in diameter that is part of the Animas Uplift. Drilling has shown that the andesite is present to a depth of more than 3,000 ft (Dunn, 1982, p. 314).

The hills surrounding Copper Flat, referred to as the Hillsboro Hills, consist of Cretaceous-age andesite flows, breccias, and volcaniclastic rocks that were erupted from the volcano (McLemore, 2001; Raugust and McLemore, 2004). The andesite is bounded on the north and south by Paleozoic limestone, and on the east by the Santa Fe Group sediments of the Palomas Basin, in fault contact. On the west, the andesite body is in fault contact with Paleozoic-age limestone, Tertiary-age volcanic rocks, and overlying Santa Fe Group sediments of the half-graben between the Animas Uplift and the Black Range (Fig. 4.1).



Geologic Source: USGS OFR 97-0052 modified

Figure 4.3. Geologic map of study area.

The ore body itself is in the Copper Flat quartz monzonite stock, within the body of andesite. The quartz monzonite porphyry intruded the vent of the volcano, and then dikes and mineralized veins intruded the monzonite porphyry and radiated outward from the porphyry into faults and fracture zones in the andesite. The porphyry copper deposit is concentrated within a breccia pipe in the quartz monzonite stock.

4.1.2 Graben West of Animas Uplift

West of the Animas Uplift, between it and the Black Range, lies a half-graben in which Tertiary-age alluvial-fan deposits, sandstones and mudstones of the Santa Fe Group overlie Tertiary-age volcanic rocks and Paleozoic-age sedimentary rocks. Dips are eastward, and the half-graben is bounded on the east by normal faults. The Santa Fe beds may reach a thickness of 1,000 ft on the east side of the half-graben (Seager et al., 1982, sheet 2).

4.1.3 Palomas Basin

The Palomas Basin is a sediment-filled structural trough, part of the Rio Grande rift system. The principal water-bearing sediments of the Palomas Basin are (1) alluvial-fan deposits, and fluvial sands and gravels of the Santa Fe Group, and (2) alluvium in the inner valleys of the Rio Grande and principal tributaries.

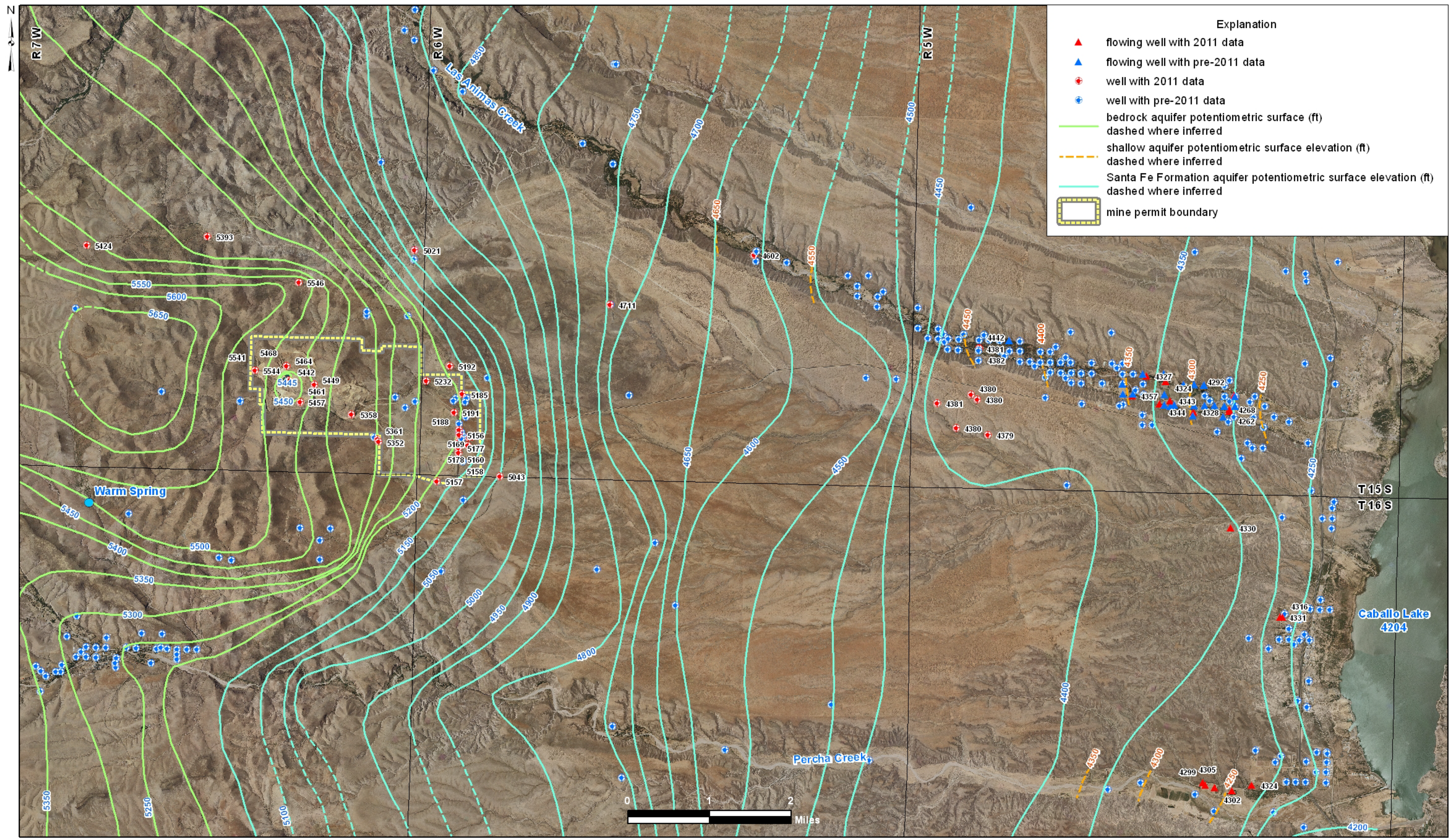
Davie and Spiegel (1967, p. 9) describe the Santa Fe Group in Las Animas Creek area as consisting of (a) an alluvial fan facies, interfingering eastward with (b) a clay facies, possibly representing the distal or deltaic beds of the alluvial fan facies, which in turn interfingers with (c) an axial river facies consisting of well-sorted sand and gravel containing well-rounded quartzite pebbles. The sediments are stratified and in general dip to the east.

This description of the distribution of fine-grained sand and clay and of coarser sand and gravel is reflected in the logs of wells and shown in cross-section on Figure 4.2. In general, the sediments become finer-grained to the east from the western margin to the axis of the basin.

4.2 Groundwater Flow Patterns

Groundwater flow patterns, recharge and discharge locations and aquifer characteristics are discussed below, for the three geologic subdivisions of the study area.

Locations of wells and water-level measurements are presented with approximate potentiometric surface contours on Figure 4.4. Interpreted contours are shown for three aquifers: (1) bedrock of the Animas Uplift and the pit area, (2) the Santa Fe Group aquifer, and (3) the shallow alluvium along Las Animas Creek. Groundwater levels range from above 5,800 ft amsl at the western edge of the graben to about 4,200 ft amsl at Caballo Lake.



Source: NAIP 2009 imagery, RGIS.

Figure 4.4. Potentiometric surface contours.

4.2.1 Animas Uplift

Groundwater recharge from local precipitation occurs over the uplift. Recharge to the quartz monzonite and andesite is limited by low hydraulic conductivity. Recharge to the limestone outcrop areas north and south of the andesite is likely greater, and includes infiltration of runoff from Las Animas and Percha Creeks that was generated at higher elevations in the Black Range and in the half-graben between the Black Range and Animas Uplift.

Groundwater discharges from the limestone at the foot of the uplift, as spring flow and base flow to Percha and Las Animas Creeks. Groundwater discharges from the andesite as subsurface flow across the fault contacts with the Palomas Basin, and as evaporation from the open pit.

The low hydraulic conductivity of the quartz monzonite and andesite is reflected in the low pumping rates required in 1982 to dewater the Quintana pit. The dewatering rate required to maintain the greater-than 45-ft drawdown, in an excavation about 100 ft by 200 ft in area at maximum depth, was estimated at 22 gallons per minute (gpm) (Shomaker, 1993). SRK (1997) reports pumping rates up to 50 gpm. The range in dewatering rates is likely influenced by precipitation and localized recharge.

It can be expected that the hydraulic conductivity of rock deeper in the andesite and quartz monzonite will have still lower hydraulic conductivity, because of the decrease in weathering effects and the closing of fractures with depth. The andesite acts as a hydrologic containment vessel for the existing and proposed open pits.

The radiating dikes and veins may be inferred to have relatively low conductivity as well. Several mine shafts in Wicks Gulch were examined, and found to be almost full of water; if there were significant hydraulic conductivity, either along fractures or through the rock matrix, water levels would be closer to the elevation of nearby surface channels.

Away from the andesite body, where the Animas Uplift consists of fractured, predominantly limestone and dolomite bedrock, it is likely that significant permeability has developed by the combination of fracturing and enlargement of fracture-openings by dissolution of carbonate minerals. This hypothesis is supported by the account of an air-drilled exploration hole in the vicinity of the windmill well in the SW/4 SE/4 Sec. 3, T. 16 S., R. 7 W., which was abandoned because large water production overcame the capacity of the compressor to continue circulation (Sonny Hale, personal communication). The well is close to the fault which offsets the andesite against the predominantly limestone Paleozoic-age section.

4.2.2 Graben West of Animas Uplift

Local precipitation and runoff from the Black Range provide groundwater recharge to the graben. Discharge occurs mainly as spring flow and possibly also as subsurface discharge to the Animas Uplift. Spring flow in the Warm Springs drainage discharges as base flow to Percha Creek. The emergence of water at Warm Springs at the eastern edge of the graben demonstrates that the andesite of the Animas Uplift acts as a barrier to flow at depth from the graben. Groundwater in the graben flows west to east across the Animas Uplift south toward Percha Creek and north toward Las Animas Creek (Fig. 4.4) flowing around the low-permeability andesite.

The contrast between the chemical makeup of Warm Springs water and that of wells and springs within the Animas Uplift indicates that the source of Warm Springs water is not within the uplift, as might otherwise be inferred from the relative heads at the spring and at wells and springs within the uplift. The chemistry of groundwater in the vicinity of the project is discussed more fully by Newcomer and Finch (1993).

4.2.3 Palomas Basin

Water recharges the Palomas Basin at its western edge, through alluvial fans at the edge of the Animas Uplift, including infiltration of runoff from Greenhorn and Grayback Arroyos and as infiltration of base flow and runoff from the upper catchments of Las Animas and Percha Creeks. Groundwater flows east toward the Rio Grande and Caballo Lake. Besides discharging to the Rio Grande and Caballo, groundwater discharges as evapotranspiration from irrigated and riparian-vegetation areas along Las Animas and Percha Creeks.

Stratification and heterogeneity of the Santa Fe Group creates confined conditions at depth in the lower Palomas Basin. Seepage along Percha Creek, Grayback Arroyo, Greenhorn Arroyo, and Animas Creek alluvial systems recharges the Santa Fe Group sediments in the upper basin and the recharge hydraulically loads the more permeable zones down-dip. Overlying clay beds create artesian-well conditions in the basin down-dip of recharge zones.

Artesian pressures are relatively low, generally less than 10 ft of head above land surface. A survey of artesian wells (Shomaker, unpublished) from 1993 has been updated, indicating reduction of artesian flow and pressure over 18 years. The history and effects of artesian discharge are discussed further below.

4.3 Hydrogeologic Conceptual Model

The hydrogeologic system described above is summarized on Figure 4.5, a map of hydrogeologic units, and on Figure 4.6, a map of the boundary conditions (inflows and outflows of water) on the system. The hydrogeologic units and boundary conditions presented form the basis of the numerical groundwater-flow model.

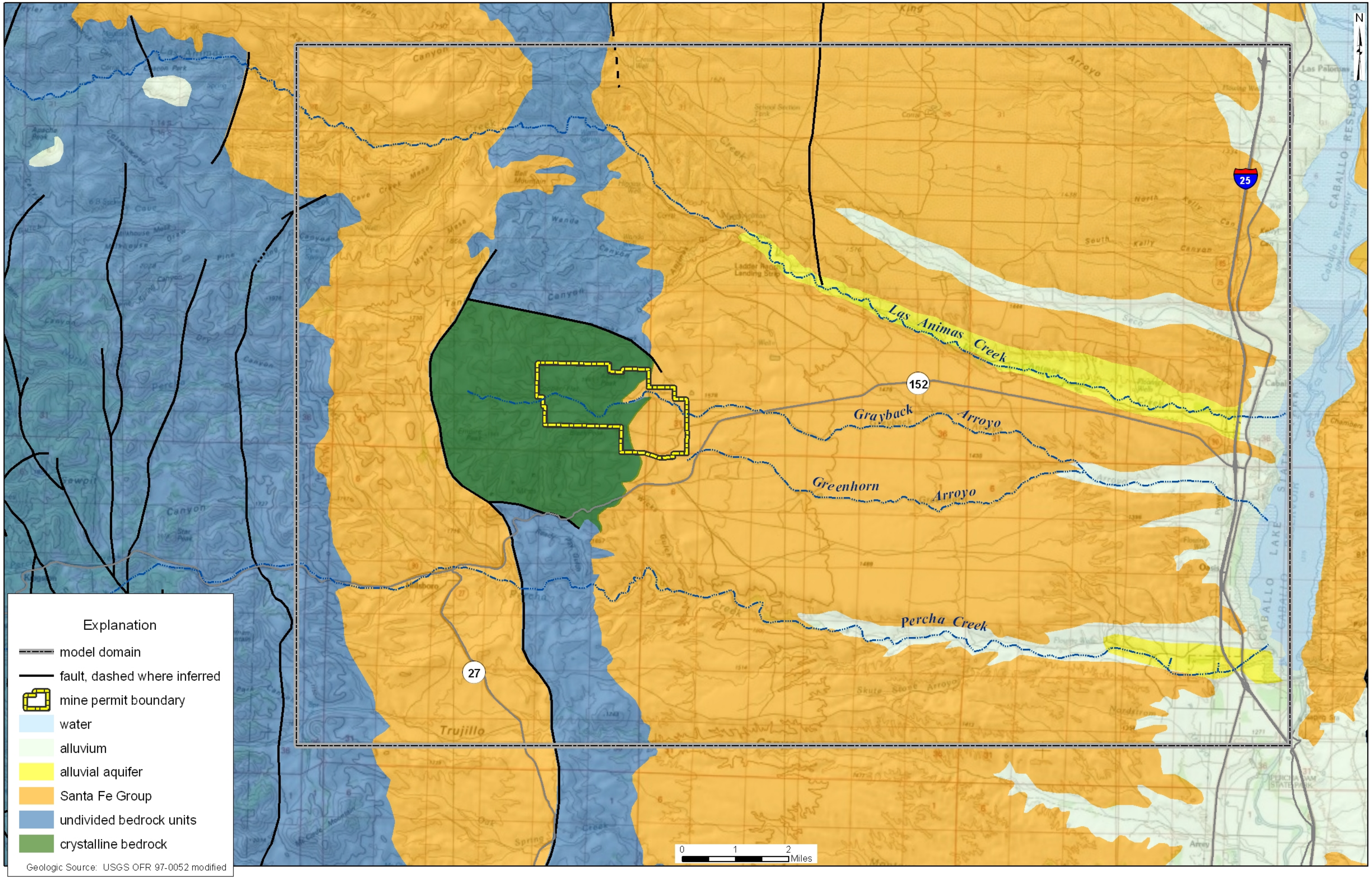


Figure 4.5. Hydrogeologic map of study area.

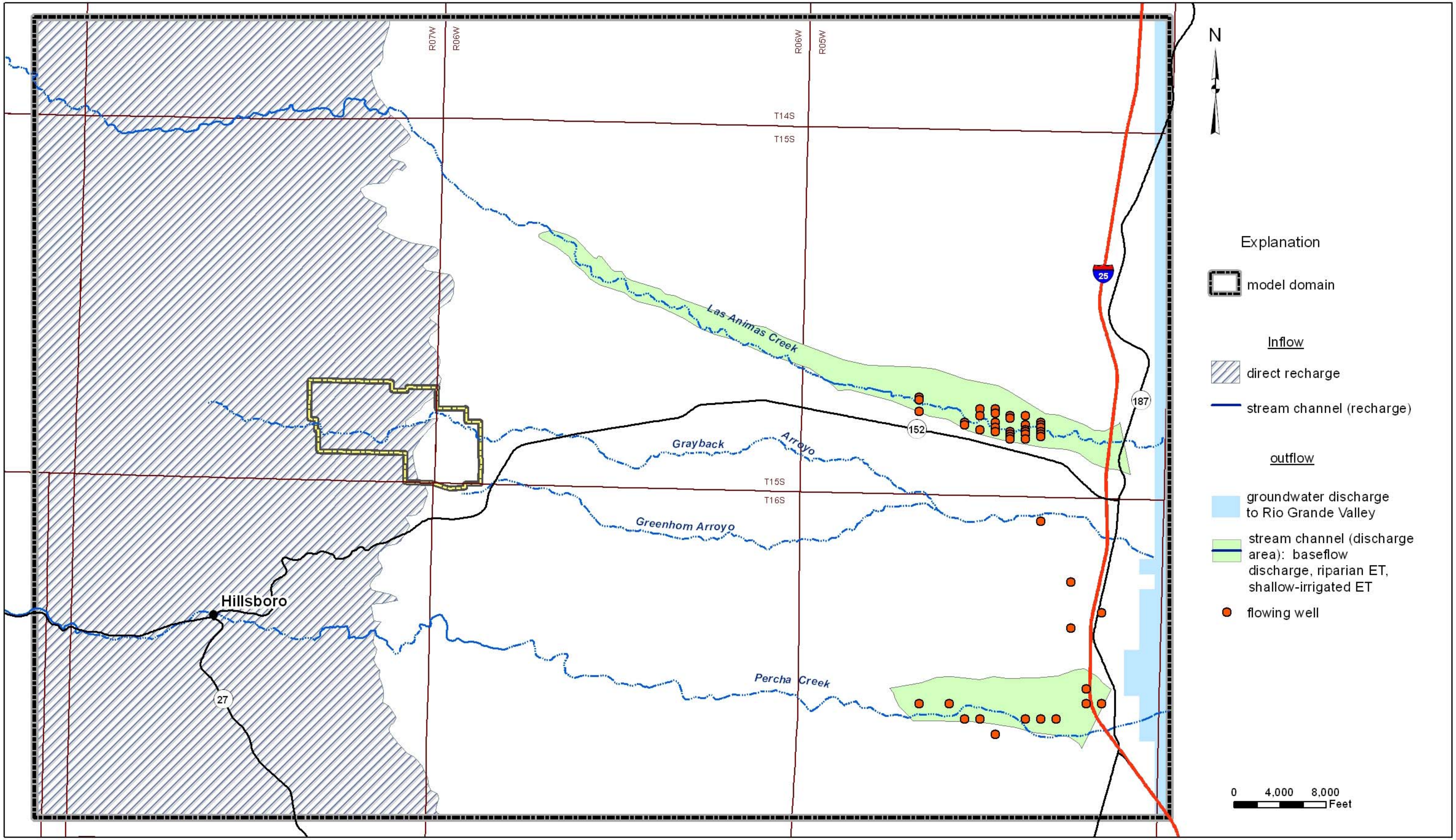


Figure 4.6. Hydrogeologic boundary conditions.

5.0 CALIBRATION DATA

This section describes the data on aquifer stresses and responses available to guide the development and calibration of a numerical groundwater-flow model. These include information on (1) the area of the water-supply wells (well field), (2) the former tailings facility, (3) the open pit, and (4) the artesian zones in the lower Animas and lower Percha basins. The locations of the wells discussed below are shown on Figure 5.1.

5.1 Well Field Area

The NMCC water supply wells (PW-1, PW-2, PW-3, and PW-4) were constructed and tested in 1975-76 (Green and Halpenny, 1976). Local transmissivity of the Santa Fe Group aquifer is estimated below from the PW-1 and PW-2 test data. Effects of the period of well field operation, from March through June, 1982, are then discussed. Finally, results of a 1994 pumping test of MW-9, evaluating vertical transmission of effects, is presented.

5.1.1 PW-2 Test, January 1976

PW-2 was pumped at 2,020 gpm for 72 hours in January 1976. Measured drawdown and recovery at observation wells PW-1 and MW-5 are shown on Figures 5.2 and 5.3. Aquifer transmissivity is estimated at about 20,000 ft^2/day by matching the solution of Theis (1938) to measured drawdown and recovery at PW-1 and MW-5, and to measured recovery at the pumping well PW-2, shown on Figure 5.4.

5.1.2 PW-1 Test, December 1975

PW-1 was pumped at 1,500 gpm for 70 hours in December 1975. Measured drawdown and recovery at observation well MW-5 are shown on Figure 5.5. Aquifer transmissivity of about 17,000 ft^2/day is estimated by matching the solution of Theis (1938) to measured drawdown and recovery at MW-5, and to measured recovery at the pumping well PW-1, shown on Figure 5.6.

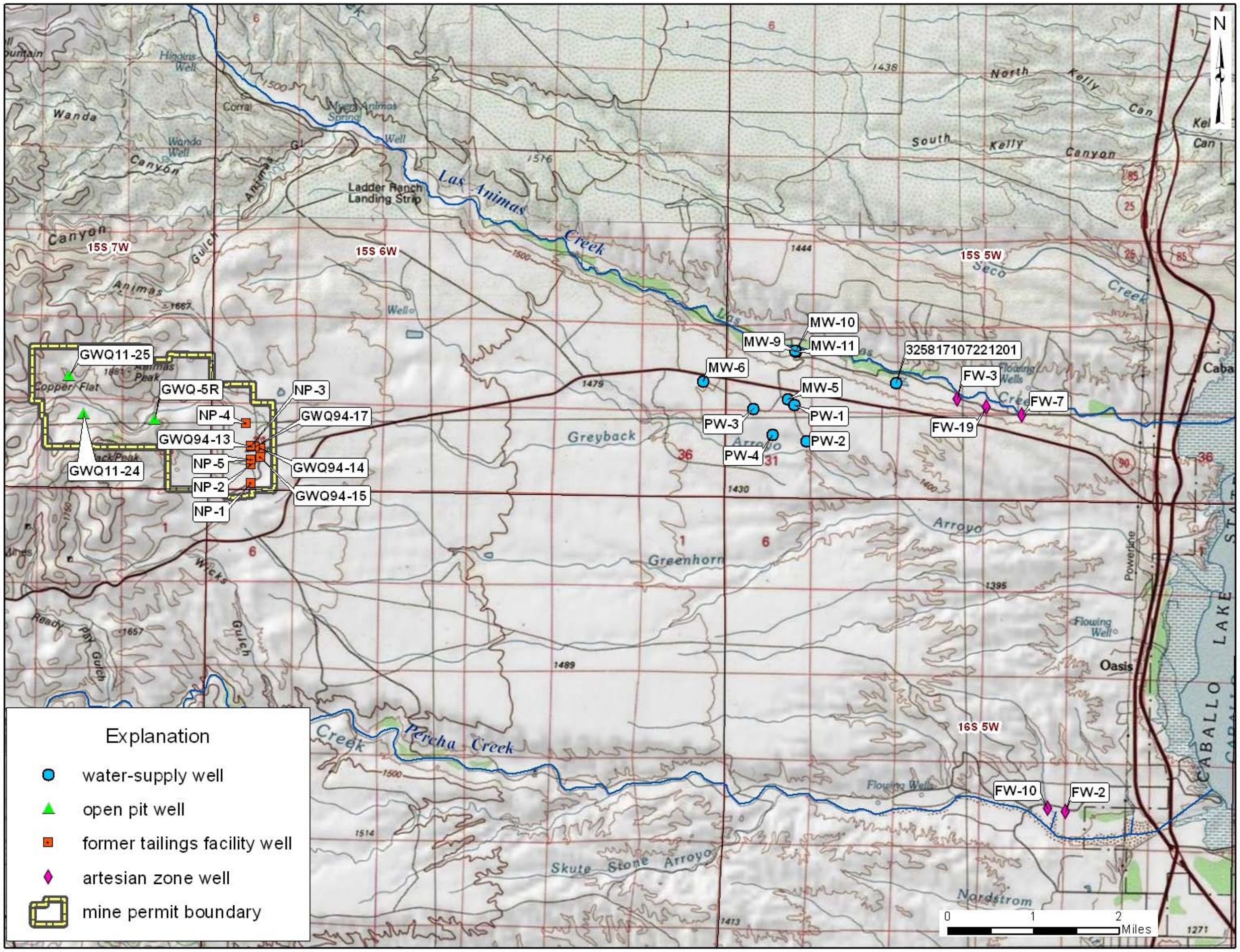


Figure 5.1. Well locations.

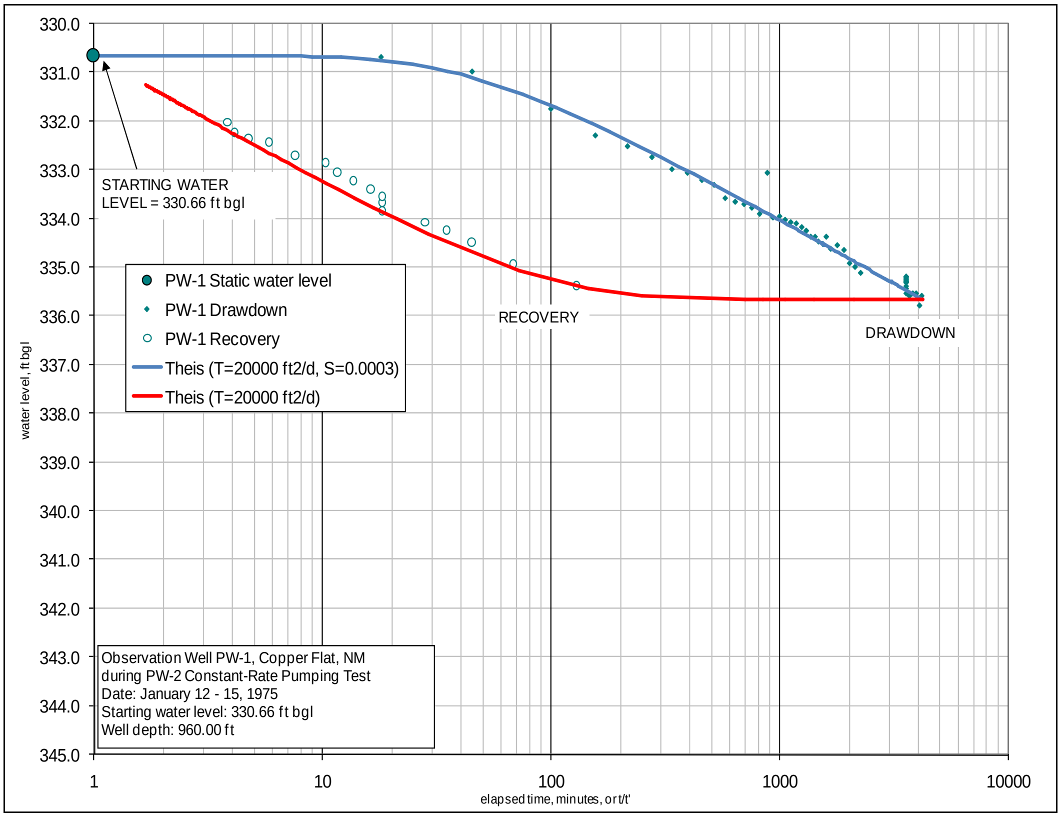


Figure 5.2. Drawdown and recovery in PW-1 during PW-2 pumping test.

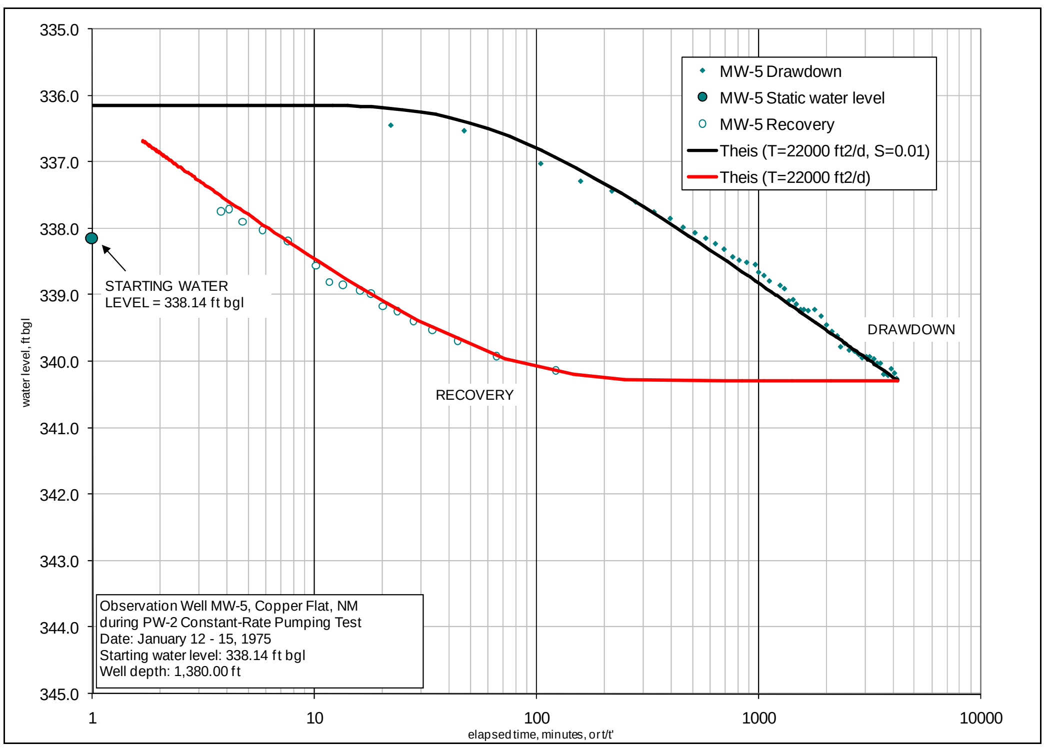


Figure 5.3. Drawdown and recovery in MW-5 during PW-2 pumping test.

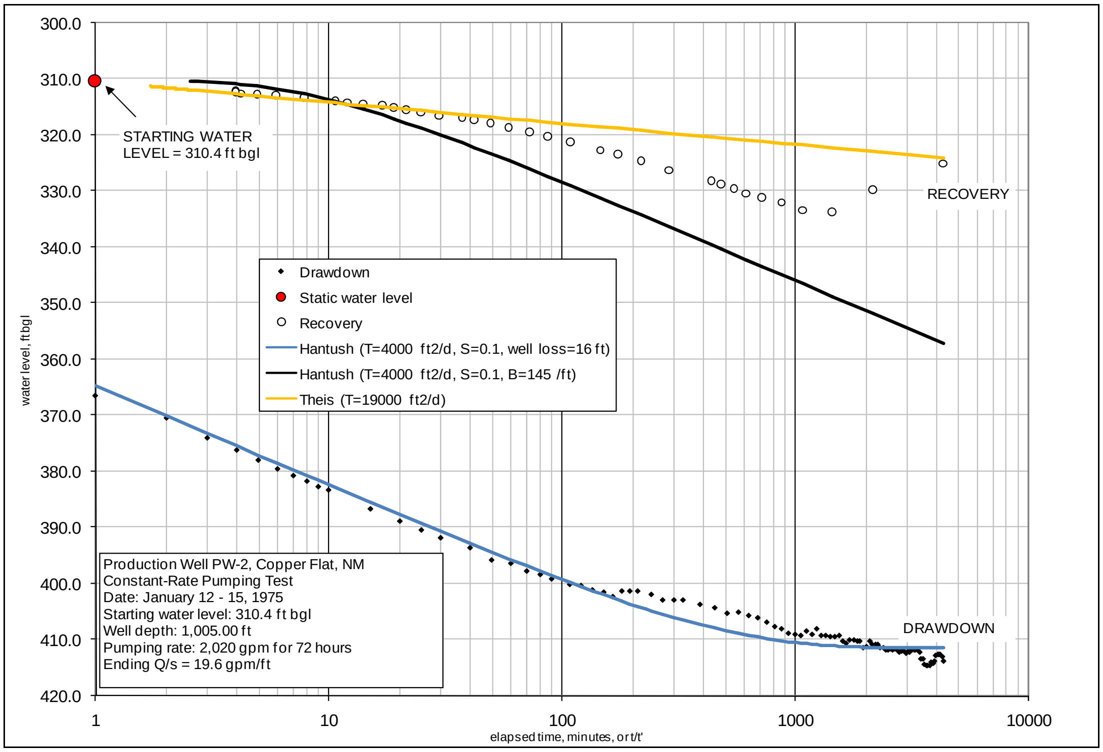


Figure 5.4. Drawdown and recovery in PW-2 during PW-2 pumping test.

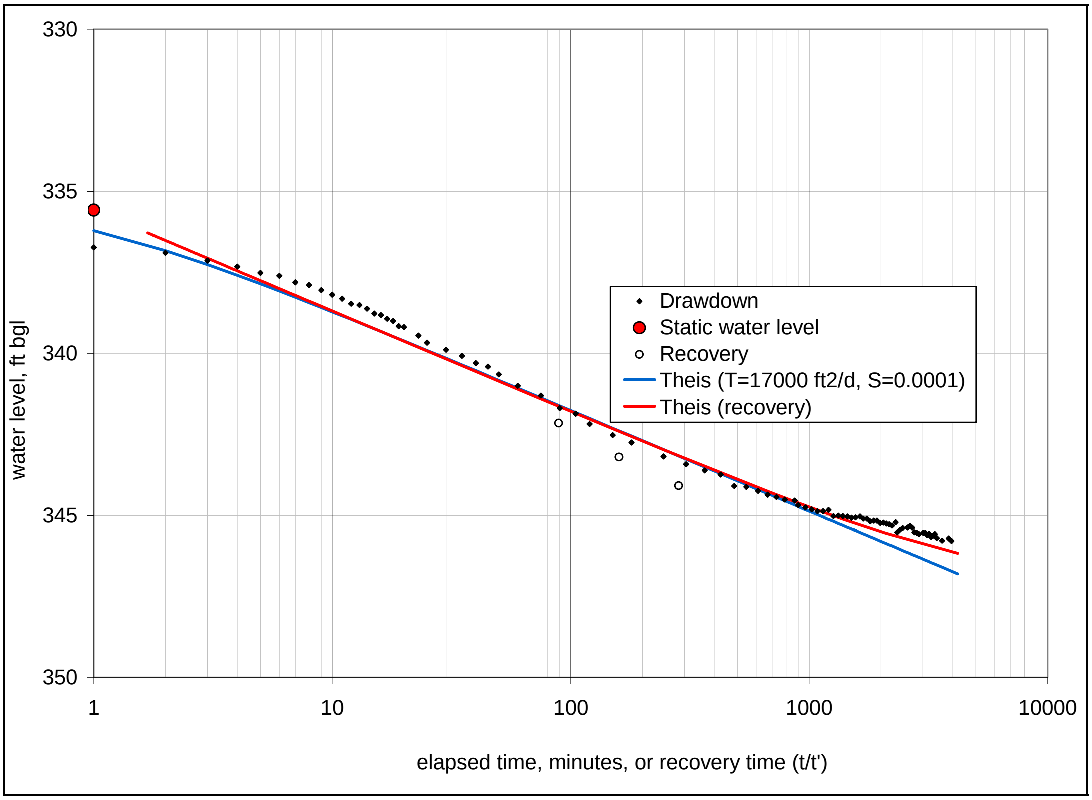


Figure 5.5. Drawdown and recovery in MW-5 during PW-1 pumping test.

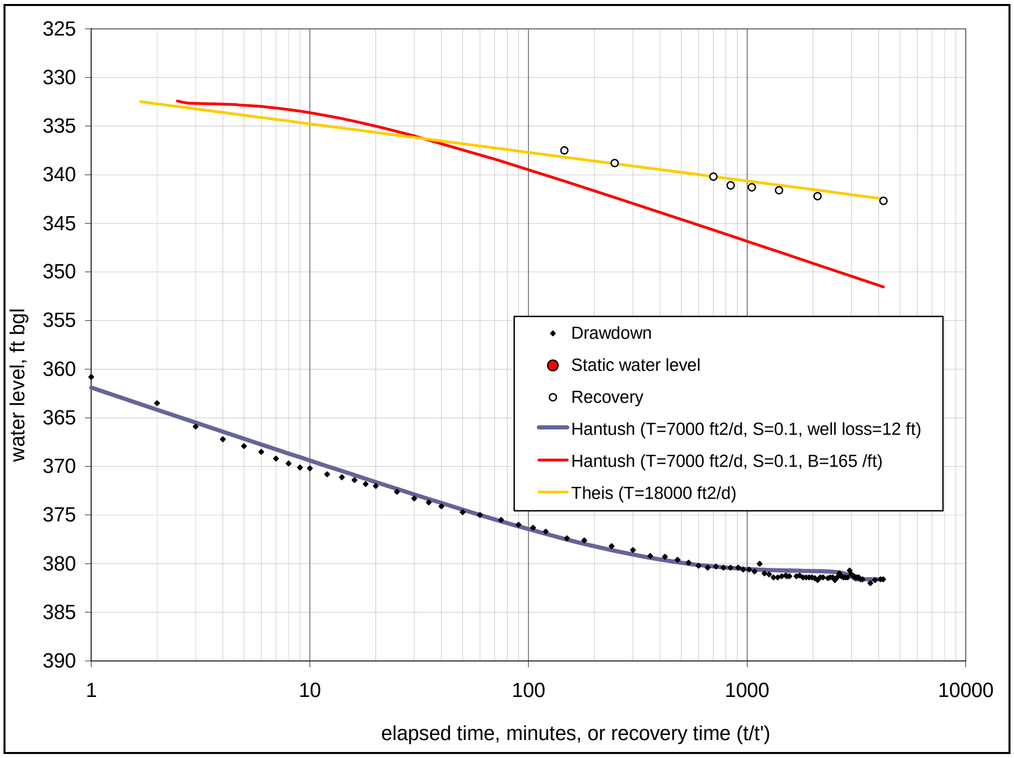


Figure 5.6. Drawdown and recovery in PW-1 during PW-1 pumping test.

5.1.3 Period of Mine Operation, 1982

The well field was operated for four months from March through June, 1982, at an average pumping rate of 2,272 gpm. Some pumping, averaging 40 gpm, continued for sixteen months further. Average pumping rates (Frost, 2010) are presented in Table 5.1. Total pumped for 1980-83 was 1,317 ac-ft.

Water levels measured in MW-5, in the immediate area of the production wells, are shown along with well field pumping on Figure 5.7, showing about 20 feet of water level drawdown due to pumping.

Table 5.1. Recorded average well field pumping in gallons per minute

1980	1	Jul-82	70	Mar-83	29
1981	1	Aug-82	43	Apr-83	31
Jan-82	29	Sep-82	60	May-83	68
Feb-82	29	Oct-82	34	Jun-83	26
Mar-82	1,817	Nov-82	40	Jul-83	43
Apr-82	3,042	Dec-82	43	Aug-83	25
May-82	1,501	Jan-83	43	Sep-83	16
Jun-82	2,727	Feb-83	48	Oct-83	29

West of the well field, no response to pumping can be seen in water levels at MW-6, shown on Figure 5.8.

Water levels in USGS Well No. 325817107221201, east of the well field along Animas Creek, are shown on Figure 5.9. There is no clear response to pumping; the slight (0.15 ft) drop in water level is well within the background fluctuation.

5.1.4 MW-9 Test, January 1994

Well MW-9, along Animas Creek, is completed at a depth of about 250 ft. MW-10 and MW-11 are each about 50 horizontal feet from MW-9. MW-10 is completed at a depth of 125 ft and MW-11 at 37 ft. Responses at MW-10 and MW-11 to pumping at MW-9 therefore characterize the resistance to vertical flow through the Santa Fe Group and alluvial aquifers. MW-9 was pumped at 90 gpm for 24 hours. Drawdown and recovery at MW-9 are presented on Figure 5.10 along with a matching Hantush leaky type curve estimating transmissivity of 900 ft^2/day.

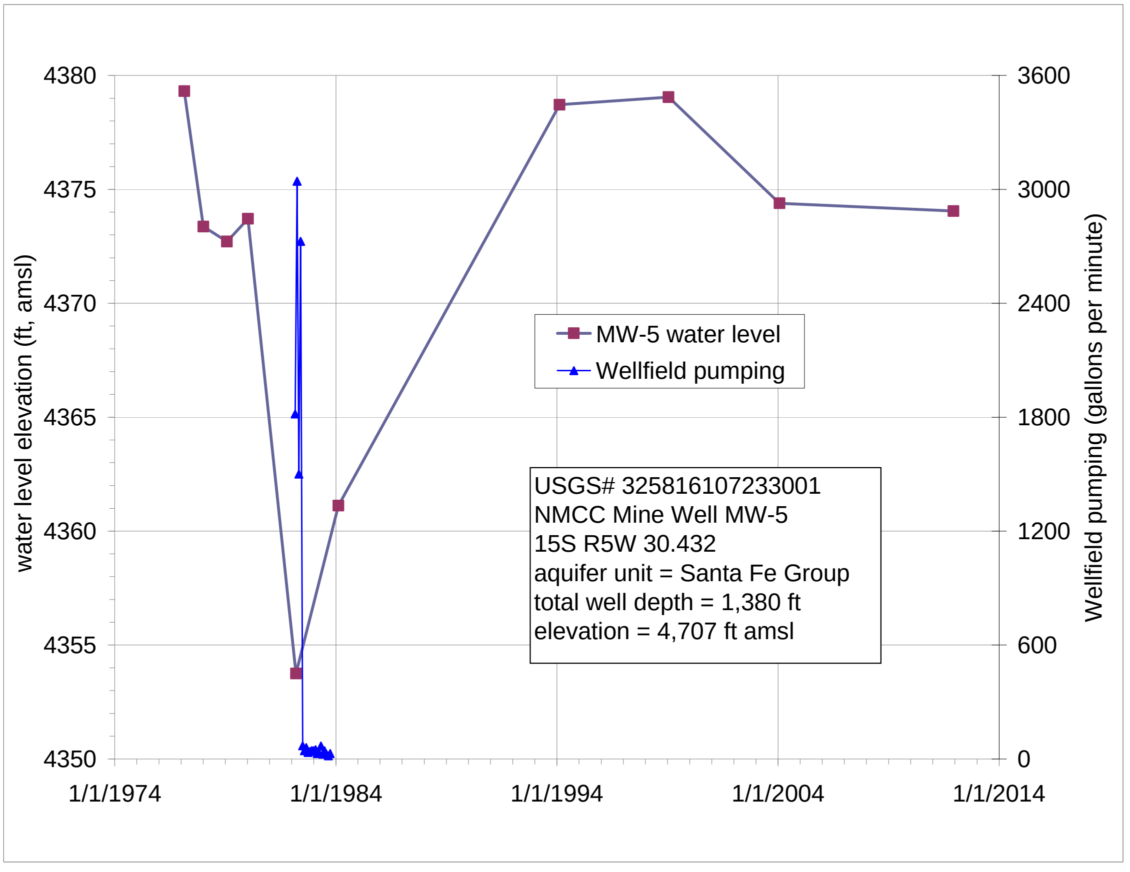


Figure 5.7. Well field pumping history and water level in MW-5.

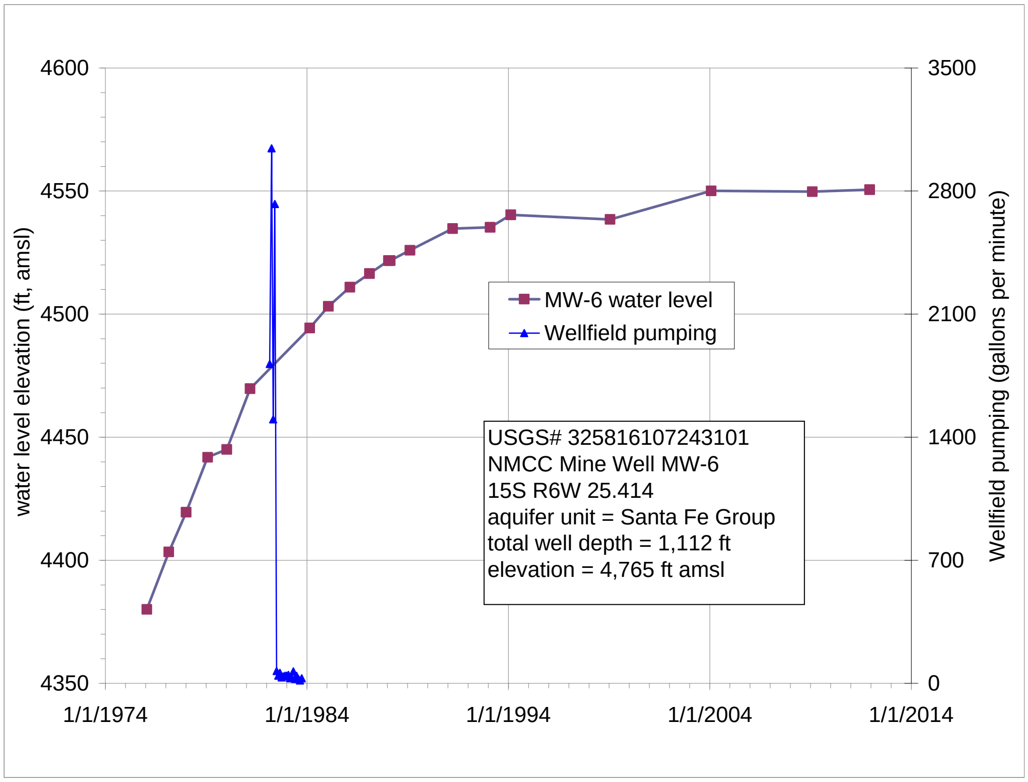


Figure 5.8. Well field pumping history and water level in MW-6.

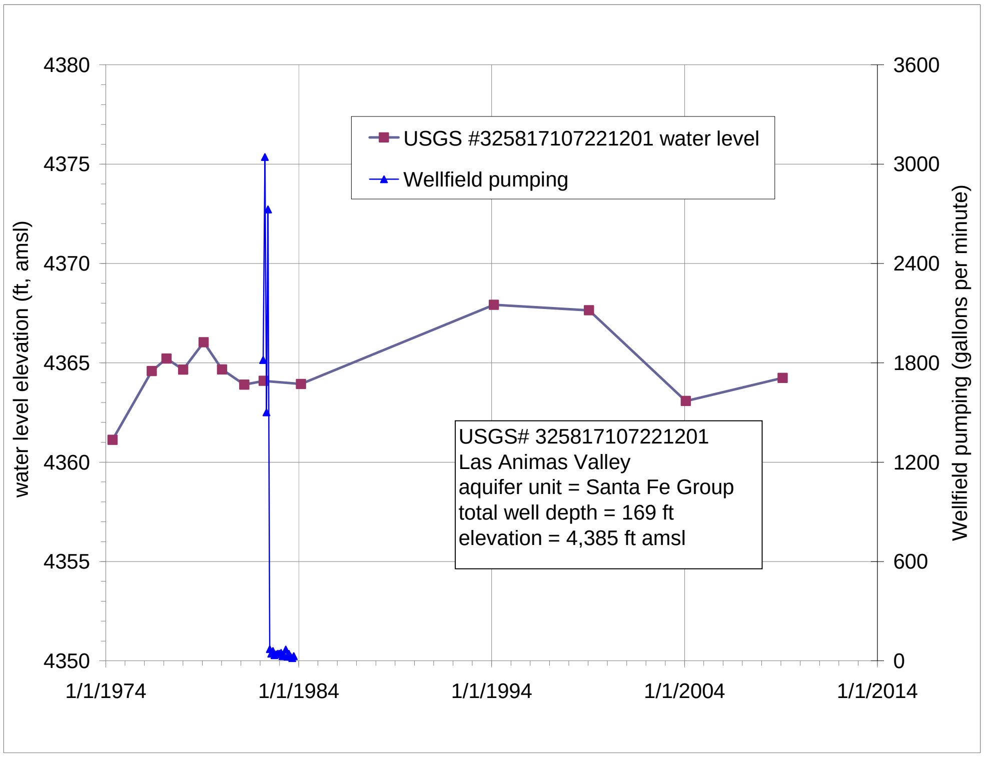


Figure 5.9. Well field pumping history and water level in USGS No. 325817107221201.

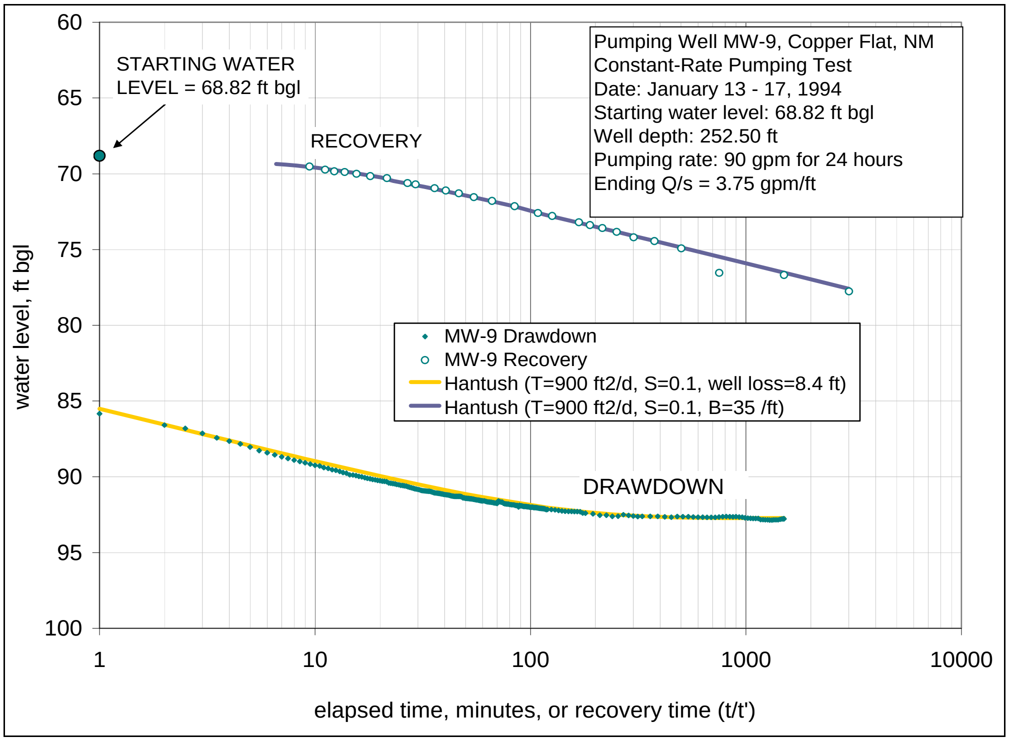


Figure 5.10. Drawdown and recovery in MW-9.

Drawdown and recovery in the overlying MW-10 are shown on Figure 5.11, showing a small response (<1 ft) to pumping, indicating limited vertical transmission of effects. No response to pumping was detected in the shallow alluvium well MW-11, as shown on Figure 5.12.

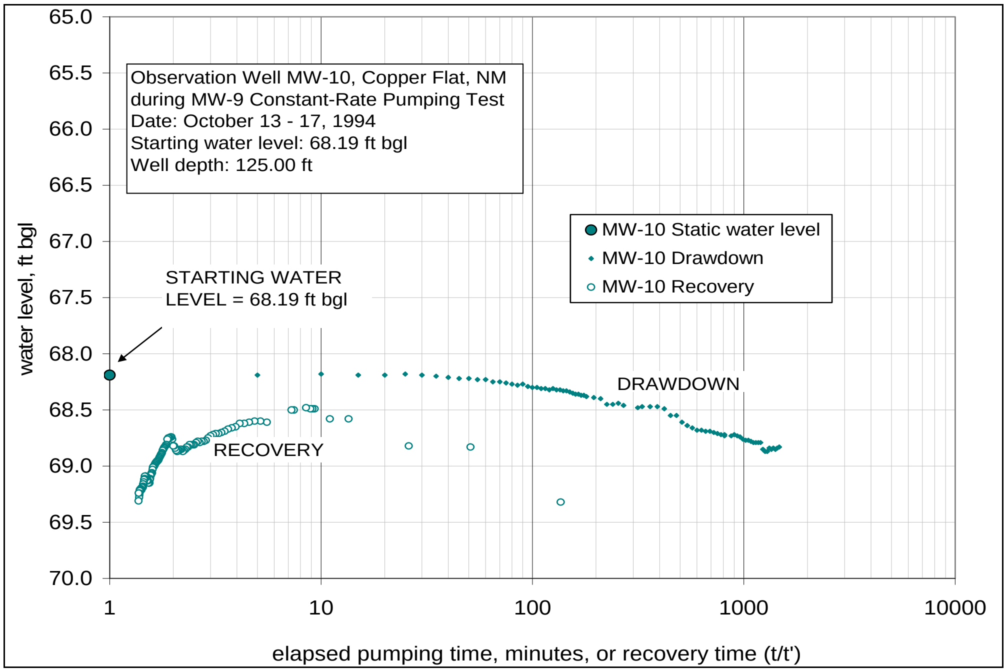


Figure 5.11. Drawdown and recovery in MW-10 during and after pumping of MW-9.

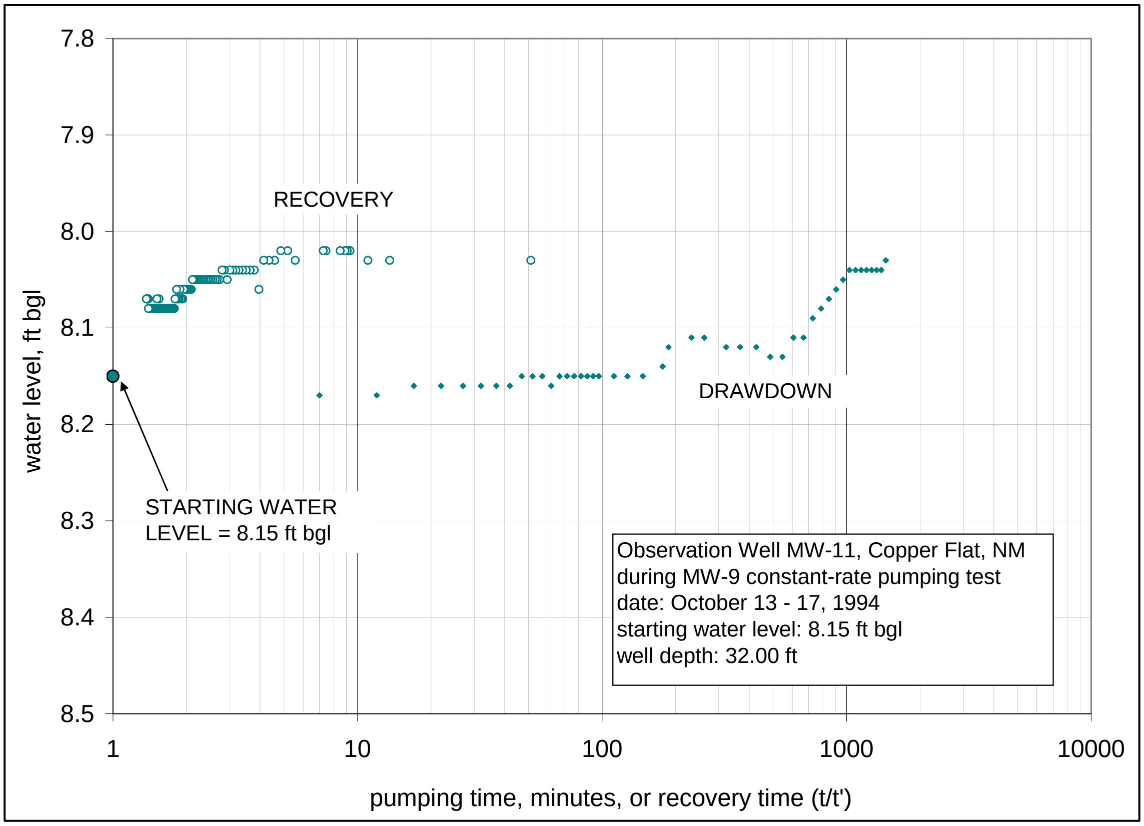


Figure 5.12. Drawdown and recovery in MW-11 during and after pumping of MW-9.

5.2 Tailings Impoundment Area

During the period of mine operations, the groundwater system beneath the unlined tailings facility was recharged by seepage from the tailings, in the portion of the impoundment overlying alluvium. Measured tailings-area water levels, shown on Figure 5.13, indicate 60-70 ft of water level rise that has persisted to the present, indicating a fault or other barrier to flow holding the water in place.

Transmissivity in the range of 100 to 240 ft^2/day is estimated for this area at the edge of the Santa Fe Group aquifer, based on the results of a 1994 aquifer test at well GWQ94-17, presented below.

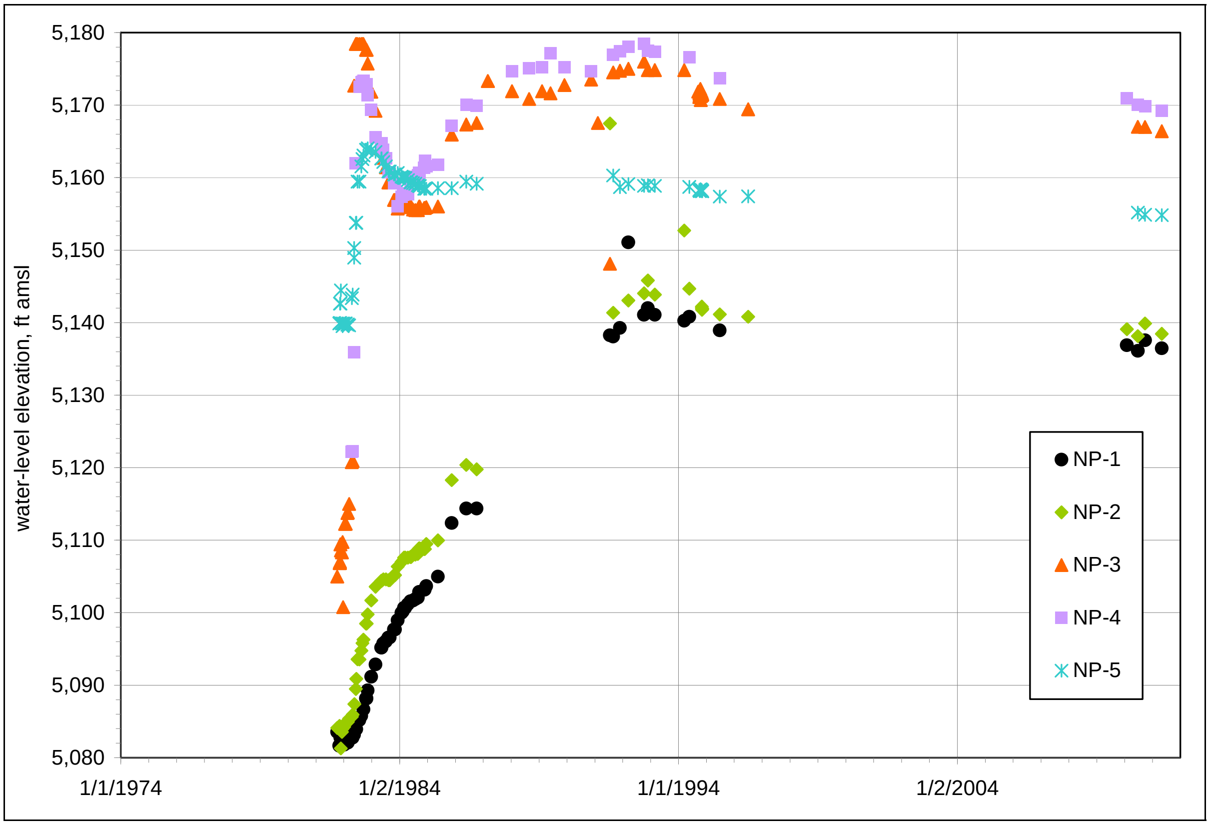


Figure 5.13. Tailings-area water levels.

5.2.1 GWQ94-17 test, November 1994

Well GWQ94-17 was pumped at 23 gpm for 4,688 minutes (3.26 days), with responses measured in GWQ-13, GWQ-14 and GWQ-15 (Fig. 5.1). Drawdown and recovery in GWQ-13 and GWQ-14 are presented on Figures 5.14 and 5.15 respectively, along with analytical (Theis, 1938) solutions. Drawdown in GWQ-14 is presented on Figure 5.16 (recovery data were unavailable). Recovery in the pumping well GWQ-17 is presented on Figure 5.17 (pumping water level was constant at about 123 feet).

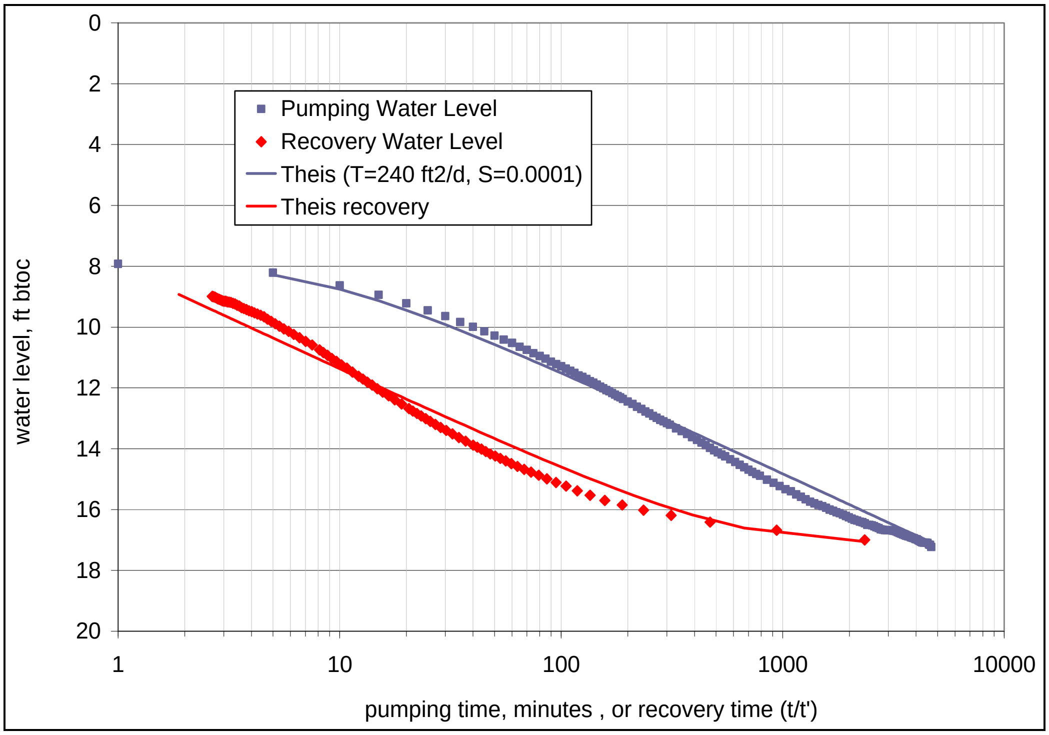


Figure 5.14. Drawdown and recovery in GWQ-13 during GWQ-17 pumping test.

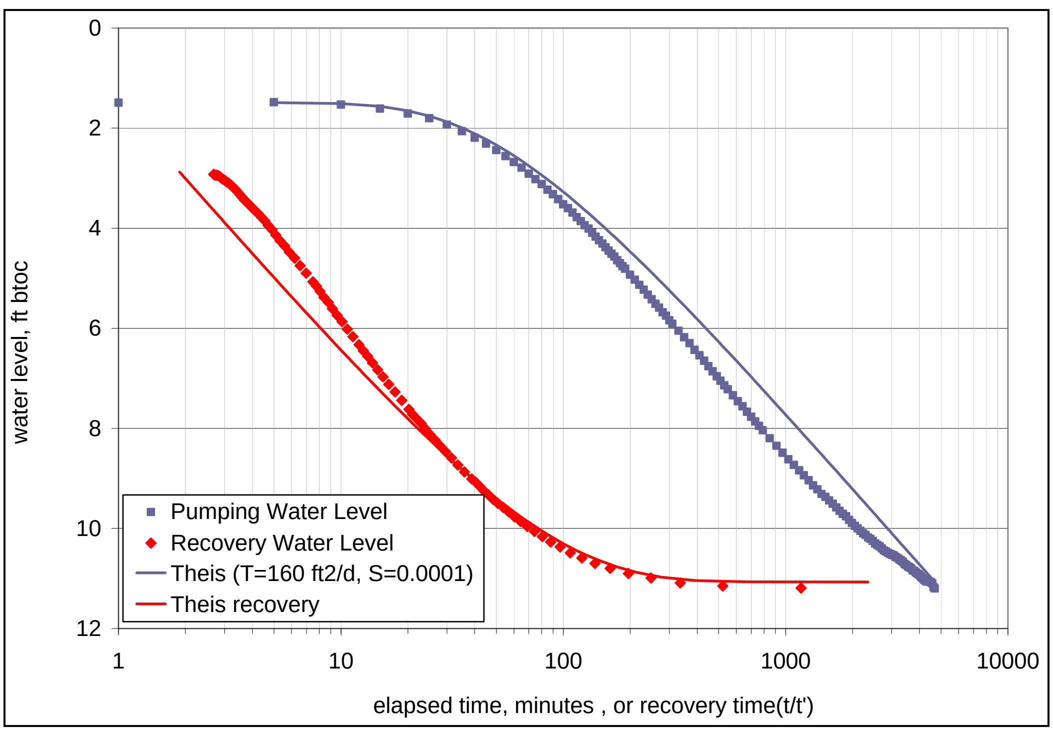


Figure 5.15. Drawdown and recovery in GWQ-14 during GWQ-17 pumping test.

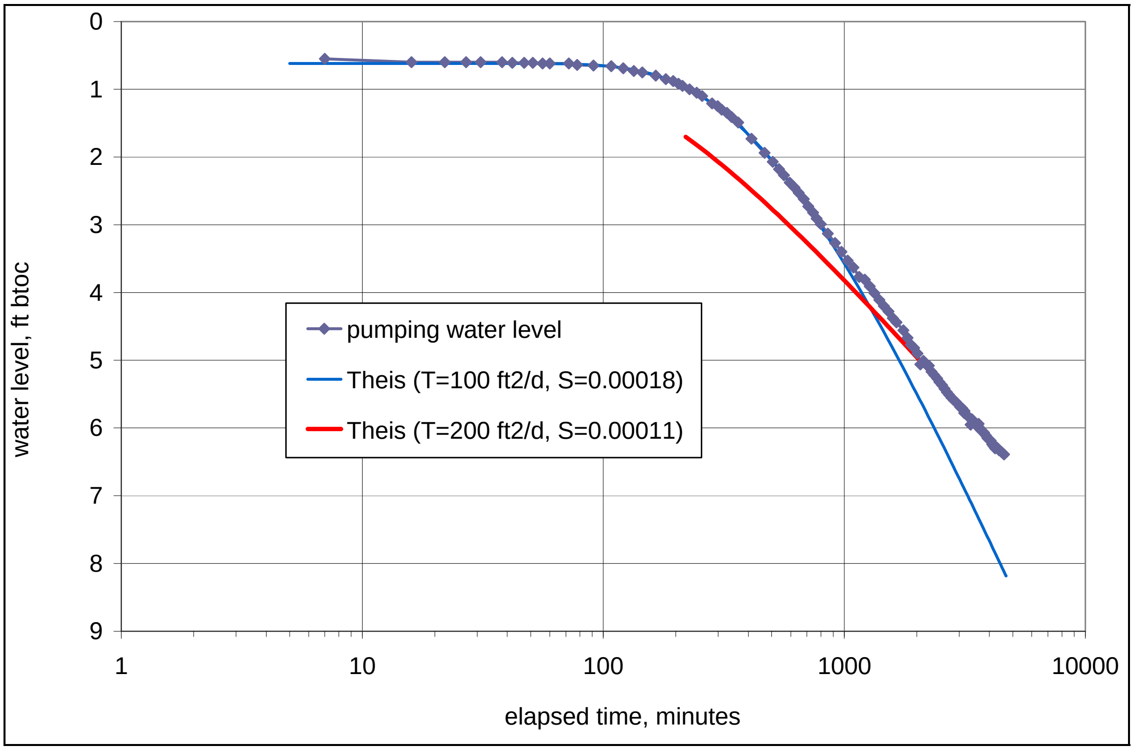


Figure 5.16. Drawdown in GWQ-15 during GWQ-17 pumping test.

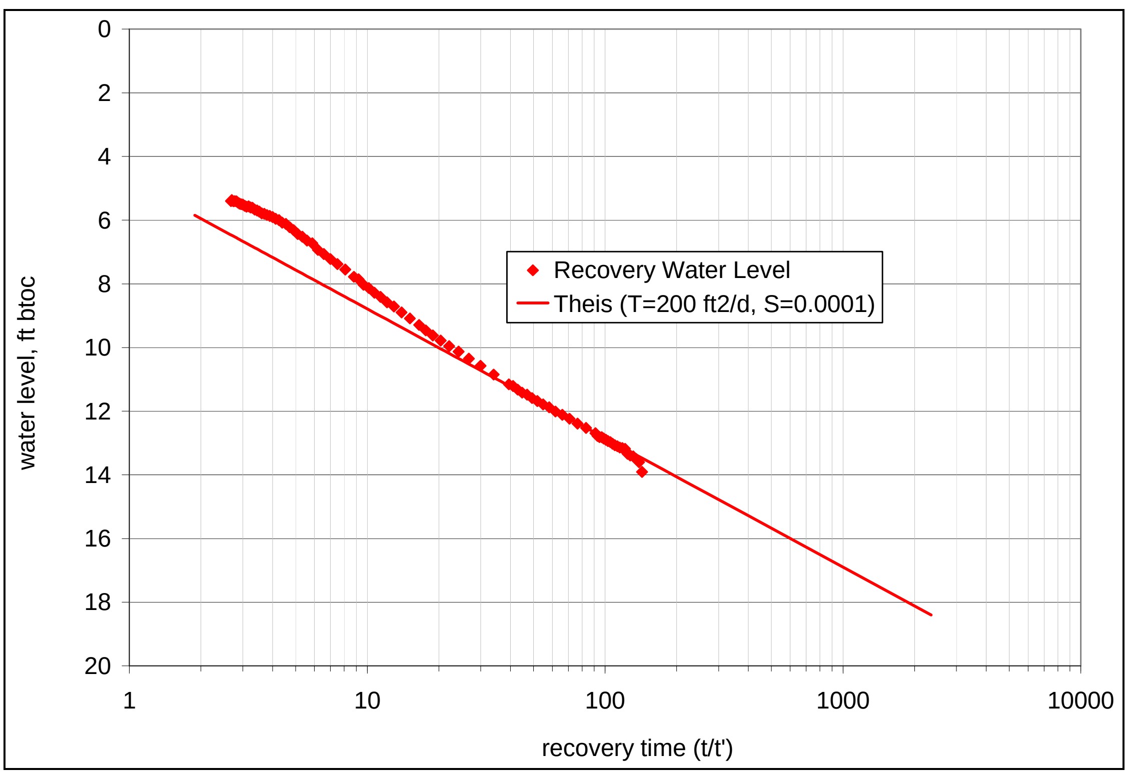


Figure 5.17. Recovery in GWQ-17 after pumping test.

5.3 Open Pit Area

The historical water level in the open pit has ranged between 5,436 and 5,450 ft amsl, corresponding to a water surface area between 5 and 14 acres. Based on an evaporation rate of 62.4 inches/year (Table 2.1), annual average open-pit evaporation rate ranges from about 16 gpm to 45 gpm.

This discharge is supported by a combination of groundwater inflow, and precipitation and runoff. Based on precipitation records it is estimated that the annual pit water balance (16 to 45 gpm) is provided by 6 to 10 gpm of groundwater inflow and the rest (6 to 40 gpm) by precipitation and runoff.

Current pit water levels are below 5,440 ft amsl, with water balance in the low range of the estimate. The pit is a hydrologic sink, as shown by the form of the local piezometric surface, Figure 5.18.

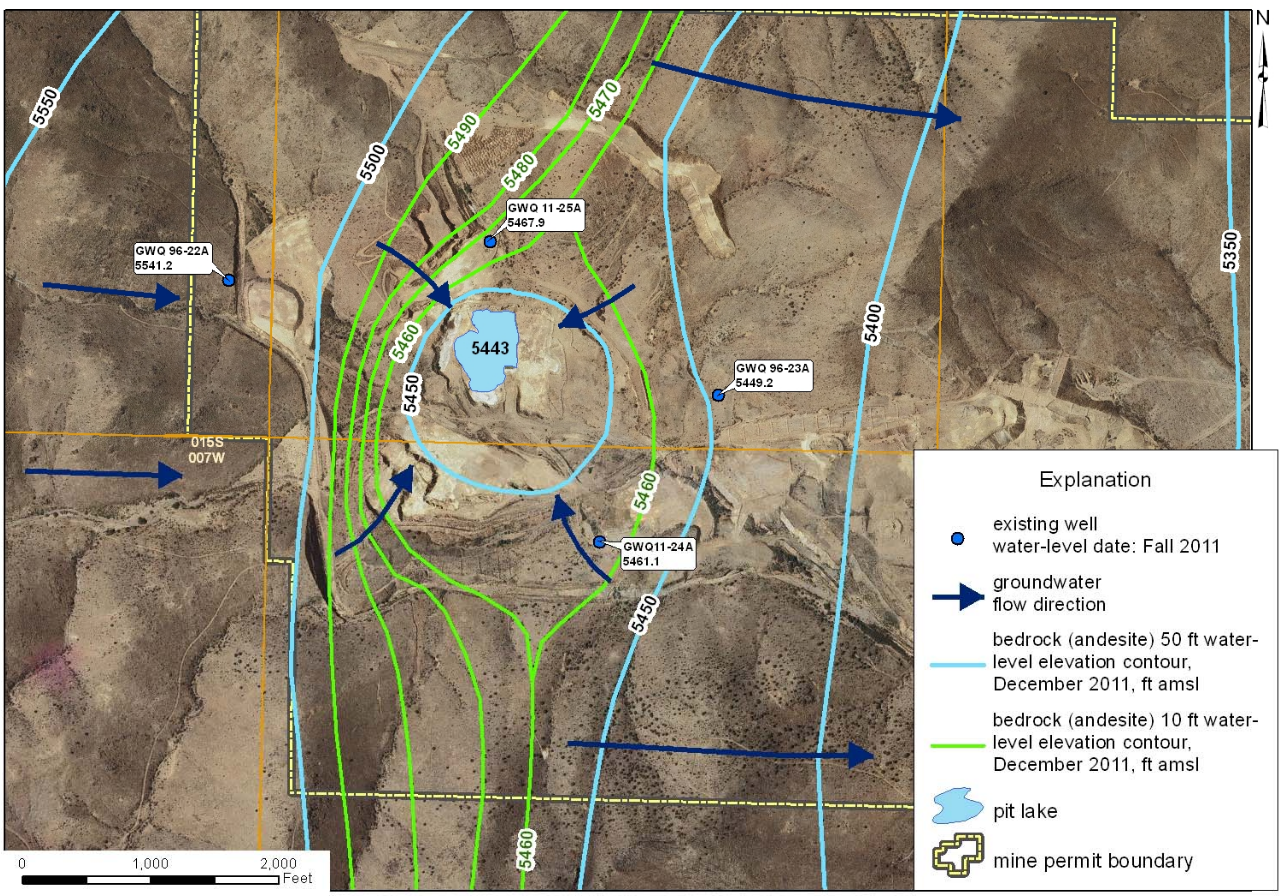


Figure 5.18. Measured pit-area groundwater levels.

5.3.1 Pit Area Pressure-Injection Tests, September 2011

Pressure-injection testing in the bedrock around the pit, in wells GWQ 5-R, GWQ 11-24 and GWQ 11-25, is summarized in Table 5.2. Apparent permeability of the bedrock ranges from near zero, to about 0.1 ft/day in the most fractured zones.

Table 5.2. Summary of pressure-injection test results

borehole and zone	depth interval, ft	apparent permeability	
		cm/sec	ft/day
GWQ 5-R, Zone 1	64-100	~0	~0
GWQ 11-24, Zone 1	100-147	7×10^{-6}	0.02
GWQ 11-24, Zone 2	150-197	3.0×10^{-5}	0.085
GWQ 11-24, Zone 3	204-251	4.9×10^{-5}	0.14
GWQ 11-25, Zone 1	100-148	~0	~0
GWQ 11-25, Zone 2	150-198	2.9×10^{-5}	0.081
GWQ 11-25, Zone 3	207-251	2.6×10^{-5}	0.074

5.4 Flowing Wells

The first artesian wells in the study area were drilled in the late 1930s. Most of the artesian wells were drilled prior to the New Mexico Office of the State Engineer (NMOSE) declaration of the Las Animas Creek and Lower Rio Grande Underground Water Basins.

Flow from selected artesian wells has been measured by Murray (1959), Davie and Speigel (1967), JSAI (1995), and JSAI (2011). A summary of aggregate measured artesian flow rates is presented as Table 5.3.

Table 5.3. Summary of measured artesian flow rates

source	number of wells	year	total artesian flow (gpm)	comments
Murray (1959)	23	1946	460	Included Percha, Las Animas Creek, and Oasis areas
Davie and Spiegel (1967)	29	1966	1,186	Las Animas creek area only.
JSAI (1995)	12	1995	1,319	Survey limited to accessible wells with owner permission
JSAI (2011)	21	2011	222	Survey limited to accessible wells with owner permission

gpm - gallons per minute

Construction details for the artesian wells are limited, but it appears a number of artesian wells were drilled without proper annular seals to prevent flow of water from the artesian zone into the overlying alluvium and stream channels. Furthermore, many of the artesian wells were never valved, and therefore left open to flow continuously at the land surface. Since the area was declared by the State Engineer, valves to regulate artesian flow, and metering, have been conditions attached to many of the permits.

Over the last 50 years significant changes in flow rates have been observed in the few artesian wells that have time-series data. Measured artesian flow rates over time are presented in Figure 5.19. It is apparent that artesian flow rates from individual wells have declined significantly in both Percha and Las Animas Creek valleys.

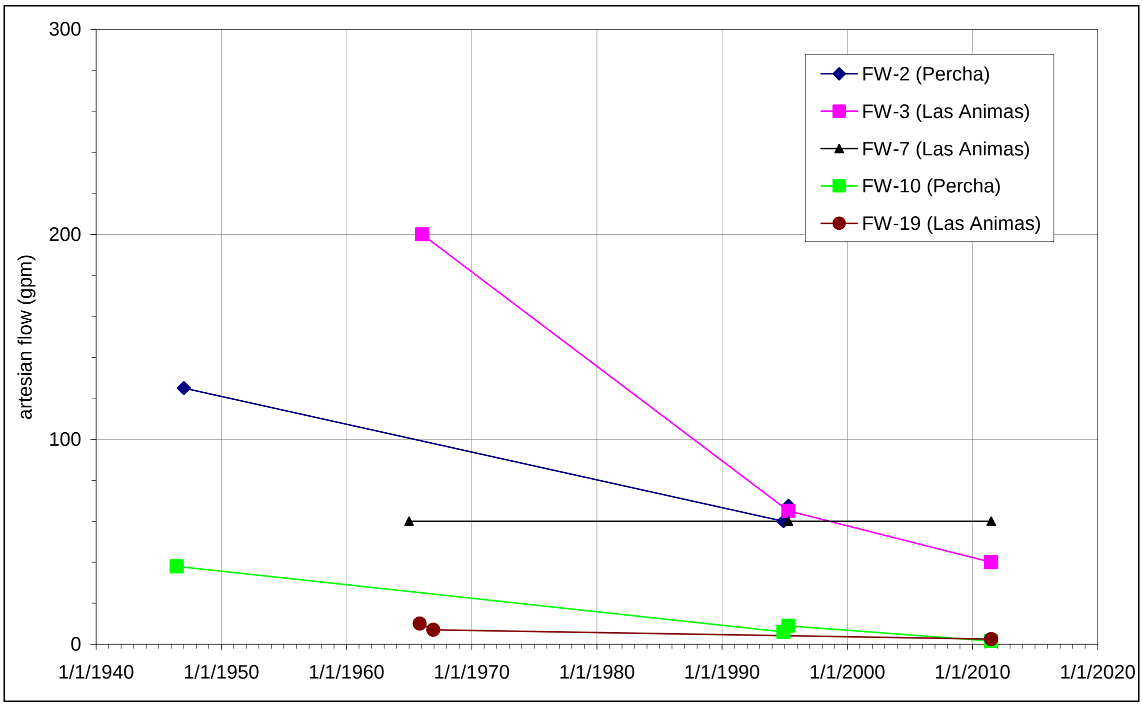


Figure 5.19. Measured artesian flow rates.

There are many factors that affect artesian flow, including climatic conditions and recharge, and Caballo Reservoir stage. Upward leakage via artesian wells and open flow, however, appear to be mainly responsible for the long-term decline in artesian flow rates.

The assessment of aquifer properties will be further refined based on planned aquifer testing (JSAI, 2011) to more fully characterize hydraulic properties around the existing production wells, including vertical resistance to flow. The evaluation of aquifer properties will be further refined during development of the numerical groundwater-flow model.

6.0 SUMMARY

The conceptual model as presented above forms the framework of the ongoing numerical model development. This report will form a part of the final model report which, additionally, would include the following:

Numerical model description and layout

- discretization
- aquifer parameters
- boundary conditions

Model calibration

- measured and simulated current water-level contours
- x-y plot of measured vs. simulated water levels
- measured and simulated MW-5 hydrographs
- measured and simulated MW-6 hydrographs
- measured and simulated USGS hydrographs
- measured and simulated tailings-area water levels
- measured and simulated flowing well discharges

Model projection - effects of water-supply pumping

- end-of mining groundwater drawdown contours
- water balance changes with time on Animas, Percha, and Rio Grande systems
- contour of maximum drawdown extent
- contours of projected subsidence

Model projection - effects of pit-area dewatering and recovery

- projected dewatering rates
- contour map of final pit
- pit stage-area-volume curves
- projected pit water-level hydrograph
- projected pit area and volume
- projected pit water balance
- detailed water balance for pit water quality projections
- evaluation of any pit outflows
- post-recovery pit-area groundwater drawdown contours

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