Pine Valley is located north of the Project Area. The drainage area of the entire basin is approximately 1,010 square miles, although the portion of Pine Valley that is within the HSA is limited to approximately 730 square miles of the southern portion of the basin because the inclusion of the northern portion of the basin would not provide any additional information for the analysis in this EIS **and the potential impacts from the Proposed Action would not propagate to that portion of the basin**. Pine Valley is bounded on the north and west by the northeast-trending Cortez Mountains, on the south by the Roberts Mountains, and on the southeast by the Sulphur Spring Range (Figure 3.2.4). Lowland elevations in Pine Valley range from approximately 5,800 feet amsl along Henderson Creek in the southern part of the valley to approximately 4,840 feet amsl at the Humboldt River at the north end. The Garden Valley subbasin of Pine Valley is directly north of Mount Hope. Surficial drainage from Garden Valley flows into central Pine Valley and ultimately drains into the Humboldt River approximately 56 miles north of Mount Hope.

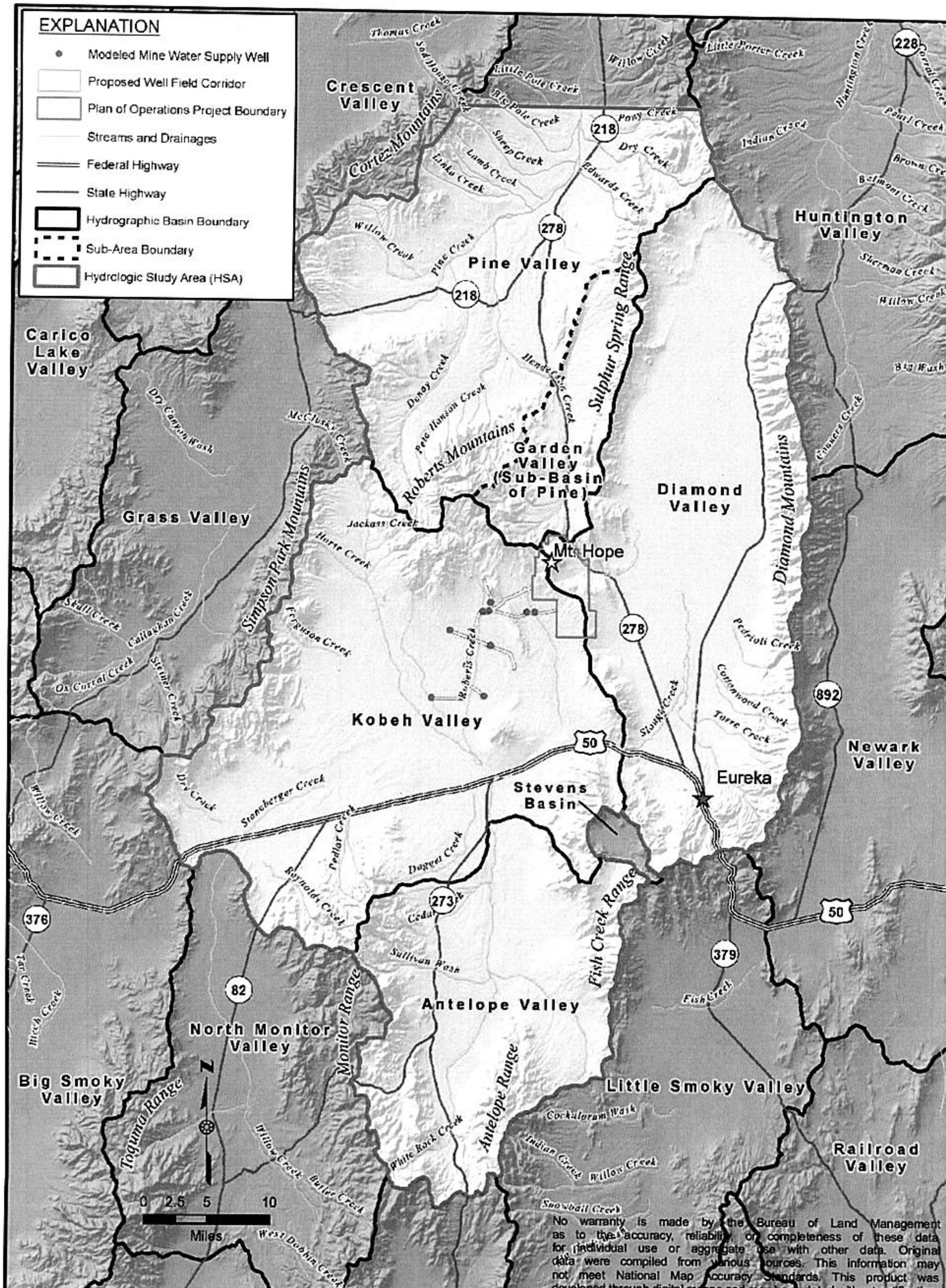
Antelope Valley is a V-shaped valley, in plan view, open to Kobeh Valley on the northern end and bounded by the Monitor Range on the west and the Antelope and Fish Creek Ranges to the east (Figure 3.2.5). The drainage area of the valley is approximately 450 square miles. The lowlands of Antelope Valley range in elevation from more than 6,800 feet amsl at the south end of the valley to approximately 6,075 feet amsl in the north. Antelope Valley appears to be a connected tributary to Kobeh Valley.

The Kobeh, Diamond, and Antelope Valley portions of the HSA, together with North and South Monitor Valleys and Stevens Basin (Figure 3.2.1) constitute the Diamond Valley Regional Flow System, as defined by Harrill et al. (1988). The basins comprising this system are internally connected by ephemeral streams and subsurface ground water flow through basin-fill aquifers and possibly through deep carbonate aquifers (Tumbusch and Plume 2006). Diamond Valley is the terminus of the flow system and the water resources of the southern part of this basin have been developed for irrigation, mining, municipal, and domestic uses. The Pine Valley portion of the HSA is part of the Humboldt Regional Flow System, as defined by Harrill et al. (1988).

3.2.2.2.2 General Geologic Setting

The structural basins within the HSA are typical of those that occur in the Great Basin. The rocks that form the mountain ranges and structural basins forming the valleys are composed primarily of complexly faulted and folded Paleozoic sedimentary rocks, with widespread occurrences of Jurassic, Cretaceous, and Tertiary intrusive rocks and Tertiary volcanic rocks. At various locations in the HSA, the volcanic rocks overlie all of the older hydrogeologic units. The structural depressions in the valleys have been partially filled by Tertiary and Quaternary lacustrine and subareal deposits, which are unconsolidated to semi-consolidated. The general stratigraphic and structural framework throughout the HSA and the Project Area is described in Section 3.4 Geology and Minerals. Figure 3.2.6 shows the distribution of generalized hydrolithologic units within the HSA.

Geomorphic and sedimentary evidence of Pleiocene and Pleistocene lakes have been recognized within portions of the Kobeh, Diamond, Pine, and Antelope Valleys and reflect a cooler, wetter climate. Lake Jonathan occupied the majority of Kobeh Valley and the northern part of Antelope Valley (Figure 3.2.7), while Lakes Pine and Diamond occupied their respective basins, with Lake Diamond extending slightly westward into eastern Kobeh Valley (Reheis 1999). The



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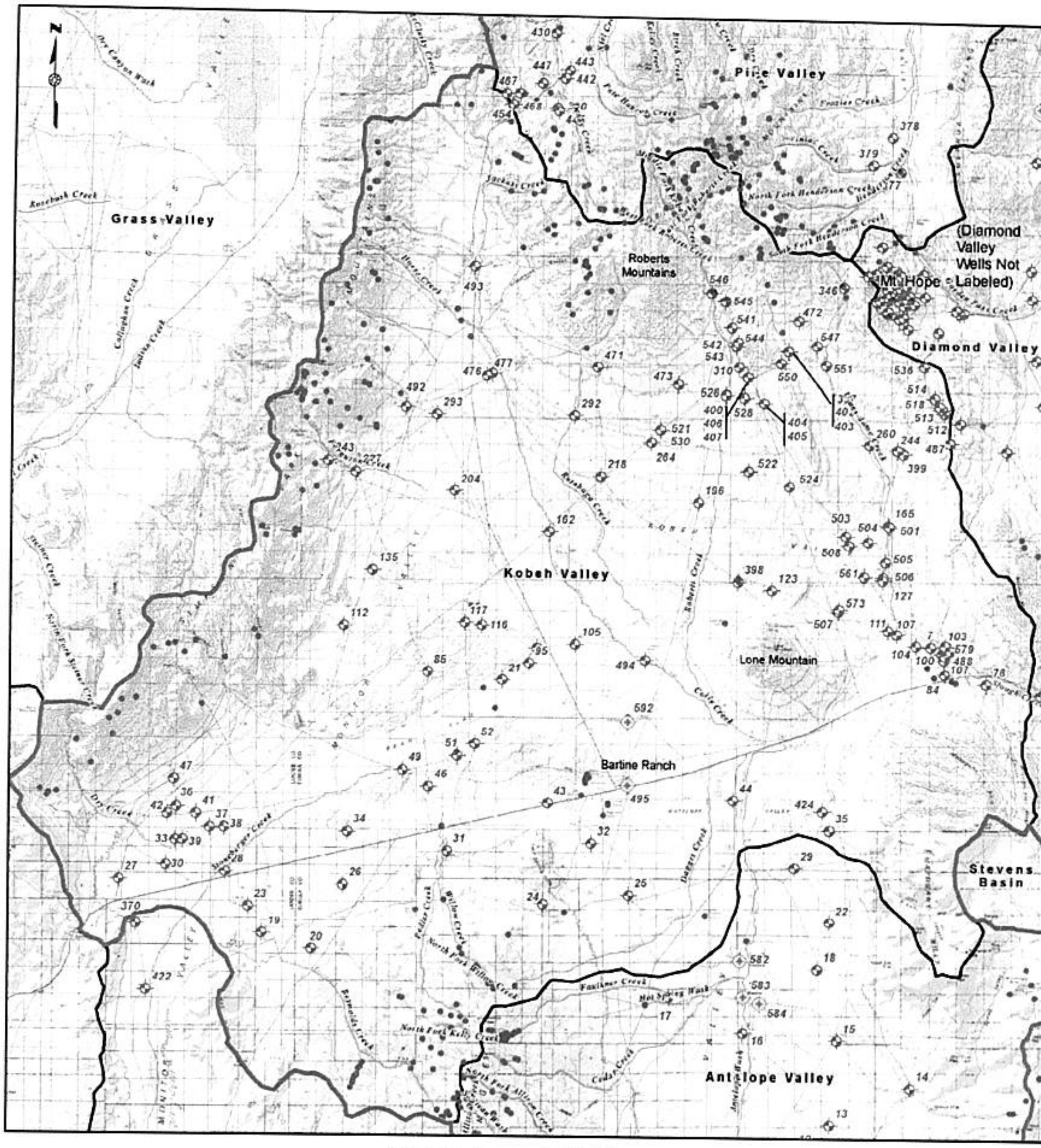
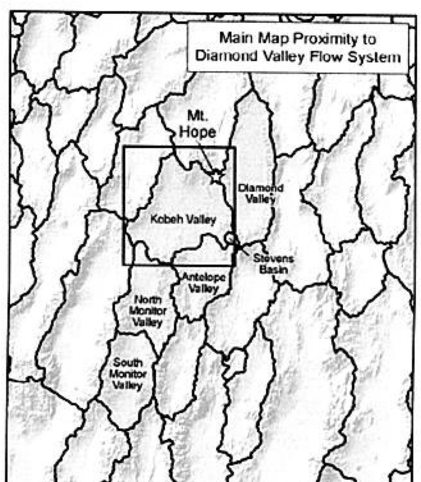


Source: Montgomery et al. (2010).

EXPLANATION

- Springs
- Wells (Number is Database ID, as listed in Montgomery et al. (2010) Appendix G)
- Flowing Wells (Wells reported to have artesian flow at the time they were initially drilled.)
- ☆ Mt. Hope
- Streams and Drainages
- Hydrographic Basin Boundary
- Hydrologic Study Area Boundary



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BUREAU OF LAND MANAGEMENT

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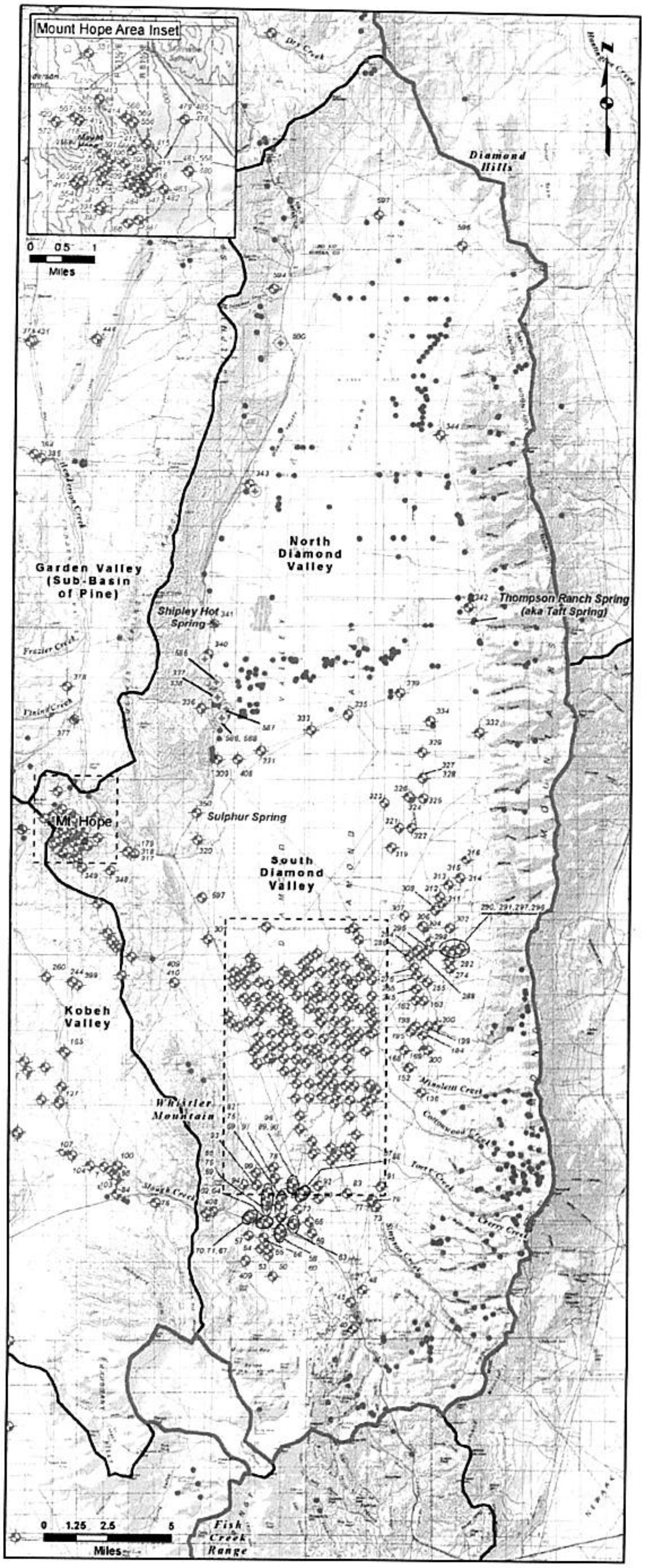
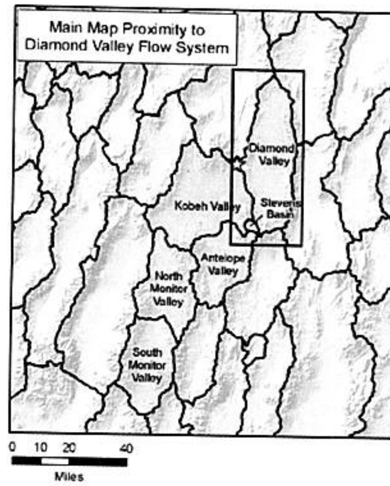
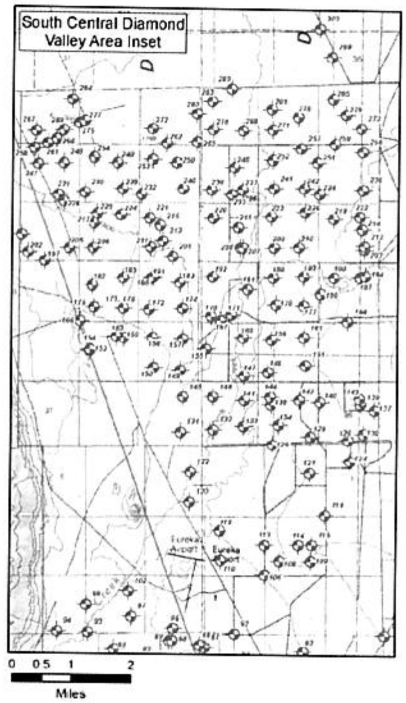
DRAWING TITLE:

Basin Detail of Kobeh Valley

Figure 3.2.2







EXPLANATION

- Springs
- Wells (Number is Database ID, as listed in Montgomery et al. (2010) Appendix G)
- Flowing Wells (Wells reported to have artesian flow at the time they were initially drilled.)
- Mt. Hope
- Streams and Drainages
- Hydrographic Basin Boundary
- Hydrologic Study Area Boundary

Source: Montgomery et al. (2010).

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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

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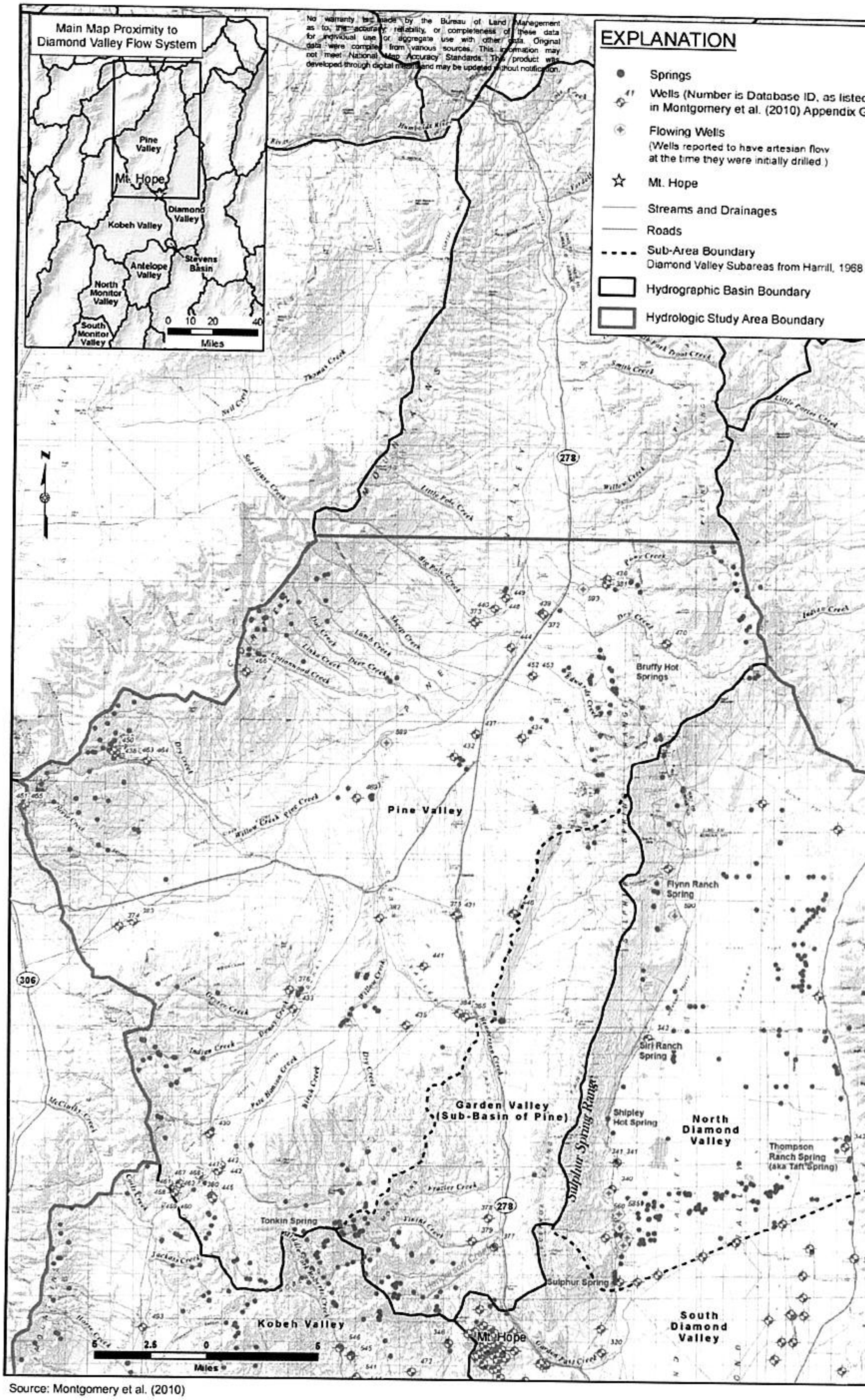
Basin Detail of Diamond Valley

Figure 3.2.3



Source: Montgomery et al. (2010)

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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE

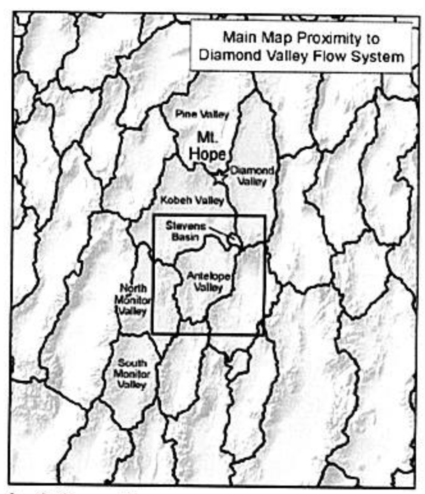
Basin Detail of the Southern Part of Pine Valley

Figure 3.2.4

Source: Montgomery et al. (2010).

EXPLANATION

- Springs
- Wells (Number is Database ID, as listed in Montgomery et al. (2010) Appendix G)
- Flowing Wells (Wells reported to have artesian flow at the time they were initially drilled.)
- Mt. Hope
- Streams and Drainages
- Hydrographic Basin Boundary
- Hydrologic Study Area Boundary



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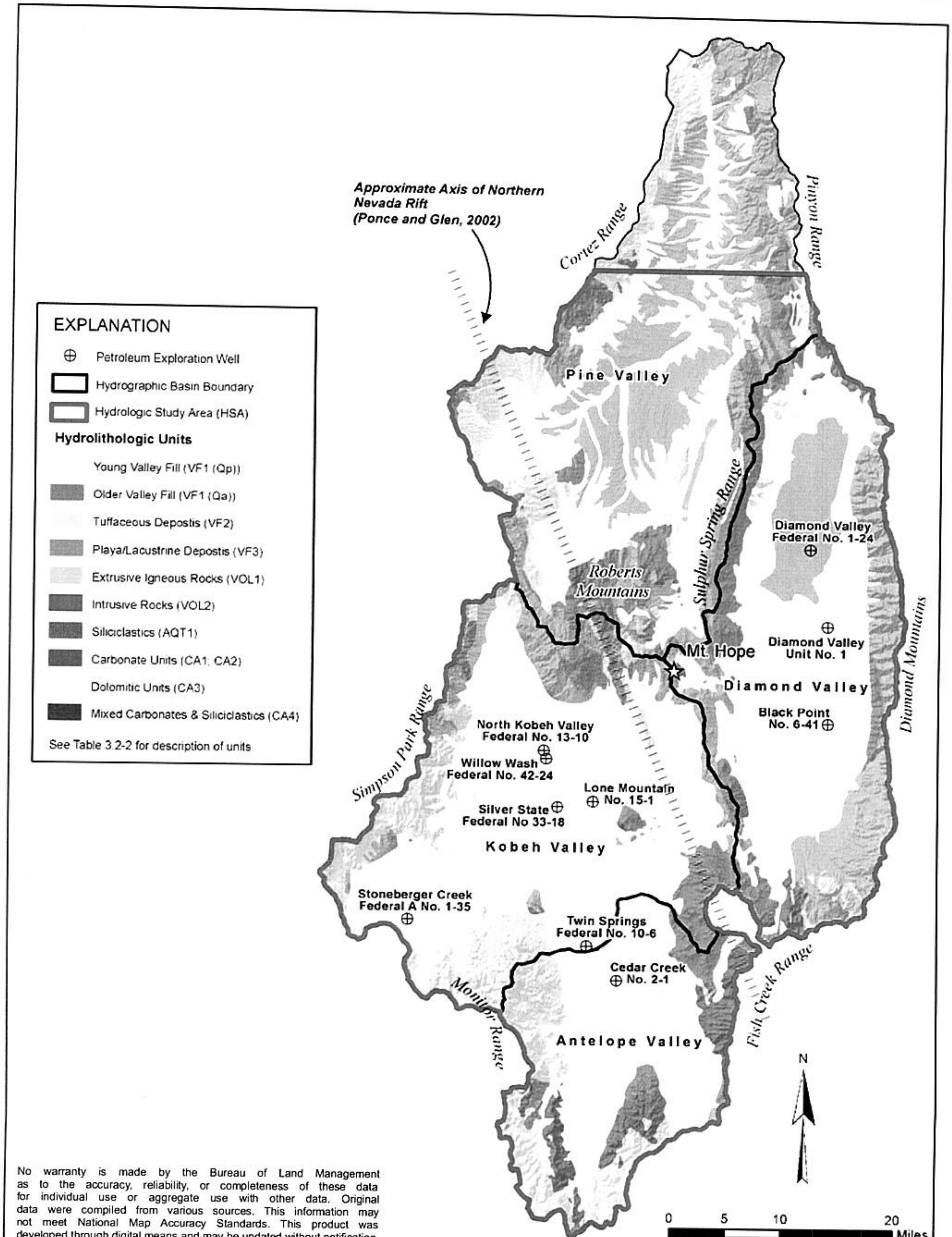
BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Basin Detail of Antelope Valley

Figure 3.2.5



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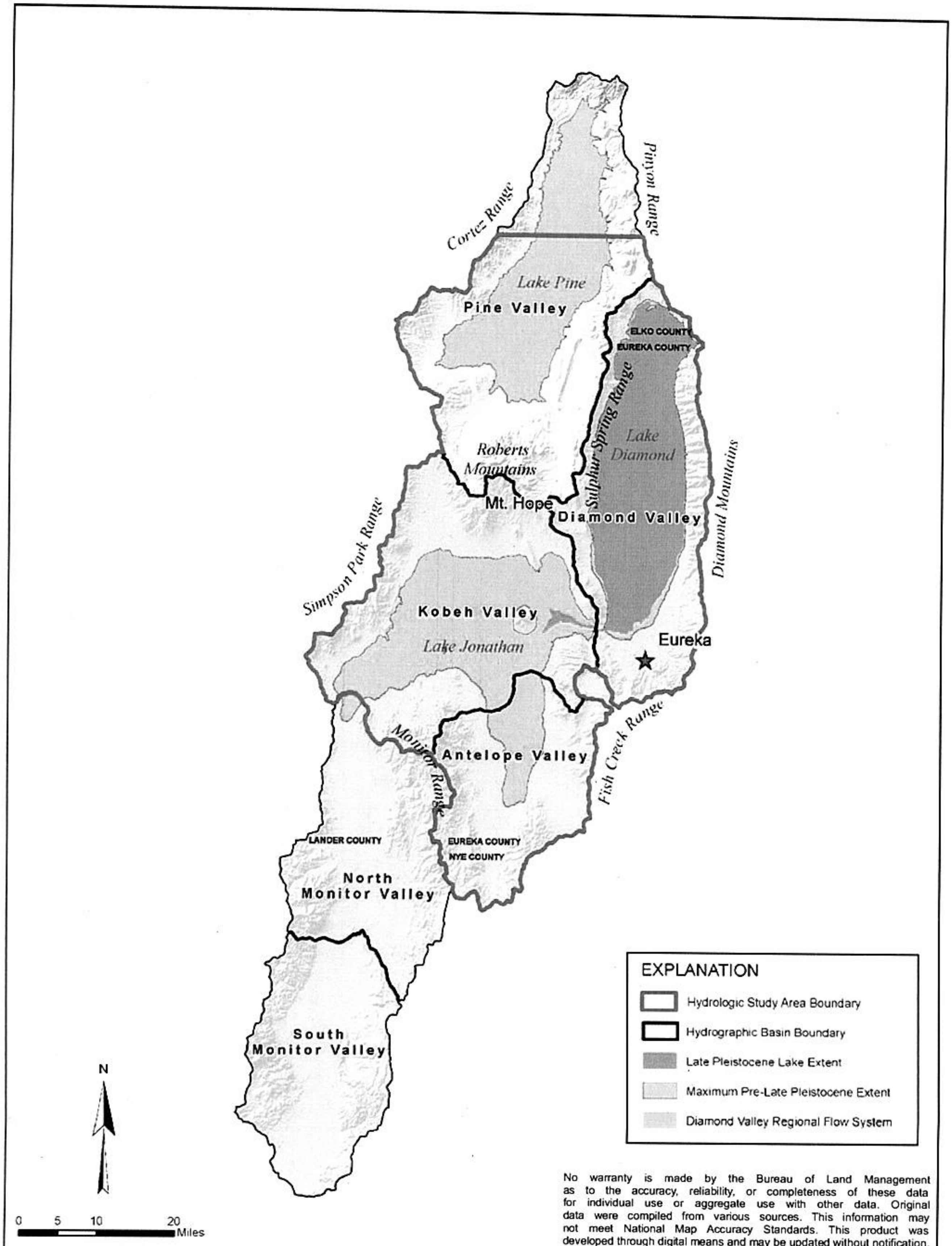
BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Generalized Hydrogeologic Map of the HSA

Figure 3.2.6



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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Extent of Pleistocene Lakes within the Hydrographic Basins that are Part of the HSA

Figure 3.2.7

lithologic units of the valley-fill deposits, below the recent alluvium in the HSA, include claystone, fresh water limestone, and tuffaceous sediments indicative of lacustrine deposition associated with these ancestral lakes.

3.2.2.2.3 Climate

The climate of the HSA is characterized as mid-latitude steppe in the basin lowlands and as subhumid continental in the mountains. The mid-latitude steppe zone is semiarid, with warm to hot summers and cold winters. The subhumid continental zone has cool to mild summers and cold winters, with annual precipitation occurring mostly as snow (Houghton et al. 1975). Most precipitation in the HSA comes from winter storms. Although summer thunderstorms can produce large amounts of precipitation as rain in a short time, their effects are usually localized and do not contribute significantly to total annual precipitation.

Throughout the region, precipitation varies widely between seasons and years, as well as with elevation. The variation in average annual precipitation for weather stations within 60 miles of Mount Hope is summarized in Table 3.2-1. Three stations are within 25 miles of the Project Area: Beowawe – University of Nevada, Reno (UNR) Ranch; Eureka; and U.S. Department of Agriculture (USDA) Diamond Valley stations. Annual 30-year normal precipitation as computed by the National Weather Service (NWS) for the period from 1971 through 2000 is 11.04 inches at the Beowawe UNR Ranch station (elevation 5,740 feet amsl), 12.06 inches at the Eureka station (elevation 6,540 feet amsl), and 9.14 inches at the Diamond Valley USDA station (elevation 5,970 feet amsl). According to the Precipitation Elevation Regressions on Independent Slopes Model (PRISM) developed by the Spatial Climate Analysis Service at Oregon State University, 1971-2000 annual normal precipitation was estimated at approximately 13.6 inches at Mount Hope (SRK 2008a).

The BLM operated three flow-recording stations and 20 bulk precipitation-collection stations in the Coils Creek watershed, a 50-square mile area in the northwestern part of Kobeh Valley, during the time period 1963 to 1980 (Houng-Ming et al. 1983). Those data showed an average annual precipitation of 11.4 inches for the period of record, but they did not demonstrate a clear altitude- precipitation trend, which is uncommon in the Great Basin, where orographic lift effects usually produce a well-defined elevation-to-precipitation relationship. The precipitation data from the Coils Creek watershed may indicate unusual storm tracks, a lack of orographic lift effect, or potentially a data problem that cannot be resolved with existing information. (Montgomery et al. 2010).

Evaporation rates vary with a number of factors, of which temperature, wind speed, relative humidity, and solar radiation are primary. Two weather stations that measure pan evaporation are located near Mount Hope (SRK 2008a). During the period from 1948 through 2002, measured pan evaporation averaged approximately 51.5 inches per year at the Ruby Lake station, located at an altitude of 6,010 feet amsl approximately 46 miles to the northeast of the site. At the Beowawe UNR Ranch station, located at an altitude of 5,740 feet amsl approximately 23 miles west of the site, the measured pan evaporation averaged approximately 51.2 inches per year during the period from 1972 through 2002. Due to freezing conditions, pan evaporation is not measured in the winter months, November through March, at either station. With a typical pan coefficient of 0.7 applied to these measurements, the mean annual evaporation from an open-water surface would be approximately 36 inches. However, this calculation probably underestimates the actual annual open-water evaporation rate because some evaporation does occur during the winter months and is unaccounted for in the available data sets. Average annual ET, which includes the effects of vegetation, the ground surface, and other factors, may differ substantially from this estimate, as discussed in Section 3.2.2.6.5.

Table 3.2-1: Mean Annual Precipitation at Weather Stations within 60 Miles of the Project Area

Station Name	Approximate Distance and Direction From Project Center	Approximate Elevation (feet amsl)	WRCC Period of Record Mean Annual Precipitation[1] (inches)	NWS 30-Year Normal Annual Precipitation[2] (inches)
Austin	51 miles southwest	6,600	13.02	14.33
Beowawe	58 miles northwest	4,700	8.69	8.84
Beowawe UNR Ranch	23 miles west	5,740	10.63	11.04
Diamond Range SNOTEL[3]	**25 miles east**	**8,000**	-	**21.71**
Diamond Valley USDA	10 miles southeast	5,970	9.14	9.14
Eureka	21 miles southeast	6,540	12.02	12.06
Fish Creek Ranch	37 miles southeast	6,050	4.82	-
Jiggs	54 miles northeast	5,420	11.09	-
Jiggs Zaga	50 miles northeast	5,800	14.28	13.35
Pine Valley Bailey	45 miles north	5,050	10.57	10.24
Ruby Lake	46 miles northeast	6,010	12.93	13.66
Snowball Ranch	51 miles south	7,160	9.02	8.81

[1] Western Regional Climate Center (WRCC). Source: Jeton et al. (2006)
[2] NWS 30-year normals for 1971 to 2000. Source: Jeton et al. (2006)
[3] **28-year record from WY1984 to WY2011.**

Most of the annual runoff within and through the HSA is derived from snowmelt. A large percentage of the annual precipitation falls as snow and is stored as snow pack in the higher elevations during the winter months. In the spring months, typically April through June, water from snowmelt produces runoff, which often results in the highest annual flows in many of the high mountain drainages. Occasionally, spring season rainfall coincides with the snowmelt runoff, resulting in extremely high runoff flows. The hot, dry weather in mid- to late-summer, with little or no rain and high evaporation rates generally produces the lowest annual flows.

3.2.2.3 Surface Water Resources

As is typical in the Great Basin, the HSA is dominated by mountain block watersheds that drain onto broad alluvial fans and valley bottoms. Perennial, intermittent, and ephemeral stream reaches occur in the bedrock-controlled mountain drainages, and flows typically dissipate into the fans along the valley margins or drain toward playas near the basin centers. Playas have formed in the topographically low areas of Kobeh and Diamond Valleys. The playa in Kobeh Valley is situated just west of Devil's Gate and has a relatively small surface area (note: at the scale of the maps in this section of the EIS, this small area is not shown). The Diamond Valley playa covers a large portion of the northern end of the basin. These playas are where ground water is naturally discharged.

The locations of streams and creeks and inventoried spring and seep sites are shown on the maps of the individual basins comprising the HSA (Figures 3.2.2 through 3.2.5). Available information on the streams and creeks within each basin of the HSA is summarized in the following paragraphs, followed by a discussion of the main springs and seeps within the HSA. Available measured flows for some of the major drainages in the HSA from the **United States Geological Survey** (USGS) database are outlined in Table 3.2-2 (Enviroscientists 2011a).

Table 3.2-2: Measured Flows in Some Major Drainages Located in the Hydrologic Study Area

Stream Name	Valley	Period of Measure	Measurements	Average Flow (gpm)
Coils Creek	Kobeh Valley	2/2/11 – 7/6/11	4	4,375
Henderson Creek	Pine Valley	7/27/10 – 6/27/11	7	2,904
Tonkin Springs	Pine Valley	7/26/10 – 6/29/11	16	673
Pete Hanson Creek	Pine Valley	10/18/85 – 6/29/11	17	1,131
Roberts Creek	**Kobeh Valley**	**5/4/11 – 7/6/11**	**4**	**4,367**

3.2.2.3.1 Streams and Creeks

Precipitation and geologic conditions in the HSA are such that perennial stream flow only occurs in a few isolated stream reaches. In general, perennial segments have their source in the mountains and, although they do respond to snow melt and rainfall events, much of their flow is provided by ground water discharge that occurs as spring and seep flow. Stream flows in the HSA primarily occur as intermittent flows from isolated springs, short-term seasonal runoff from snowmelt or winter storms, or as ephemeral flow from intense but infrequent thunderstorms. Ephemeral channels primarily carry runoff from rainfall. Rapid snowmelt may cause runoff in ephemeral channels; however, this occurs only infrequently.

Numerous drainages leave the mountain fronts and cross over alluvial fans where flows from those drainages typically dissipate on the fans. When water does reach the valley floor during larger runoff events, the water is soon taken up by ET and seepage into valley-floor sediments. Clearly defined stream channels tend to be confined to the margins of the basins where slopes are steepest and runoff is greatest during precipitation events. Channels become poorly defined as they near the flatter portion of the basins and runoff infiltrates into permeable alluvial fan material.

Kobeh Valley

In Kobeh Valley, surface drainage is directed generally from the mountains to the central valley floor and then eastward toward Devil's Gate, where flow occasionally passes into Diamond Valley via Slough Creek. Surface water occasionally flows into the southern part of Kobeh Valley via the main ephemeral drainages in Antelope Valley (Antelope Wash) and the northern part of Monitor Valley (Stoneberger Creek). The Stoneberger Creek drainage enters the southwestern side of Kobeh Valley from Monitor Valley and crosses southern Kobeh Valley in a west to east direction through Bean Flat (Figure 3.2.2). Antelope Wash enters Kobeh Valley from the south at a point where several ephemeral drainages join on the southeastern side of Kobeh Valley to form Slough Creek. Slough Creek, also ephemeral, drains east through Devil's Gate into southern Diamond Valley. Channel geomorphology and a lack of vegetation scour indicate that outflow through Devil's Gate is a rare occurrence related to low frequency, high runoff events. Reported flows in Slough Creek in May of 1964, during a peak period of seasonal flow, ranged from approximately 670 to 1,120 gpm (1.5 to 2.5 cubic feet per second [cfs]) (Robinson et al. 1967).

The two main internal drainages within Kobeh Valley are Coils Creek in the western part of the valley, which drains the east side of the Simpson Park Mountains and the western side of the Roberts Mountains, and Roberts Creek, which drains the central and southeastern part of the Roberts Mountains (Figure 3.2.2). Rutabaga Creek lies between these two drainages and drains the southern part of the Roberts Mountains.

Roberts Creek is identified as being perennial from the headwaters of its middle and east fork tributaries to near the mountain front (BLM 1997). A segment of the Cottonwood Canyon drainage, on the southwest side of the Roberts Mountains, is also identified as containing perennial flow upstream of its confluence with the Coils Creek drainage. The only other identified perennial stream reaches in Kobeh Valley are Snow Water Canyon and Ferguson Creek on the east side of the Simpson Park Mountains, as well as Ackerman Creek, Basin Creek, Coils Creek, Dry Canyon, Dry Creek, Kelly Creek, Jackass Creek, and Meadow Canyon. A small segment of U'ans-in-dame Creek to the east-northeast of Lone Mountain is also classified by the BLM (1997) as perennial. However, based on 2010 field observations and a review of Landsat images and the USDA's National Agricultural Imaging Program (NAIP) aerial photography, it is now believed that this stream segment is not perennial (Montgomery et al. 2010).

Stream discharge measurements were taken by Interflow along the course of Roberts Creek in 2007. Measurements made during August 2007 on the tributaries of Roberts Creek indicated that most of the flow originated from the east fork, at 108 gpm (0.24 cfs), which received its flow from springs along the west and south to southeast flanks of the Roberts Mountains. The west and middle forks of Roberts Creek contributed little flow at that time, with the west fork being dry, and the middle fork discharge estimated at 4.5 gpm (0.01 cfs) (Montgomery et al. 2010). Measured discharge below the confluence of the three forks of Roberts Creek consistently decreased with distance downstream, indicating that Roberts Creek is a losing stream over most of its length. These stream losses are assumed to result in recharge to the local alluvial and carbonate aquifer systems. Flow loss due to evaporation and transpiration from riparian vegetation adjacent to the stream bed may also be a contributing factor to the consistent downstream decrease in flow.

Coils Creek is interpreted by Rush and Everett (1964) to be the principal tributary to Slough Creek. They reported a flow of approximately 3,600 gpm (eight cfs) in May 1964 at a location in Section 27, T22N, R49E (near the locations of wells #476 and #477, shown on Figure 3.2.2). Intermittent reaches of upper Coils Creek are mainly fed by spring flow and are used for irrigation purposes. More recent estimates of intermittent flows in Coils Creek have not been found.

In August 2007, Interflow measured a flow of nine gpm (0.02 cfs) in Rutabaga Creek on the southern flanks of the Roberts Mountains (Montgomery et al. 2010). Along the east slope of the Simpson Park Mountains, on the west side of Kobeh Valley, Interflow observed the following: no surface flow in Snow Water Canyon during both June and December 2007 and also in April 2008; no flow in Ackerman Canyon in April and a flow of 27 gpm (0.06 cfs) in May of 2008; an estimated flow of less than 112 gpm (0.25 cfs) in Ferguson Creek in May and no flow in August 2007; and no flow in Dry Canyon in June 2007. At the stream gage on Roberts Creek, Interflow measured flows of 561 and 1,872 gpm (1.25 and 4.17 cfs) in April and May 2008, respectively.

Reported flows in Willow Creek and Dagget Creek, which drain the north end of the Monitor Range in southern Kobeh Valley, were approximately 450 and 670 gpm (one and 1.5 cfs), respectively, in May 1964 (Robinson et al. 1967). No other drainages within the Kobeh Valley basin have recorded stream flows.

Antelope Valley

A limited number of perennial stream segments have been identified in Antelope Valley (Figure 3.2.8). In April and May 1964, flows of approximately 450 and 900 gpm (one and two cfs) were observed in Alison Creek and Copenhagen Canyon, respectively, along the east slope of the Monitor Range on the west side of Antelope Valley; also, a flow of approximately 670 gpm (1.5 cfs) was measured in Ninemile Creek on the eastern side of Antelope Valley in May of 1964 (Robinson et al. 1967). Interflow estimated a flow of less than 112 gpm (0.25 cfs) in Alison Creek in June of 2007 (Montgomery et al. 2010).

Pine Valley

The main streams in Pine Valley are in the Horse Creek, Denay Creek, Henderson Creek, and Pine Creek drainages. Pine Creek is the principal stream in the valley and is a tributary to the Humboldt River. Eakin (1961) reported that the flow in Pine Creek is maintained primarily by the discharge from hot springs in the northwest quarter of Section 12, T28N, R52E, which are located near the northern boundary of the HSA.

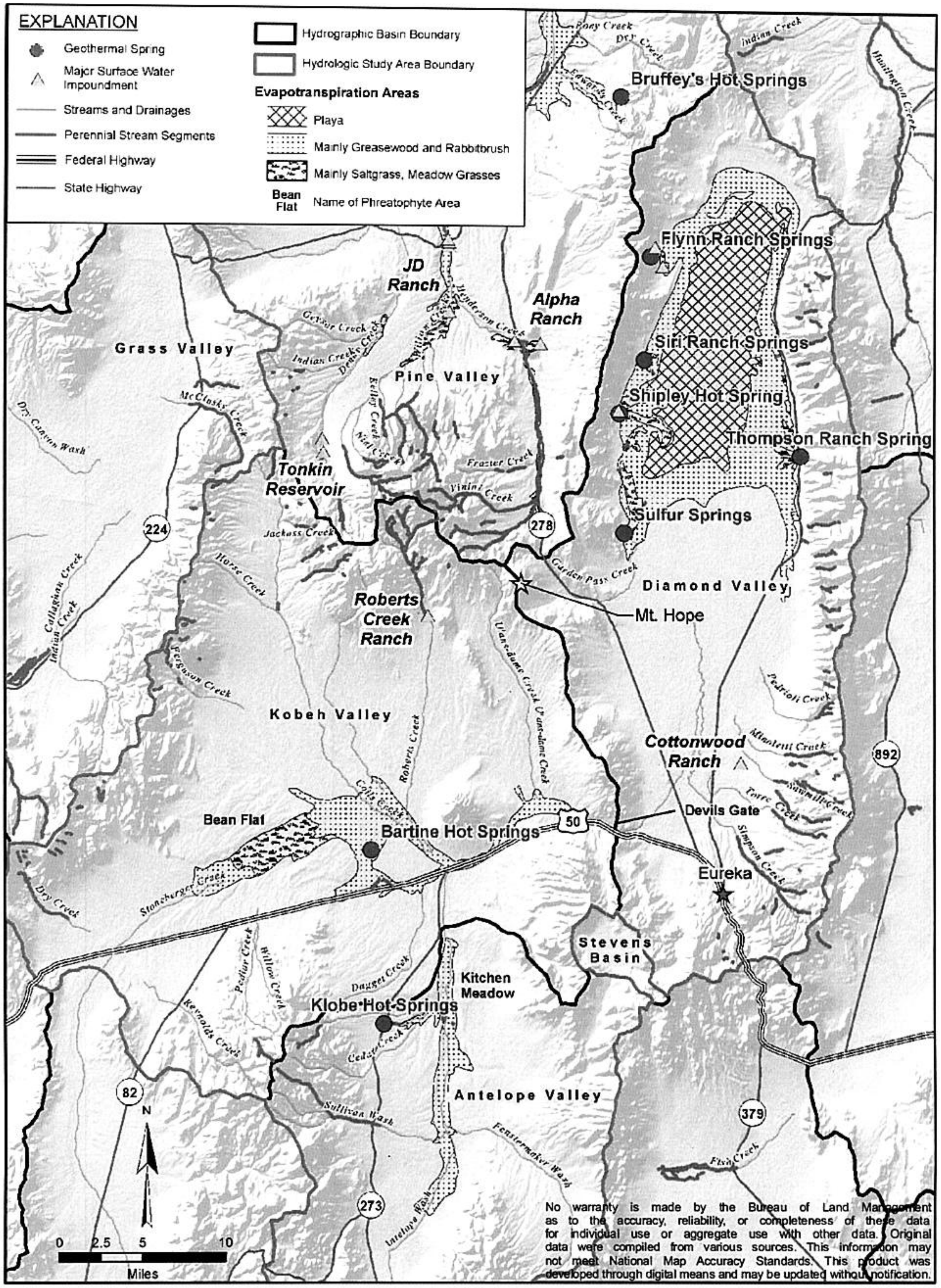
In the Pine Valley portion of the HSA, numerous headwater tributaries to Pine Creek form on the east and southeast-facing slopes of the Cortez Mountains (Horse Creek drainage) and the northern part of the Simpson Park Mountains (Denay Creek drainage), on the north to northwest flanks of the Roberts Mountains (Pete Hanson Creek, Neil Creek, Kelly Creek, Birch Creek, Willow Creek, and Dry Creek), and on the northeast side of the Roberts Mountains in the Garden Valley subbasin (Henderson Creek, Vinini Creek, and Frazier Creek). Perennial stream-flow segments have only been identified on portions of Denay Creek, Pete Hanson Creek, Willow Creek, Vinini Creek, and Henderson Creek (BLM 1997).

Isolated reaches in the Horse Creek drainage of Pine Valley were reported to have flows ranging from nine to 58 gpm (0.02 to 0.13 cfs) during August 2005 before surface flows were lost to infiltration or ET (BLM 2008b). The Denay Creek drainage arises from headwater springs in Red Canyon on the north slope of the Roberts Mountains, and is fed lower down in the drainage by perennial discharge from Tonkin Spring (discussed in Section 3.2.1.2.2). Denay Creek discharges into Tonkin Springs Reservoir, a small surface-water impoundment, approximately one mile downstream of Tonkin Spring. Between August 2007 and September 2009, Interflow measured the discharge from Tonkin Spring during all months of the year, and the range of observed flows was from 525 to 1,086 gpm (1.17 to 2.42 cfs) (Montgomery et al. 2010). This provides an estimate of the flows in Denay Creek just downstream of Tonkin Spring. Further east, along the north side of the Roberts Mountains, Interflow reported no flow in Pete Hanson Creek during August 2007 and a flow of 1,023 gpm (2.28 cfs) in June of 2009. Also, Willow Creek was observed to have flows of 31 and nine gpm (0.07 and 0.02 cfs) in August and October 2007, respectively.

As part of the baseline characterization investigations in 2006, SRK (2008a) established three surface water monitoring stations on Henderson Creek, allowing two distinct reaches of the creek to be studied. The upper monitoring station is approximately one-half mile southeast and downgradient of Spring 585 (discussed in Section 3.2.2.3.2) at an elevation of approximately 7,177 feet amsl. SRK reported that the creek flow is perennial at the upper monitoring station, with the flow sustained by discharge from local springs and seeps. The middle monitoring station is approximately two miles downgradient of the upper station and is located approximately 50 feet below the confluence of the north and south forks of Henderson Creek at an elevation of approximately 6,688 feet amsl. The creek flow at this location is also thought to be perennial and fed by springs and seeps in the upper part of the watershed. The stream channel morphology at the middle monitoring station is described as being substantially incised, with arroyo-like features. The lower monitoring station is approximately 2.5 miles downgradient of the middle station and is located roughly 60 feet west of SR 278 at an elevation of approximately 6,446 feet amsl. SRK characterized the lower reach as being perennial, but noted that the actual flowing locations of the creek near the lower monitoring station vary on a seasonal basis, such that the established sampling-point location was observed to be dry in the third and fourth quarters of 2006 and the first quarter of 2007.

During the field investigation site visits in 2006 and 2007, SRK (2008a) recorded maximum flow rates of approximately 400, 3,180, and 2,600 gpm (0.9, 7.1, and 5.8 cfs) at the upper, middle, and lower monitoring stations, respectively, on Henderson Creek in May 2006. Subsequent monitoring events recorded smaller flow rates, ranging from 45 to 112 gpm (0.1 to 0.25 cfs), at the upper and middle monitoring stations and no flow at the lower station. The measured stream-flow data indicate that the reach of Henderson Creek between the upper and middle stations generally gains flow, whereas the reach between the middle and lower stations generally loses flow.

Stream flow measurements were also made by Interflow on Henderson and Vinini Creeks, north of Mount Hope in the Garden Valley subbasin of Pine Valley (Montgomery et al. 2010). During August and October 2007, Vinini Creek was observed to be dry, whereas in May 2008 and June 2009 flows of 3,110 and 950 gpm (6.93 and 2.12 cfs), respectively, were recorded. Henderson Creek was measured in August 2007 at the confluence of its north and south fork tributaries. No stream flow was observed from the north fork at that time, whereas discharge from the south fork was reported to be 27 gpm (0.06 cfs). Other flow measurements in Henderson Creek are 36 gpm (0.08 cfs) in December 2007 and 135 gpm (0.3 cfs) in May of 2008. According to Interflow, Henderson Creek contained observable flow in a reach approximately 2.3 miles long before losing all of its surface flow to infiltration and ET (Montgomery et al. 2010). As shown on Figure 3.2.8, Henderson Creek is also perennial in its lower reaches near the Alpha Ranch.



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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Geothermal Resources, Perennial Stream Segments, and Major Surface-Water Impoundments within the HSA

Figure 3.2.8

Diamond Valley

Lamke, in Harrill (1968), described the existence of only a few perennial streams in Diamond Valley, all of which are located on the east side of the valley on the western slopes of the Diamond Mountains. Cottonwood and Simpson Creeks were mentioned as the two most prominent perennial streams, and the only ones that supported ranching operations in the 1960s. Figure 3.2.8 shows the location of the perennial stream segment in Diamond Valley. The only intermittent streams in Diamond Valley with a significant volume of seasonal runoff are also located in the Diamond Mountains. The rest of the streams in Diamond Valley are intermittent or ephemeral and were reported to have only minor flows.

Between May of 1965 and October of 1966, reported stream flows in 11 drainages along the western side of the Diamond Mountains ranged from zero flow to a maximum of 785 gpm (1.75 cfs) in Cottonwood Creek on one occasion; all other observed flows during that time period were less than 287 gpm (0.64 cfs) (Harrill 1968). No flow was observed during March and June of 1966 in Garden Pass Creek, an ephemeral creek on the western side of Diamond Valley that originates at the topographic divide between Pine and Diamond Valleys, and an unnamed drainage on the eastern slopes of the Sulphur Spring Range in the northern part of Diamond Valley was also reported to be dry in April and October of 1966 (Harrill 1968). Peak flow measurements made by the USGS in Garden Pass Creek between 1965 and 1981 ranged from 224 to more than 290,000 gpm (0.5 to 650 cfs) (Hydro-Search 1982).

Mount Hope Project Area

There are no perennial stream segments within the Project Area boundary, and the majority of the ephemeral streams near Mount Hope drain east and south into Diamond Valley. The closest perennial stream segment to Mount Hope is approximately three miles to the north, in the upper reaches of Henderson Creek, as described above in the discussion of Pine Valley.

Surficial drainage from Mount Hope occurs via ephemeral streams that radiate away from the mountain. Some of the ephemeral streams near Mount Hope drain to the west and south into Kobeh Valley. A minor, unnamed tributary to Henderson Creek drains a small area on the northwest flank of Mount Hope and is the only surface drainage from the Project Area into Pine Valley. The northern and eastern sides of Mount Hope drain into Garden Pass Creek. Tyrone Creek drains the south side of the mountain and joins Garden Pass Creek southeast of the mountain, just upstream of where Garden Pass Creek cuts through the Sulphur Spring Range and enters Diamond Valley. A short distance east of this erosional gap, the creek disappears into the alluvium of Diamond Valley. Two ephemeral streams drain the western side of Mount Hope. These streams join to become a relatively well-defined channel (U'ans-in-dame Creek), which persists for approximately two miles before the stream channel becomes difficult to discern in the surficial alluvium of eastern Kobeh Valley.

The Zinc Adit, located approximately 0.25 mile east of the current core-shed building, is one of several adits associated with the historical workings of the Mount Hope Mine. Drainage from the Zinc Adit is the only known mine drainage from historical workings within the Project Area. Measurements of flow from the Zinc Adit were made quarterly from October of 2005 through the first quarter of 2007 and were fairly constant throughout the year, ranging from 7.6 to 9.4 gpm (0.017 to 0.021 cfs) (SRK 2008a).

3.2.2.3.2 Springs and Seeps

Springs and seeps are numerous within the HSA, and an inventory has been compiled from various sources, including the USGS National Hydrography Dataset, the Great Basin Center for Geothermal Research (GBCGR) database, field exploration by mine consultants (SRK and Interflow), and spring locations digitized from 1:24,000-scale USGS topographic maps. Interflow has compiled all of the available spring and seep data into a single inventory (spreadsheet file), which lists 1,102 individual sites within the HSA (Montgomery et al. 2010, Appendix E). The locations of inventoried springs and seeps are shown on the maps of the individual basins comprising the HSA (Figures 3.2.2 through 3.2.5) and a large-format composite map showing the location and inventory identifier for each spring and seep is presented in Montgomery et al. (2010, Appendix E).

Many of the springs in the HSA occur along the contacts between rocks of differing hydraulic properties. This condition can result from a variation in lithology or permeability, or be a result of faulting that juxtaposes differing rock units. Many of the springs in the HSA are seasonal in nature, with flow occurring during brief periods of time when ground water levels are temporarily elevated in response to recharge. To varying degrees, the flow of springs in the HSA is regulated by long-term climatic conditions and, in some cases, also by anthropogenic water use. Springs occur primarily in the mountains and along the mountain fronts, although some seeps occur on the valley floors where the depths to ground water are shallow.

Within the Diamond Valley basin, flows from some of the springs and seeps in the southern part of the valley and along the mountain fronts have declined since the mid-1960s, coincident with the observed changes in water levels in the basin-fill aquifer of that valley as discussed in Section 3.2.2.6.4. Outside of Diamond Valley, there have been no reports of generally declining spring and seep flows in any of the other basins in the HSA.

Most of the springs in the HSA that have substantial perennial flow or have some unique historical, cultural, ecological, or aesthetic significance, are described below in the discussion of geothermal springs. Of the numerous cold springs that exist in the HSA, Tonkin Spring (Spring 378) in the Denay Creek drainage of Pine Valley has the largest flows. Between August of 2007 and September of 2009, Interflow measured the discharge from Tonkin Spring during all months of the year (Montgomery et al. 2010). A minimum flow of 525 gpm (1.17 cfs) was observed during March of 2009, and a maximum flow of 1,086 gpm (2.42 cfs) was recorded during August of 2007. Measurements made for three consecutive years (2007, 2008, and 2009) during the month of August ranged between 718 and 1,086 gpm (1.60 and 2.42 cfs), with a mean value of 862 gpm (1.92 cfs). The recorded temperature of the spring is 55.6 °F.

Geothermal Springs

Springs with water temperatures elevated above the mean annual surface temperature are affected by heat from geologic materials at depth and are referred to as geothermal springs. The majority of the geothermal springs in the HSA are associated with major range-bounding faults and are thought to involve deep ground water circulation (Montgomery et al. 2010). The most prominent of these geothermal fault zones is the southern portion of the 22-mile long Piñon Range fault, which lies on the east side of Pine Valley along the Sulphur Spring Range. Another fault zone associated with elevated spring temperatures within the HSA is the Western Diamond

Mountain fault zone, which runs along the base of the Diamond Mountains in a north-south orientation for approximately 40 miles. The Antelope Peak Fault System, located along the northern edge of the Monitor Range in Kobeh and Monitor Valleys is likely responsible for the elevated temperatures of waters located at Klobe Hot Springs, the Bartine Ranch area, and the Hot Spring Hill complex.

Brief descriptions of the geothermal springs within the HSA are presented below, with the spring inventory identifier numbers included for reference (Montgomery et al. 2010, Appendix E). The locations of known geothermal resources within the HSA are shown in Figure 3.2.8.

Klobe Hot Springs (also known as Bartholomae Springs, Springs 930 and 931): These springs are located at the northeastern end of the Monitor Range in Antelope Valley. Water temperatures in the flowing springs have been recorded as high as 156 °F (Fiero 1968), and were 158 °F in a water well installed over the spring complex (Rush and Everett 1964). Mariner et al. (1974) estimated reservoir temperatures of 163 °F using a sodium (Na)-potassium-Ca geothermometer technique. Two wells located four miles east of the springs have ground water temperatures of 72 °F and 74 °F, which were measured by Bartholomae Corporation; this difference in temperature indicates that the influence of the geothermal springs diminishes to the east. Montgomery et al. (2010) report a historical flow measurement of approximately 500 gpm (1.11 cfs) during April of 1964 at Klobe Hot Springs.

Bartine Hot Springs (Springs 816, 820, 824, and 826): These springs are located approximately 2.5 miles north of the Bartine Ranch along U.S. Highway 50 in Kobeh Valley. They are near the west side of Lone Mountain and are 11 miles north of, and along the same fault zone as, Klobe Hot Springs. Montgomery et al. (2010) report that two of the springs (824 and 826) emanate from a large travertine deposit (tufa mound), with an average water temperature of 106 °F and a discharge of approximately two to three gpm (0.004 to 0.007 cfs). The tufa-mound is locally referred to as "Hot Spring Hill".

Bruffey's Hot Springs (Springs 74 through 79): These springs are located on the west side of the Sulphur Spring Range in Pine Valley, along the Piñon Range fault. Large calcareous sinter terraces containing barite and fluorite have accumulated around multiple spring discharge points (White 1955). Montgomery et al. (2010) report recorded temperatures as high as 152 °F and a flow rate of approximately 50 gpm (0.11 cfs) in June of 2007 for Bruffey's Hot Springs.

Flynn Ranch Springs (Springs 186 and 187): These springs are located along the east side of the Sulphur Spring Range in the northern part of Diamond Valley. They consist of several warm springs discharging into a deep pool. Water temperatures of approximately 70 °F and a combined discharge of ten gpm (0.022 cfs) have been reported (Reed et al.1983).

Shipley Hot Spring (Spring 330): This spring is located on the eastern flanks of the Sulphur Spring Range in the northern part of Diamond Valley. Estimated reservoir temperatures of 109 °F were determined using silica geothermometers (Mariner et al. 1983). As summarized by Montgomery et al. (2010), historical discharge measurements at Shipley Spring recorded between April of 1965 and January of 1991 ranged from 2,303 to 3,707 gpm (5.13 to 8.26 cfs). More recent discharge measurements made in 2008 and 2009 by SRK and Interflow recorded flows in the range of 935 to 1,600 gpm (2.08 to 3.56 cfs) (Montgomery et al. 2010).

Siri Ranch Springs (Springs 285 and 288): The Siri Ranch Springs are located on the eastern flanks of the Sulphur Spring Range in the northern part of Diamond Valley, approximately 4.5 miles north of Shipley Hot Spring. The reported temperature for the springs is 85 °F, and a nearby ranch well is reported to have a water temperature of approximately 95 °F (Reed et al. 1983). Mifflin (1968) reported a discharge of approximately 290 gpm (0.65 cfs) from the Siri Ranch Springs.

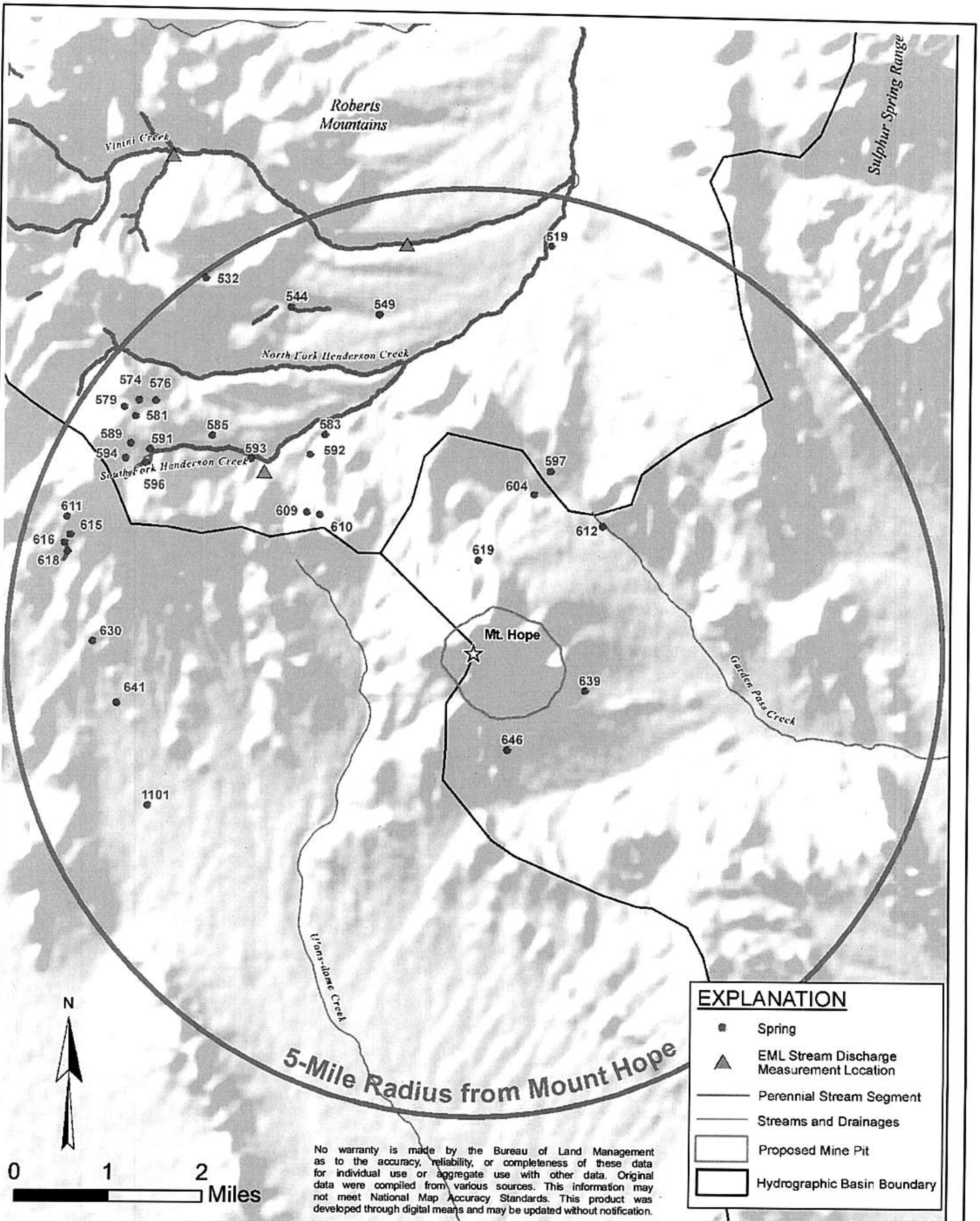
Sulfur Springs (Springs 560, 562, 564, 567, and 570): These springs are located along the eastern flanks of the Sulphur Spring Range in central Diamond Valley, approximately eight miles south of Shipley Hot Spring. These warm springs were reported to have a temperature of 74 °F and a discharge of 40 gpm (0.09 cfs) in November of 1965 (Harrill 1968). SRK observed no flow from Sulfur Springs during a field inspection in 2007 (SRK 2008c).

Thompson Ranch Spring (also known as Taft Spring, Spring 362): This spring is located on the east side of Diamond Valley along the western flanks of the Diamond Mountains and is reportedly associated with the Western Diamond Range fault zone (Harrill 1968). The recorded temperatures of the spring ranges from 69 to 75 °F (Mifflin 1968). Historical discharge measurements at Thompson Ranch Spring during the 1965 through 1990 time period ranged from 18 to 1,900 gpm (0.04 to 4.23 cfs). Montgomery et al. (2010) reported that the spring ceased flowing around 1990.

Mount Hope Area Springs and Seeps

SRK (2008a) inventoried the land area within approximately five miles of Mount Hope in September and October of 2005 and reported seven springs within the Project Area boundary and 13 springs outside of the Project Area boundary but within the five-mile radius. Brief descriptions of those inventoried springs are presented below along with the corresponding spring inventory identifier numbers (Montgomery et al. 2010, Appendix E). Subsequent field investigations by SRK (2008c) and spring database review by Interflow (Montgomery et al. 2010) identified 16 additional spring and seep locations with a five-mile radius of Mount Hope. Detailed descriptions of these additional springs and seeps are unavailable, but they were included in the overall inventory of springs and seeps within the HSA as Springs 519, 532, 544, 549, 576, 580, 583, 589, 591, 593, 594, 611, 616, 618, 638, and 639. In total, there are 31 inventoried springs and seeps within a five-mile radius of Mount Hope, as shown on Figure 3.2.9.

McBrides Spring (Spring 612): This spring is located approximately 150 feet east of SR 278, between Garden Pass and the Mount Hope road turnoff at an elevation of about 6,389 feet amsl. Within the riparian corridor of the spring there was no surface expression of water and the soil was dry to a depth of approximately 18 inches when visited by SRK. A pipe buried beneath the riparian area collects water and conveys it to a cattle trough approximately one mile south of the riparian area. A discharge of 1.8 gpm was recorded in October of 2006; during other quarterly visits the spring was dry. The site consists of a very small riparian area of approximately 200 feet square, containing Mexican rush (*Juncus mexicanus*), Kentucky bluegrass (*Poa pratensis*), and various forbs species surrounded by dense Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and rubber rabbitbrush (*Ericameria nauseosus*).



BATTLE MOUNTAIN DISTRICT OFFICE Mount Lewis Field Office 50 Bastian Road Battle Mountain, Nevada 89820			BUREAU OF LAND MANAGEMENT MOUNT HOPE PROJECT	DRAWING TITLE: **Surface Water Resources within Five Miles of Mount Hope** **Figure 3.2.9**
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Garden Spring (Spring 597): This spring is located approximately 1.5 miles northwest of SR 278 at an elevation of approximately 6,468 feet amsl. The Garden Spring site consists of two separate points of discharge within the same general area; both were reported to be perennial water features with no visible outlet for surface water. Water that emanates from the spring collects in local depressions. Flow measurements for the spring have not been obtained because there is no discrete flow from either point of discharge. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye (*Elymus cinereus*), and Nebraska sedge (*Carex nebraskensis*).

Unnamed (Spring 604): This spring is located approximately 1,500 feet south of Garden Spring and 1.5 miles west of SR 278 between Garden Pass and the Mount Hope road turnoff at an elevation of approximately 6,400 feet amsl. The site consists of a permanent pond with no visible inlet or outlet for surface water flow. Since the site has been monitored, no flow measurements have been obtained from the spring, although the pond has been observed to contain varying amounts of water released from an upgradient artesian well, IGM-152, which is located approximately one mile from the spring site. The site is dominated by rubber rabbitbrush, with an understory of Great Basin wild rye.

Mount Hope Spring (Spring 619): This spring is located west of the preceding spring (Spring 604) and SR 278 between Garden Pass and the Mount Hope road turnoff at an elevation of approximately 7,175 feet amsl. The site consists of a buried steel pipe that daylights out of the hillside under a tree and runs above ground for about 30 feet to a cattle trough. The pipe is a permanent source of water for a partially buried cattle trough, which fully captures the inflow of water. The rate of inflow to the trough has been observed to vary by season, with a maximum recorded discharge of approximately 0.3 gpm in May 2006. The site vegetation community consists primarily of singleleaf piñon (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), and Wyoming big sagebrush.

Unnamed, next to monitoring well IGM-154 (Spring 631): This spring is located in close proximity to monitoring well IGM-154, and is approximately five miles southeast of SR 278 along the Garden Pass dirt road at an elevation of approximately 6,923 feet amsl. The site consists of a small gully with riparian vegetation that conveys water downgradient into two stock ponds, with no visible outflow of water from the stock ponds. This site was dry or frozen during all of SRK's quarterly visits except for August of 2006, when a flow of two gpm was recorded. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, and various unidentified forbs species. The site has a riparian area of approximately 200 square feet surrounded by dense Wyoming big sagebrush, and rubber rabbitbrush.

Unnamed (Spring 637): This spring is located one-half mile south of monitoring well IGM-154 and the preceding spring (Spring 631), and is approximately five miles southeast of SR 278 along the Garden Pass two-track dirt road at an elevation of approximately 7,001 feet amsl. The site consists of a small riparian corridor surrounded by piñon and juniper. Discharge from the spring was observed to be intermittent during SRK's quarterly site visits; when present, measured flows ranged from approximately 0.8 to 8.6 gpm (in March of 2007 and May of 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, and various forbs species. The site is surrounded by an upland dominant vegetative community including singleleaf piñon, Utah juniper, and Wyoming big sagebrush.

Unnamed (Spring 646): This spring is located south of the Mount Hope Mine office building and core shed, approximately one mile due south of monitoring well IGM-169 at an elevation of approximately 6,819 feet amsl. The site consists of a small (roughly two feet by two feet) depression in the soil that contains one to two feet of standing water. The site appears to be a permanent water feature with a seasonally-fluctuating water level in the depression. SRK was unable to obtain a flow measurement from this spring during the 2005-2007 quarterly site visits. The immediate vicinity of the spring is dominated by Mexican rush. The site is surrounded by singleleaf piñon, and Utah juniper.

Unnamed, Henderson Creek watershed (Spring 585): This spring is located on the southeast side of Roberts Mountains near the south fork of Henderson Creek at an elevation of approximately 7,557 feet amsl. During wet periods, water issues from several points of discharge along a generally straight line, possibly indicating a fault. Flows from these multiple sources are conveyed into a common channel for approximately one-half mile before joining Henderson Creek. A discharge of approximately two gpm was recorded in May of 2006, but no spring flow was observed during SRK's other quarterly visits to the site. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, and various forbs species.

Unnamed, Henderson Creek watershed (Spring 592): This spring is located south of the south fork of Henderson Creek at an elevation of approximately 6,953 feet amsl. The spring was reported to be perennial, with seasonal variation in flow. Recorded discharge during SRK's quarterly site visits ranged from less than 0.1 to nine gpm (in August 2006 and May 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, coyote willow (*Salix exigua*), and various forbs species.

Unnamed (Spring 610): This spring is located on the northwest slope of Henderson Summit near historical mine prospects identified on USGS topographic maps at an elevation of approximately 7,313 feet amsl. SRK reported that the spring is perennial, with seasonal variation in flow. Spring discharge accumulates in a sump that is covered by several logs. From this sump, the water flows approximately 60 feet downgradient into a small stock pond. Recorded discharge during SRK's quarterly site visits ranged from approximately 0.15 to two gpm (in March 2007 and May 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, coyote willow, and various forbs species. Upland dominant vegetation surrounding the spring site includes Wyoming big sagebrush, singleleaf piñon, and Utah juniper.

Unnamed (Spring 606): This spring is located near the preceding spring (Spring 610) on the northwest slope of Henderson Summit at an elevation of approximately 7,203 feet amsl. The spring consists of several points of discharge that converge and then dissipate approximately 75 feet downgradient from the source. A discharge of approximately 0.15 gpm was recorded in May 2006, but no spring flow was observed during SRK's other quarterly visits to the site. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, coyote willow, and various forbs species. Upland dominant vegetation surrounding the spring site includes Wyoming big sagebrush, singleleaf piñon, and Utah juniper.

Unnamed (Spring 609): This spring is located near the two preceding springs (Springs 610 and 606) on the northwest slope of Henderson Summit at an elevation of approximately 7,334 feet amsl. The spring's flow is intermittent. During wet periods, water issues from several points of discharge and is conveyed approximately 120 feet downgradient in several small, discrete channels before terminating in a small stock pond. Flow measurements have not been collected from the site due to the distributed nature of the discharge points. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, coyote willow, aspen trees (*Populus tremuloides*), and various forbs species. Upland dominant vegetation surrounding the spring site includes Wyoming big sagebrush, singleleaf piñon, and Utah juniper.

Unnamed, east of Roberts Creek in Kobeh Valley (Spring 1101): This spring is located in the northeast part of Kobeh Valley in an unnamed drainage approximately two miles west of the Project Area at an elevation of approximately 6,650 feet amsl. The spring site is developed and consists of a seep area with a series of cattle troughs that are fed by a black pipe, which is buried in a small hill behind the troughs. Two small stock ponds are located immediately downgradient of the seep area and troughs, and they collect water from the seep area. No water was observed flowing from the pipe and the cattle troughs were dry during SRK's quarterly site visits, although the area immediately surrounding the cattle troughs showed different degrees of saturation depending on the season. Due to consistently dry conditions, there have been no spring flow measurements at this site. The spring site consists of an unvegetated area disturbed by cattle, surrounded by upland vegetation.

Unnamed, east of Roberts Creek in Kobeh Valley (Spring 641): This spring is located approximately one mile north of the preceding spring (Spring 1101) in an unnamed drainage in the northeast part of Kobeh Valley, approximately 2.5 miles west of the Project Area at an elevation of approximately 6,901 feet amsl. Spring discharge accumulates in a sump and then flows approximately 150 feet downgradient in a single channel that terminates in a series of small stock ponds, with no apparent outlet for flow from the stock pond area. Based on persistent discharge during the quarterly site visits, SRK (2008a) inferred that the spring is perennial, with seasonal variation in flow. Recorded discharge during SRK's quarterly site visits ranged from less than 0.1 to 3.4 gpm (in August and October of 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, stinging nettles (*Urtica dioica*), and Nebraska sedge.

Unnamed, east of Roberts Creek in Kobeh Valley (Spring 630): This spring is located approximately one-half mile north of the preceding spring (Spring 641) in an unnamed drainage in the northeast part of Kobeh Valley, approximately three miles west of the Project Area at an elevation of approximately 7,142 feet amsl. Spring discharge issues from partially weathered limestone bedrock and is conveyed through a small channel approximately 300 feet downgradient before it disperses into a series of small stock ponds. Based on persistent discharge during the quarterly site visits, SRK (2008a) inferred that the spring is perennial, with seasonal variation in flow. Recorded discharge during SRK's quarterly site visits ranged from approximately 0.5 to 13.6 gpm (in March 2007 and May 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, and Nebraska sedge. The site is surrounded by an upland dominant vegetative community including singleleaf piñon, Utah juniper, and Wyoming big sagebrush.

Unnamed, east of Roberts Creek in Kobeh Valley (Spring 615): This spring is located approximately one mile north of the preceding spring (Spring 630) in an unnamed drainage in the northeast part of Kobeh Valley, approximately 3.5 miles west of the Project Area at an elevation of approximately 7,572 feet amsl. The site consists of a series of seeps with many points of discharge. During quarterly site visits, SRK noted that the spring area was **noticeably** impacted by wildlife and cattle. Water from the source area flows approximately 1,500 feet downgradient through approximately 30 acres of meadow area before dissipating in Kobeh Valley. Based on persistent discharge during the quarterly site visits, SRK (2008a) inferred that the spring is perennial, with seasonal variation in flow. However, flow measurements have not been collected from the site due to the distributed nature of the discharge points. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, and Nebraska sedge.

Unnamed, upper Henderson Creek watershed (Spring 579): This spring is located in the uppermost headwaters of the Henderson Creek watershed at an elevation of approximately 8,126 feet amsl. The spring's flow is intermittent. During wet periods, water issues from a small depression along a hill slope. A channel conveys flow to a series of low-lying natural depressions and overflow from this area spills into the upper reach of Henderson Creek. A small amount of discharge (less than 0.1 gpm) was recorded in May of 2006, but no spring flow was observed during SRK's other quarterly visits to the site. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Nebraska sedge, and wild iris (*Iris missouriensis*).

Unnamed, upper Henderson Creek watershed (Spring 574): This spring is located downgradient of the preceding spring (Spring 579) in the uppermost headwaters of the Henderson Creek watershed at an elevation of approximately 8,025 feet amsl. The spring water issues from a two-inch diameter steel pipe that is buried in the hillside and discharges to the upper reaches of Henderson Creek. Based on persistent discharge during the quarterly site visits, SRK (2008a) inferred that the spring flow is perennial. Recorded discharge during SRK's quarterly site visits ranged from approximately 1.7 to 5.5 gpm (in March of 2007 and August of 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Kentucky bluegrass, Great Basin wild rye, Nebraska sedge, wild iris, foothills lupine (*Lupinus ammophilus*), and Western Skunk cabbage (*Lysichiton americanus*).

Unnamed, upper Henderson Creek watershed (Spring 596): This spring is located in the second drainage south of, and approximately one-half mile from, Spring 579 in the uppermost headwaters of the Henderson Creek watershed at an elevation of approximately 8,039 feet amsl. Flow at this site issues from several sources within a large meadow, estimated at 100 acres in size. Water that accumulates in the meadow flows into a common channel, which reports to Henderson Creek. SRK (2008a) inferred that the spring is perennial, with seasonal variation in flow. Recorded discharge during SRK's quarterly site visits ranged from approximately 7.5 to 9.5 gpm (in October and August of 2006, respectively). The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, wild iris, foothills lupine, and Nebraska sedge.

Unnamed, upper Henderson Creek watershed (Spring 581): This spring is located approximately one-half mile south Spring 579 in the uppermost headwaters of the Henderson Creek watershed at an elevation of approximately 8,099 feet amsl. The spring's flow is intermittent. During wet periods, water issues from several points of discharge in a meadow approximately ten acres in size and collects in a single channel that reports to Henderson Creek. A discharge of approximately 23 gpm was recorded in May of 2006, but no spring flow was observed during SRK's other quarterly visits to the site. The primary vegetative community within the spring's riparian corridor consists of Mexican rush, Kentucky bluegrass, Great Basin wild rye, wild iris, foothills lupine, and Nebraska sedge. The site is surrounded by an upland dominant vegetative community that consists primarily of Wyoming big sagebrush.

3.2.2.3.3 Other Surface Water Features

There are no naturally occurring lakes or ponds within the HSA at present. However, several man-made surface-water impoundments exist within the study area and are primarily used for stockwater and irrigation purposes. The locations of surface water impoundments within the HSA are shown in Figure 3.2.8, based on field inspections and a review of USGS 7.5-minute topographic maps and NAIP aerial photography (Montgomery et al. 2010). The identified surface water impoundments that intermittently or perennially contain water include the following: 1) Tonkin Reservoir on upper Denay Creek, JD Ranch reservoirs on lower Henderson Creek and Pete Hanson Creek, and the Alpha Ranch impoundments of Henderson Creek and Chimney Springs in Pine Valley; 2) the Roberts Creek Ranch impoundment on Roberts Creek in Kobeh Valley; 3) the Shipley Hot Spring pond and the Flynn Ranch springs water impoundments in Diamond Valley; and 4) several small reservoirs on the upper Antelope Wash and its tributaries near the Segura Ranch in Antelope Valley. There may be other, smaller man-made impoundments in various drainages and downgradient of certain springs within the HSA that were not located in the field or identified on maps or aerial photographs.

Saline flats or playas exist where streams empty or ground water discharges into areas with no outflow. Temporary ponding occurs in such areas after snowmelt or prolonged rainfall, but the accumulated water typically soon evaporates.

3.2.2.4 Flood Hydrology

Flooding can occur in all seasons. Winter floods are caused primarily by large rainstorms falling on low-lying snow or frozen ground. Spring floods occur as warming temperatures melt the snow packs. Summer flash floods occur as the result of localized high-intensity rainfall from thunderstorms. These floods can deposit large volumes of debris and sediment on the valley uplands or valley floor and sometimes result in standing water in the playas.

Site-specific flood peak flows and total runoff volumes have not been estimated for all of the drainages described above. In the vicinity of Mount Hope, Hydro-Search (1982) evaluated peak discharge rate and time to peak discharge for 15 watersheds ranging in size from approximately 430 acres (Upper Tyrone Creek) to 12,315 acres (Garden Pass Creek). The 24-hour, 100-year peak flows for watersheds less than 2,000 acres in size were estimated to be approximately 400 to 600 cfs, and on the order of 1,000 to 3,600 cfs for larger watersheds such as Garden Pass Creek. Based on the estimates of storm runoff and general stream characteristics of the mountainous areas of Nevada, Hydro-Search (1982) indicated that the potential for flooding in the Mount Hope area as a result of 100-year flood events appears to be small. At upper elevations, the stream channels are well defined and gradients are relatively steep, which generally prevents overbank flow in the upper parts of the watersheds. Localized flooding is possible at lower elevations on the alluvial fans, particularly in the lower reaches of streams in Kobeh and Diamond Valleys, and in the Garden Valley subbasin.

3.2.2.5 Waters of the United States

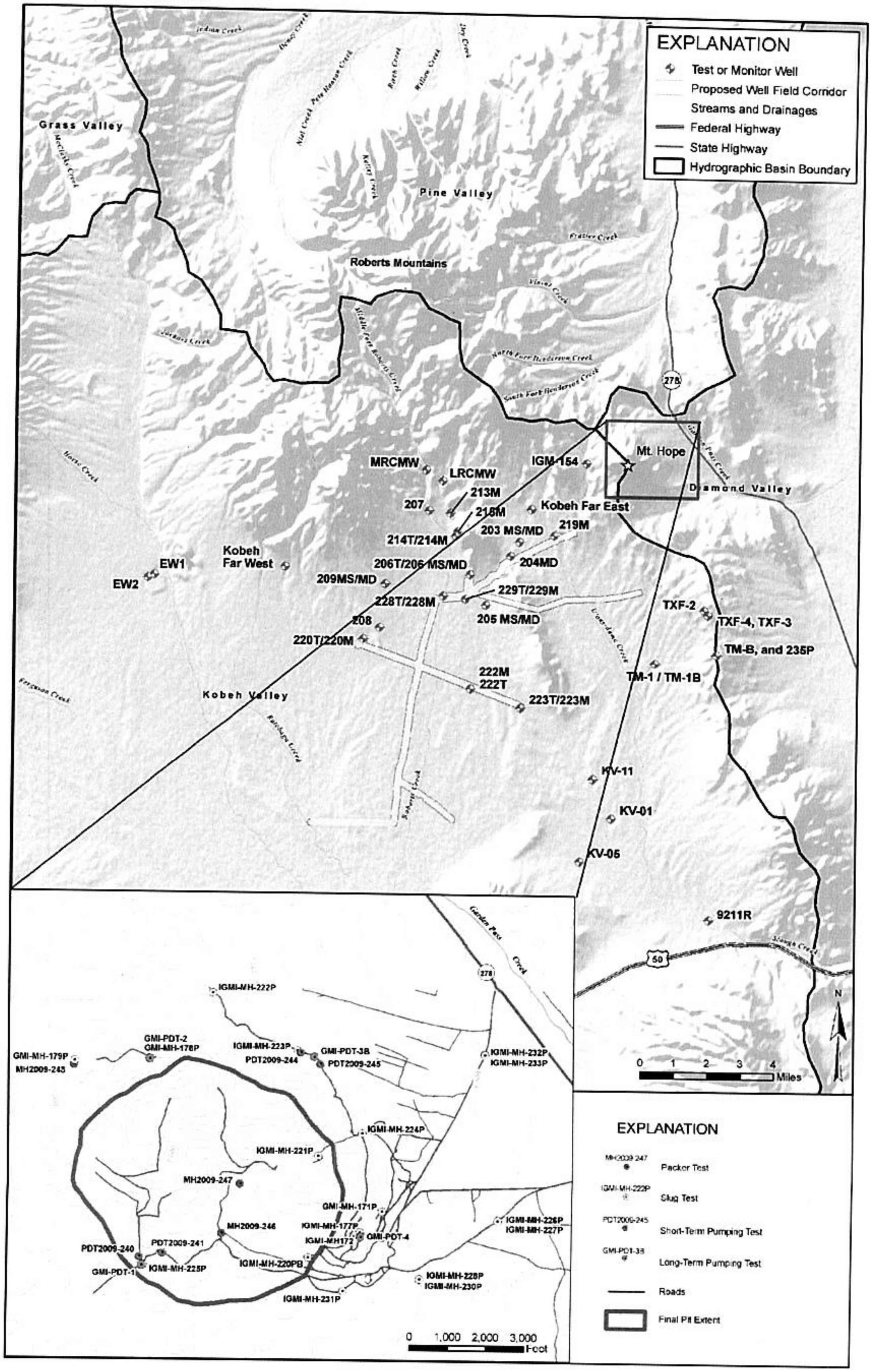
SRK (2007e) conducted a survey in September of 2005 to determine the presence or absence of waters of the U.S. and jurisdictional wetlands within the Project Area. Potential wetlands within the Project Area could be supported by spring and seep flow or ephemeral surface flows. The survey and wetlands delineations were performed in accordance with Section 404 of the CWA as administered by the USACE. The survey identified approximately 1,400 square feet (0.03 acre) of wetlands, and indicated that waters of the U.S. were not present within the Mount Hope Project Area. Based on the information in the SRK report, the USACE concurred that there are no jurisdictional waters of the U.S., including wetlands, within the surveyed area that would be regulated under Section 404 of the CWA (USACE 2007). The USACE noted that all tributaries originating from Mount Hope flow southerly into Kobeh Valley, which could ultimately flow into Diamond Valley via Slough Creek, or else flow easterly into Diamond Valley via Garden Pass Creek. The USACE determined that these are isolated, intrastate closed basins with no nexus to interstate commerce. **The current determination expires in 2012. EML has requested that the USACE extend their verification of the jurisdictional determination. The USACE has requested additional information prior to completing this verification.**

Within Pine Valley, Henderson and Vinini Creeks are the perennial drainages closest to the Project Area. In certain reaches, these creeks have defined channels, along with evidence that the drainages experience surface water flows on an average annual basis. These creeks ultimately discharge into Pine Creek, which is a tributary to the Humboldt River, a navigable waterway that is considered to be waters of the U.S.

3.2.2.6 Ground Water Resources

3.2.2.6.1 Hydrogeologic Setting

The Project Area and proposed water-supply well field (Figure 3.2.10) are located within the Diamond Valley Regional Flow System (Harrill et al. 1988), which consists of Antelope, Diamond, Kobeh, North and South Monitor Valleys, and Stevens Basin. These hydrographic basins are connected by surface and ground water flow and form an internally-drained hydrologic system that terminates in Diamond Valley. Ground water flowing into Diamond Valley is eventually discharged to springs, lost to ET from phreatophytic vegetation, consumed by pumping for agricultural, municipal, private, or industrial uses, or evaporated at the terminus of the flow system in the Diamond Valley playa. Pine Valley, to the north of the Project Area, is not part of this flow system, but is part of the Humboldt River drainage instead. Ground water resources of the HSA are mainly contained within the extensive valley-fill deposits of the hydrographic basins and, to a lesser extent, in the consolidated rocks that form the mountain blocks and underlie the valley-fill ground water systems of the valley floors.



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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Aquifer Testing and Monitoring Locations in Kobeh Valley and Near Mount Hope

Figure 3.2.10

3.2.2.6.2 Hydrolithologic Units and Properties

Recharge, storage, and movement of ground water are dependent, in part, on the geologic conditions and topography of a site. The general stratigraphic and structural framework of the HSA is described in Section 3.4, Geology and Minerals. For the purposes of characterizing the ground water conditions in the area, the various geologic formations have been grouped into seven hydrolithologic units (Montgomery et al. 2010). The general distribution of these units is presented in Figure 3.2.6, and their physical characteristics are summarized in Table 3.2-3. These seven hydrolithologic units include two distinct types of materials: consolidated rock (carbonate and dolomite, siliciclastic rocks and conglomerate, intrusive, and volcanic bedrock), and unconsolidated to poorly consolidated sediments (volcaniclastic and lacustrine sediments, alluvium, and valley-fill deposits). In the bedrock units, recharge, storage, flow, and discharge of ground water are primarily controlled by the secondary features (fractures, faults, and solution cavities) that have enhanced the overall porosity and permeability of the rock. In the unconsolidated to poorly consolidated sediments, the ground water is stored and transmitted through interconnected pores within the sediments.

Table 3.2-3: Hydrolithologic Units within the Study Area

Hydrolithologic Unit	Hydrogeologic Map Units[1] (Geologic Age)	Estimated Thickness (feet)	Lithology	General Hydrologic Characteristics
Valley-Fill Deposits	VF1 (Quaternary)	0 to >6,700 in Kobeh Valley	Alluvial fan, landslide, and floodplain deposits, playa silt and clay, terrace gravel, colluvium.	Hydraulic conductivity ranges from < **(less than)** 1 to > **(greater than)** 100 feet per day; specific yield is approximately 0.1. Permeability generally decreases with depth due to compaction.
Volcaniclastic Sediments	VF2 (Tertiary)	10 to 370	Primarily ash-flow and air-fall tuffs.	Hydraulic properties unknown; Unit generally acts as an aquitard within the HSA.
Lacustrine Sediments and Conglomerates	VF3 (Quaternary and Tertiary)	10 to >260	Claystone, sandstone, fresh-water limestone, and conglomerate.	Hydraulic properties unknown; Unit generally acts as an aquitard except where intensely fractured.
Volcanic Rocks	VOL1 (Tertiary)	0 to 1,000	Rhyolite tuffs, basalt and andesite/dacite lava flows.	Hydraulic conductivity typically ranges from 0.01 to 10 feet per day. Local slug tests in the Mount Hope area produced conductivity values of <0.00001 feet per day. Mafic dikes of the Northern Nevada Trend are considered to be low permeability.
Intrusive Rocks	VOL2 (Cretaceous to Jurassic)	-	Granodiorite, alaskite, quartz porphyry.	Hydraulic conductivity ranges from 0.0001 to approximately 3 feet per day. The larger conductivity values correspond to locally fractured rock.
Siliciclastic Rocks	AQT1 (Permian to Cambrian)	>5,000	Quartzite, sandstone, conglomerate, chert, shale, and minor limestone.	Hydraulic conductivity ranges from <0.00001 to 100 feet per day; storage coefficient ranges from 0.00001 to 0.03. The upper values of the ranges correspond to locally fractured rock.

Hydrolithologic Unit	Hydrogeologic Map Units[1] (Geologic Age)	Estimated Thickness (feet)	Lithology	General Hydrologic Characteristics
Carbonate Rocks	CA1, CA2, CA3, CA4 (Devonian to Cambrian)	>9,000	Limestone, dolomite, siltstone, mudstone, chert, quartzite, and shale.	Hydraulic conductivity ranges from 0.005 to 900 feet per day; storage coefficient ranges from 0.00002 to 0.014. Permeability is mostly secondary due to fracturing and solution widening.

[1] See Figure 3.2.6 for distribution of hydrolithologic units.
Sources: Belcher et al. (2001); Harrill and Prudic (1998); Interflow (2010); Maurer et al. (1996); Montgomery et al. (2010); Plume (1996); Winograd and Thordarson (1975).

Bedrock Units

The carbonate hydrolithologic units correlate to the eastern assemblage Paleozoic rocks discussed in Section 3.4, Geology and Minerals. Montgomery et al. (2010) define four carbonate hydrolithologic units within the HSA: 1) the lower eastern assemblage formations (Eureka Quartzite, Pogonip Group, and Hamburg Dolomite), which are deeply buried throughout Kobeh Valley and are exposed within the HSA only at Lone Mountain; 2) the Roberts Mountains and Lone Creek Dolomite Formations, which both crop out on the flanks of Lone Mountain in Kobeh Valley and also in isolated blocks on the north side of the Roberts Mountains in Pine Valley; 3) the Nevada, McColley Canyon Formation, and Denay Limestone Formation, which crop out in the Roberts Mountains, Sulphur Spring Range, and Lone Mountain area of Kobeh Valley; and 4) the Devils Gate Limestone, which crops out in the Roberts Mountains, Devils Gate area, and Mahogany Hills. Where sufficiently fractured or dissolved, these units may provide large quantities of water to wells or springs.

The hydrologic properties of carbonate rocks in the northern part of Kobeh Valley were evaluated by Interflow (2010) as part of the baseline characterization of hydrogeologic conditions in the proposed well field area. Figure 3.2.10 shows the locations of wells used in aquifer tests in the northern part of Kobeh Valley and near the proposed open pit at Mount Hope. Aquifer pumping tests were conducted for periods ranging from seven to 32 days on three test production wells (206T, 214T, and 220T) completed in the carbonate bedrock. Aquifer test data from the proposed well field area indicate that the local hydraulic conductivity of the carbonate bedrock generally ranges between eight and 18 feet per day and the storage coefficient is estimated to range from 0.0001 to 0.002. During testing of one of the wells (206T), a hydraulic conductivity value of 254 feet per day was estimated based on the early-time test data; however, the rate of drawdown increased with time as the test continued and the corresponding estimated hydraulic conductivity values decreased to approximately nine feet per day during the later part of the test (Interflow 2010), consistent with the range of values listed above for carbonate rocks in the northern part of Kobeh Valley. Interflow interpreted this behavior to indicate that the well was pumping from a highly permeable zone of fractured or dissolved carbonate rock that is also limited in its areal extent by barriers to ground water flow (i.e., compartmentalized).

The carbonate aquifer is a regionally extensive hydrolithologic unit in large portions of eastern and central Nevada. Aquifer test results throughout the region indicate that the carbonate aquifer has a wide range of hydraulic conductivity. For example, in the Carlin Trend area, just north of

Pine Valley, the hydraulic conductivity and storage coefficient of the carbonate aquifer units are estimated to range from 0.1 to 150 feet per day and 0.00002 to 0.014, respectively (Maurer et al. 1996). At the Nevada Test Site, the carbonate aquifer has an estimated hydraulic conductivity that ranges from 0.7 to 700 feet per day (Winograd and Thordarson 1975). Harrill and Prudic (1998) and Plume (1996) reported values of hydraulic conductivity for carbonate aquifer regions of eastern Nevada that range from 0.005 to 900 feet per day.

The siliciclastic hydrolithologic unit correlates to the western assemblage Paleozoic rocks of the Webb and Vinini Formations and the Garden Valley Formation of the Overlap assemblage as described in Section 3.4, Geology and Minerals. This hydrolithologic unit is composed of chert, shale, calcareous sandstone, silica-cemented conglomerate, and quartzite, with minor amounts of fine-grained limestone. Within the HSA, siliciclastic rocks are exposed on the west side of the Sulphur Spring Range and north side of the Roberts Mountains in Pine Valley, on the southwestern flanks of the Roberts Mountains and northern part of the Simpson Park Mountains in Kobeh Valley, at Mount Hope and Whistler Mountain, and in the Diamond Mountains on the east side of Diamond Valley. Except in windows where these rocks have been removed by uplift and erosion, the siliciclastic hydrolithologic units generally overlie the carbonate hydrolithologic units. Where sufficiently fractured, the siliciclastic rocks may be water bearing. However, in general, this hydrolithologic unit is thought to have limited water production potential and is interpreted to typically act as an aquitard (Montgomery et al. 2010).

Site-specific hydrologic property values for siliciclastic rocks (primarily Vinini Formation) were determined from slug, packer, and pumping tests performed in core holes, piezometers, and completed wells in the vicinity of Mount Hope and the proposed open pit (Montgomery & Associates 2010). The results indicate a range of hydraulic conductivities for the various geologic media in that area, which included some volcanic and metamorphic rocks. Slug tests in three piezometers (228P, 231P, and 232P) in the Vinini Formation outside of the proposed open pit area produced hydraulic conductivity values ranging from approximately 0.0002 to 0.15 feet per day. Packer tests in a deep core hole (248) in the Vinini Formation outside of the proposed open pit showed hydraulic conductivity ranging from a value of one foot per day at a depth of approximately 434 feet bgs to a value of less than 0.00001 feet per day at a depth of approximately 3,000 feet bgs. Short-term pumping tests in two monitor wells (240 and 241) completed in the Vinini Formation (and some metamorphic rock) near the boundary of the proposed open pit produced estimated hydraulic conductivity values of 0.00067 and 0.26 feet per day. Longer term pumping tests in two test-production wells (PDT-1 and PDT-2) completed in the Vinini Formation (and rhyolite tuff) near the proposed open pit boundary were analyzed using the dual-porosity method of Moench (1984). Based on that analysis, the hydraulic conductivity of fractures was estimated to range from approximately 0.005 to 0.2 feet per day, and matrix hydraulic conductivity was estimated to range from approximately 0.0001 to 0.0003 feet per day. The fracture-specific storage ranged from 3.7^{-10} to 3.5^{-06}, whereas the matrix-specific storage ranged from 8.3^{-07} to 2.3^{-03}.

No aquifer tests have been conducted in rocks of the siliciclastic hydrolithologic unit elsewhere within the HSA except for the Mount Hope area because these rocks typically are not targets for water production. In the Carlin Trend, reported ranges of hydraulic conductivity and storage coefficient are approximately 0.001 to 100 feet per day and 0.00001 to 0.03, respectively, for similar rocks (Maurer et al. 1996). In general, except along faults and fracture zones, the hydraulic conductivities of siliciclastic rocks are low and they tend to act as barriers to regional ground water flow (Plume 1996).

Rocks comprising the volcanic hydrolithologic unit include Tertiary rhyolitic tuffs, basalt, andesite, and dacite lava flows. Within the HSA, volcanic rocks primarily occur as follows: in the Monitor and Antelope Ranges of Antelope Valley; at the northern end of the Monitor Range and in the southern part of the Simpson Park Mountains in Kobeh Valley; in the northern part of the Simpson Park Mountains and on the east side of the Cortez Mountains in Pine Valley; and in the central and eastern parts of the Roberts Mountains, generally along the north-northwest trend of the Northern Nevada Rift. Scattered outcrops of volcanic rocks also exist in Diamond Valley. Volcanic rocks also underlie basin-fill deposits in each of the basins of the study area at different depths (Tumbusch and Plume 2006).

Site-specific hydrologic property values for volcanic rocks (primarily rhyolite tuff) were determined from slug tests and pumping tests performed in piezometers and completed wells in the vicinity of Mount Hope and the proposed open pit (Montgomery & Associates 2010). The results indicate a wide range of hydraulic conductivities for the volcanic rocks in that general area. Slug tests in three piezometers (227P, 230P, and 233P) in unaltered rhyolite tuff outside of the proposed open pit produced hydraulic conductivity values ranging from 0.0000027 to 0.000094 feet per day. Short-term pumping tests in two monitoring wells (244 and 245) completed in rhyolite tuff near the boundary of the proposed open pit produced estimated hydraulic conductivity values of 0.25 and 0.44 feet per day. A long-term (26-day) pumping test conducted in a test-production well (PDT-3B) completed in rhyolite tuff near the proposed open pit boundary resulted in an estimated fracture hydraulic conductivity of 0.1 feet per day and an estimated matrix hydraulic conductivity of 0.000005 feet per day, based on the dual-porosity method of analysis (Moench 1984).

The hydraulic conductivity of volcanic rocks in the Carlin Trend area range from 0.01 to ten feet per day (Maurer et al. 1996). At the Nevada Test Site, measured values of the hydraulic conductivity of volcanic rocks, consisting of lava flows and ash-fall tuffs, range from approximately 1.5 to 17 feet per day (Winograd and Thordarson 1975). Plume (1996) reported that 54 drill-stem tests in volcanic rocks in the Railroad and White River Valleys in eastern Nevada produced hydraulic conductivity values that range from 0.000001 to 0.3 feet per day, with a mean value of 0.02 feet per day.

Tumbusch and Plume (2006) indicate that volcanic rocks probably have low permeability over much of the study area, citing the number of perennial stream segments underlain by volcanic rocks that exist within watersheds in the southern part of the Diamond Valley Flow System.

The intrusive hydrolithologic unit primarily consists of Jurassic to Tertiary granitic rocks. Within the HSA, intrusive igneous rocks are exposed in the central Simpson Park Mountains, at Whistler Mountain on the southwest side of Diamond Valley, and in the Cortez Mountains on the west side of Pine Valley. Igneous intrusive rocks (quartz porphyry) also occur locally at Mount Hope. The extent of the outcrop area of these rocks generally does not indicate the full extent of the intrusive body in the subsurface.

Site-specific hydrologic property values for intrusive rocks (quartz porphyry mixed with altered tuffs and hornfels) were determined from packer tests of two core holes (246 and 247) in the vicinity of Mount Hope and the proposed open pit (Montgomery & Associates 2010). The tested depths ranged from approximately 560 to 2,760 feet bgs. Based on the packer-test results, hydraulic conductivity values were estimated to range from 0.0001 to 0.1 feet per day, with the smaller values generally corresponding to the upper (potassic) zones and the higher values correlated with the lower (silicic) zones of the core holes.

No aquifer tests have been conducted in rocks of the intrusive hydrolithologic unit within the HSA because these rocks typically are not targets for water production. Reported hydraulic conductivity values of granodiorite intrusions in the Carlin Trend area are approximately three to five feet per day where the rocks are highly fractured (Maurer et al. 1996). However, where fracturing is less extensive, intrusive rocks generally have very low permeability and impede the movement of ground water (Plume 1996). Belcher et al. (2001) report horizontal hydraulic conductivity values from 0.002 to 3.3 feet per day for Jurassic to Oligocene granodiorite, quartz monzonite, granite, and tonalite in southern Nevada and parts of California.

Basin Fill Deposits

The basin-fill (or valley-fill) hydrolithologic units consist of heterogeneous mixtures of fine-, medium-, and coarse-grained material eroded from mountain ranges and deposited in adjacent basins. Montgomery et al. (2010) define three basin-fill hydrolithologic units within the HSA, all of which are of late Tertiary to Quaternary: 1) younger and older alluvium, 2) volcaniclastic sediments, and 3) lacustrine deposits. The younger and older alluvium hydrolithologic unit comprises unconsolidated to semi-consolidated deposits of alluvial fans, landslides, stream flood plains, playas, and terrace deposits, which are locally interbedded with volcaniclastic sediments. The volcaniclastic sediment hydrolithologic unit consists primarily of reworked ash-flow or air-fall tuffs. The lacustrine deposit hydrolithologic unit includes claystone, sandstone, fresh-water limestone, and conglomerate. Within the HSA, these units partially fill the structural basins between mountain ranges.

The hydrologic properties of the younger and older alluvial sub-units of the basin-fill units in the northern part of Kobeh Valley were evaluated by Interflow (2010) as part of the baseline characterization of hydrogeologic conditions in the proposed well field area. Volcanoclastic and lacustrine units were not evaluated in the HSA and are generally not considered to be major water producing units. Aquifer pumping tests were conducted for periods ranging from five to seven days on three test production wells (222T, 228T, and 229T) completed in the alluvium of the proposed well field area. The completed intervals of the test wells ranged from 240 to 990 feet bgs. Aquifer test data from those wells indicate that the hydraulic conductivity of the alluvium in the well field area range from five to 19 feet per day and the storage coefficient is estimated to range from 0.0001 to 0.005. Montgomery & Associates (2008) evaluated short-term (approximately two hours to one day) aquifer tests conducted in three alluvial wells (9211R, EW-1, and KV-11) in eastern Kobeh Valley that were drilled as part of previous exploration efforts. The completed intervals of the test wells range from approximately 40 to 800 feet bgs. Reported hydraulic conductivity values of alluvium estimated from those aquifer tests range from six to 57 feet per day. In other basins of central and eastern Nevada, the estimated hydraulic conductivity of basin-fill deposits ranges from less than one foot per day to more than 100 feet per day (Plume 1996).

3.2.2.6.3 Hydrostructural Features

Ground water flow pathways are influenced by major faults and by complexities of the geologic environment that offset and displace rock units and older alluvial deposits. Depending on the physical properties of the rocks involved, faulting may create either barriers or conduits for ground water flow. For example, faulting of softer, less competent rocks typically forms zones of crushed and pulverized rock material (gouge) that behave as barriers to ground water movement. Faulting of hard, competent rocks often creates conduits along the fault trace, resulting in zones of higher ground water flow and storage capacity along the fault trace compared to the unfaulted surrounding rock.

Interflow (2010) describes three types of faults in the HSA that can be hydrologically important: thrust faults, normal faults, and young faults. The thrust faults are generally oriented north-south and reflect the eastward thrusting of western assemblage siliciclastic rocks over eastern assemblage carbonate rocks. In some cases, thrust fault contacts have fine-grained gouge and may also be associated with mineralization, both of which can reduce the permeability of the fault zone relative to the surrounding rocks. The tectonic activity that produced Basin and Range block faulting resulted in numerous northwest to southeast and conjugate east-northeast to west-southwest-trending high-angle normal faults. In the Roberts Mountains, some of these structures are thought to have provided conduits for the upward movement of mineralized fluids. Such mineralization associated with faults and the juxtaposition of rocks with contrasting hydraulic properties can create barriers to ground water movement, which lead to horizontal compartmentalization of the preexisting Paleozoic sedimentary rocks. Young faults are Quaternary structures that often act as conduits for ground water flow due to their relatively recent formation. Young faults in the HSA, as mapped by Dohrenwend et al. (1996), are located on the west side of the Roberts Mountains; on the north, south, and southwest sides of Lone Mountain; in the south-central part of the Roberts Mountains; and on the eastern side of Kobeh Valley.

As described in Section 3.4, Geology and Minerals, three Quaternary faults have been mapped within ten miles of the Project Area. Another group of normal faults in the Garden Valley area appear to down-drop to the Quaternary deposits of Garden Valley and place them in contact with Paleozoic and Tertiary bedrock of the Roberts Mountains and Sulphur Spring Range. A northwest-striking fault that follows the southwestern flank of the Roberts Mountains approximately ten miles southwest of Mount Hope is a major range front fault that appears to continue to the southeast beneath the piedmont-slope deposits of northern Kobeh Valley. None of these faults has been studied in detail and very little is known concerning their nature, movement history, and hydrogeologic behavior.

Dikes of basaltic composition have intruded fractures in carbonate rocks of the Roberts Mountains in a north-northwest-trending zone approximately six miles long and three to four miles wide, which are part of the Northern Nevada Rift. The average width of individual dikes is less than ten feet, although some are as wide as 50 feet, with lengths ranging from a few hundred feet to one or two miles (Tumbusch and Plume 2006). The hydrologic effect of the dikes is that they have reduced the fracture porosity and permeability of the carbonate rocks. The inferred extent of the zone of dikes across Kobeh Valley to the southeast, at least as far as the northern end of the Fish Creek Range, means that the dikes may create major barrier to ground water flow in these areas of carbonate rocks.

3.2.2.6.4 Ground Water Elevations and Flow Directions

Montgomery et al. (2010) compiled water level data for the HSA basins from published and unpublished sources. The majority of water level records were obtained from the USGS National Water Information System (NWIS) database (NWIS 2007). Some records were obtained from piezometers and monitoring wells in the Mount Hope area (Montgomery & Associates 2010) and from data published in USGS and Nevada Department of Natural Resources Reconnaissance Series Reports (Eakin 1961 and 1962; Rush and Everett 1964). Harrill (1968) was used as a source of historic water level data for Diamond Valley. Additional historic and more recent (2005) data for Antelope, Diamond, Kobeh, Pine, and North and South Monitor Valleys were obtained from Tumbusch and Plume (2006). In total, more than 4,400 water level measurements were assembled into an electronic database for this study, which includes data from 551 locations and spans the time period from 1900 to 2009 (Montgomery et al. 2010, Appendix F).

The locations of wells used to define ground water elevations in the basin-fill aquifers of the HSA under pre-development conditions (circa 1955) are shown in Figure 3.2.11. Contours of ground water elevations under pre-development conditions show that northward trending ground water flows from North Monitor and Antelope Valleys and easterly trending ground water flows from the Simpson Park Mountains and southerly trending ground water flows from the Roberts Mountains converge to an area of ground water discharge by ET in central and eastern Kobeh Valley. Ground water not discharged by ET in Kobeh Valley would have been directed eastward toward Devil's Gate and then eventually into the southern part of Diamond Valley at that time. Prior to irrigation development in the 1960s, ground water flow in Diamond Valley was from valley margins toward the valley axis and then northward to the large playa discharge area at the north end of the valley. In the Pine Valley basin, the primary flow pattern was laterally inward from the mountains toward the axis of the valley and then to the northeast, generally following the course of Pine Creek toward the Humboldt River.

The ground water elevations in the basin-fill aquifers of the HSA in 2005, interpreted from the available data, are shown in Figure 3.2.12. The 2005 water levels in North Monitor, Antelope, Kobeh, and Pine Valleys are interpreted to be generally the same as those shown for pre-development conditions (Figure 3.2.11). However, after approximately 40 years of agricultural pumping, a large area of ground water decline has developed in the basin-fill aquifer of southern Diamond Valley around the irrigated area, and the decline has created a divide between northward flow to the playa discharge area and southward flow to the pumped area. Tumbusch and Plume (2006) report that in 2005 water levels in the southern part of Diamond Valley exhibited a decline of as much as 90 feet relative to pre-irrigation development conditions. According to Montgomery et al. (2010), the water level data compiled for this study indicate that historic and continuing rates of water level declines range from approximately 1.3 to 3.3 feet per year for the wells in southern Diamond Valley.

In the proposed Mount Hope open pit area, ground water levels were measured in approximately 40 piezometers and wells between 2007 and 2009 (Montgomery & Associates 2010). The measured ground water elevations range from greater than 7,200 feet amsl near the summit of Mount Hope to less than 5,800 feet amsl approximately six miles east of the summit in Diamond Valley. The ground water elevations and directions of movement in the proposed open pit area appear to be correlated with topography, and a local ground water divide may exist approximately one mile northwest of the proposed open pit (Montgomery & Associates 2010). Locally confined ground water conditions have been encountered at a few locations in the vicinity of the proposed open pit, with some recorded water pressures corresponding to hydraulic heads nearly 200 feet above the local ground surface.

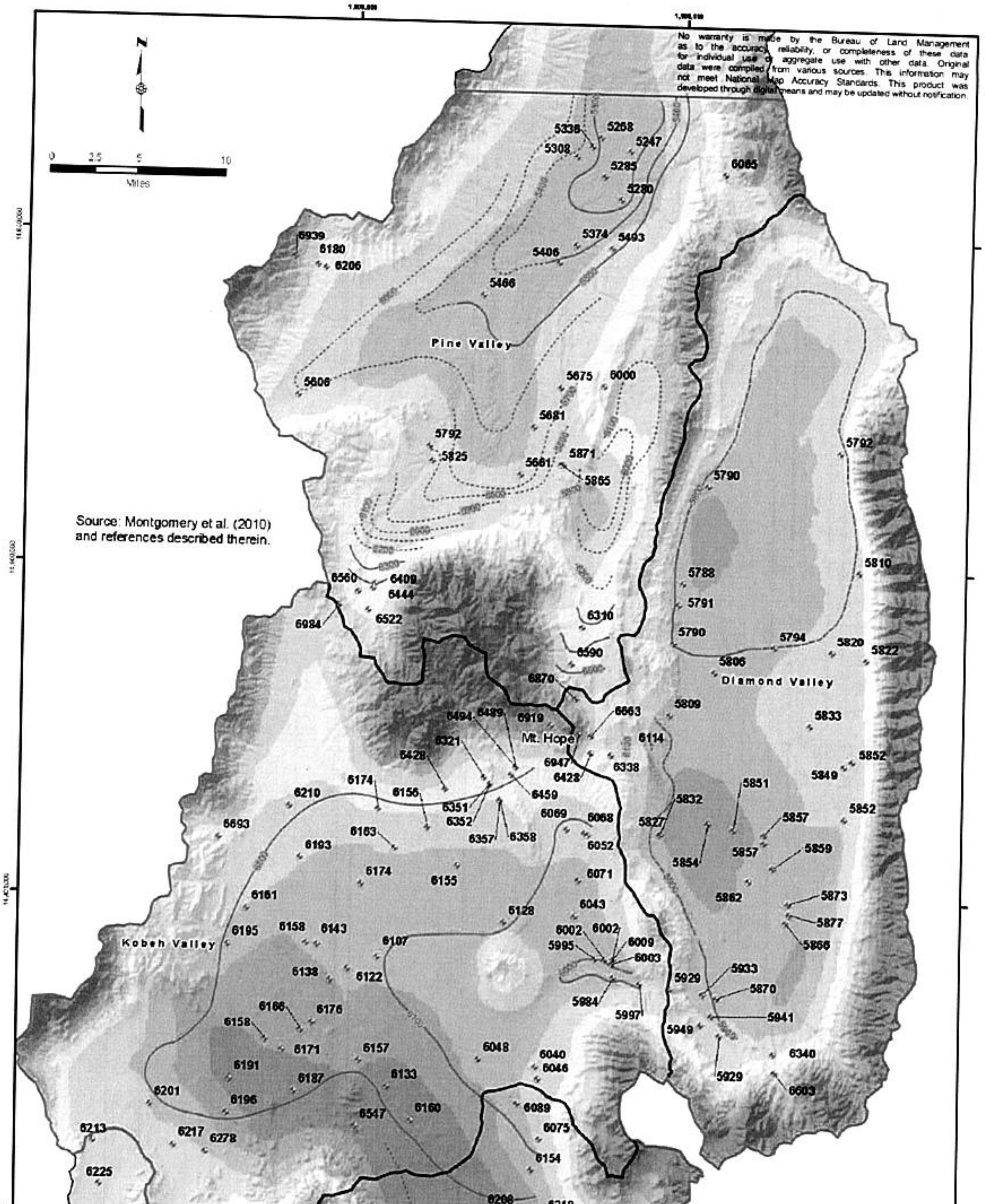
Flowing (artesian) wells also have been encountered in each of the basins in the HSA and their reported locations are shown on the individual basin detail maps (Figures 3.2.2 through 3.2.5). In the 1960s, the estimated individual discharges from 14 flowing wells within the HSA ranged from approximately five to 233 gallons per minute (Montgomery et al. 2010).

3.2.2.6.5 Ground Water Recharge and Discharge

Inflow and outflow from the ground water system were estimated by Montgomery et al. (2010) to establish a baseline water balance for the HSA. The estimated average annual ground water budgets for pre-development (circa 1955) and existing (2009) conditions are presented in Tables 3.2-4 and 3.2-5, respectively. Existing ground water inflow components include precipitation recharge and subsurface inflow from North Monitor Valley across the southern HSA boundary into Kobeh Valley. Ground water outflow components include the following: **ET** from phreatophyte areas in each of the HSA basins; evaporation from the playa area at the north end of Diamond Valley; ground water withdrawal for irrigation, municipal, domestic, and mining uses; discharge at springs and seeps; and subsurface outflow across the northern HSA boundary in Pine Valley.

The largest contribution to ground water recharge comes from precipitation in the mountain ranges of the HSA, with stream runoff from snowmelt considered to be part of that contribution. As is typical in Nevada, the higher elevations generally receive more rain and snow than lower elevations. This increase in precipitation at higher elevations recharges the bedrock aquifers and local perched systems through fractures in the bedrock outcrops or where bedrock is a porous sedimentary or volcanic unit. Where streams emerge from the mountains, some of the stream flow is lost as water infiltrates and recharges the alluvium.

Recharge to the ground water system from direct precipitation was estimated using an empirically-derived relationship between precipitation, recharge, and altitude developed by Maxey and Eakin (1949) and Eakin et al. (1951). The Maxey-Eakin relationship is based on a distribution of average annual precipitation into zones, with the amount of ground water recharge in each zone determined by empirically-derived recharge coefficients. For this study, the precipitation-altitude relationships and recharge coefficients reported in the USGS and Nevada Department of Natural Resources Reconnaissance Series Reports (Eakin 1961 and 1962; Rush and Everett1964) and in Harrill (1968) were utilized in combination with more recent (updated) calculations of precipitation-zone areas to estimate recharge for each basin in the HSA. The methodology used to estimate recharge is described in Montgomery et al. (2010). On the basis of the updated Maxey-Eakin calculations, and accounting for the spatial distribution of recharge to different landforms, the total recharge to the HSA is estimated to be approximately 75,900 afy (Tables 3.2-4 and 3.2-5).



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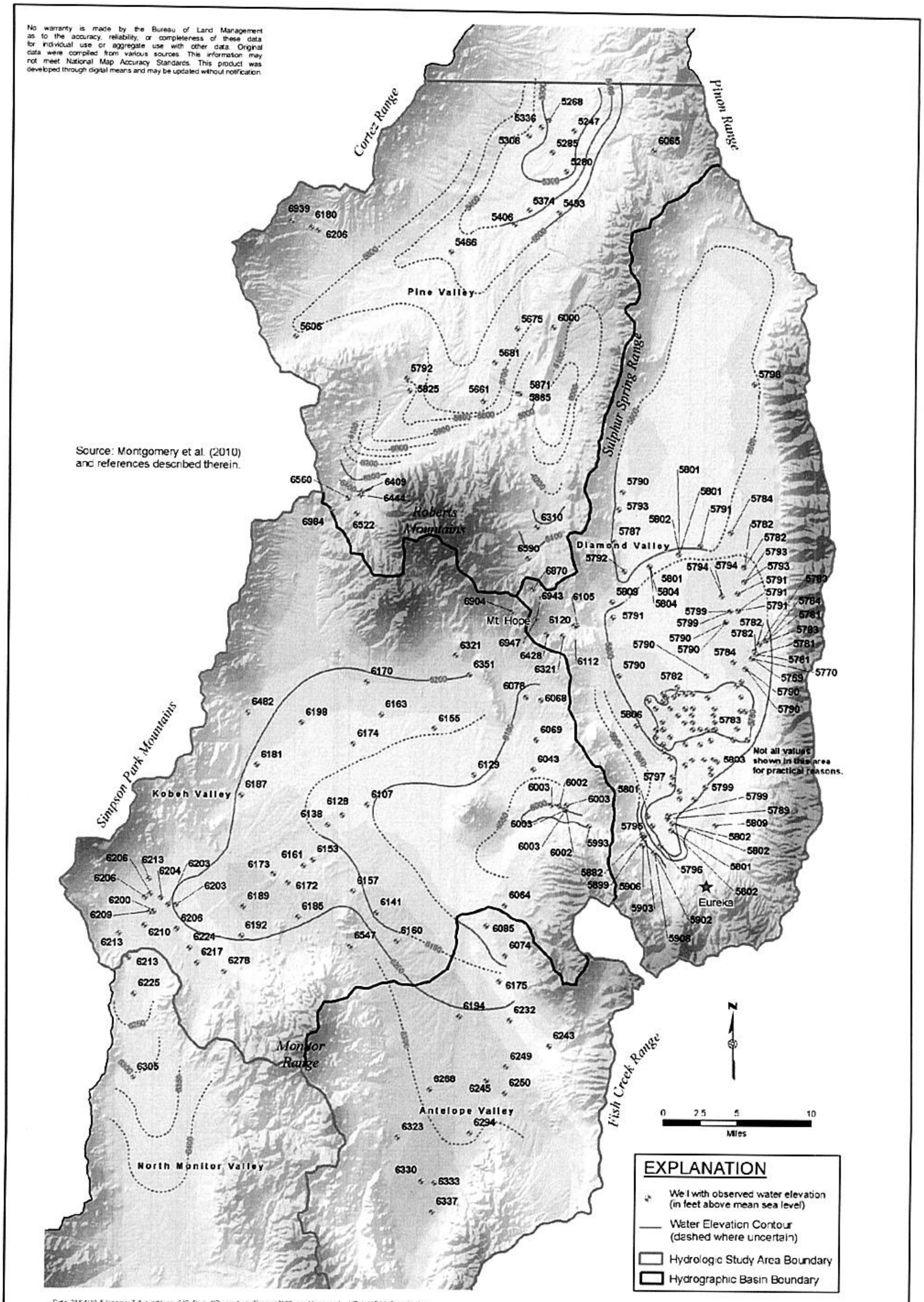

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BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

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Hydrologic Study Area Basin-Fill Aquifer Ground Water Elevations in 2005

Figure 3.2.12

Table 3.2-4: Pre-Development (circa 1955) Estimated Annual Ground Water Budget for Individual Basins and the Entire HSA[1]

Budget Component	Antelope Valley	Diamond Valley	Kobeh Valley	Pine Valley (within HSA)	Entire HSA
Ground Water Inflow[2] (afy)					
Precipitation Recharge[4]	4,100	21,400	13,200	34,900	73,600
Subsurface Inflow[5]	0	7,300 (5,700 from Pine Valley and 1,600 from Kobeh Valley)	4,600 (1,400 from Monitor Valley, 2,700 from Antelope Valley, and 500 from Pine Valley)	0	1,400 (from Monitor Valley to Kobeh Valley)
Total Inflow	**4,100**	**28,700**	**17,800**	**34,900**	**75,000**
Ground Water Outflow[2] (afy)					
Evapotranspiration[3,6]	1,400	27,600	16,200	17,100	62,300
Net Ground Water Pumping[7]	negligible	800	negligible	negligible	800
Subsurface Outflow[5]	2,700 (to Kobeh Valley)	0	1,600 (to Diamond Valley)	17,500 (5,700 to Diamond Valley, 500 to Kobeh Valley, and 11,300 to northern Pine Valley)	11,300 (from southern to northern Pine Valley)
Total Outflow	**4,100**	**28,400**	**17,800**	**34,600**	**74,400**
Inflow - Outflow	**0**	**300**	**0**	**300**	**600**

[1] Estimation based on sources of data and methods described in Montgomery et al. (2010), including results from the calibrated numerical ground water model.
[2] Values rounded to nearest 100 afy.
[3] Includes ET from phreatophyte areas and evaporation from playas and spring discharge.
[4] Source: Montgomery et al. (2010), Table 4.1-5.
[5] Source: Montgomery et al. (2010), Table 4.1-13.
[6] Source: Montgomery et al. (2010), Table 4.1-12.
[7] Source: Montgomery et al. (2010), Table 3.5-4.

Table 3.2-5: 2009 Estimated Annual Ground Water Budget for Individual Basins and the Entire HSA[1]

Budget Component	Antelope Valley	Diamond Valley	Kobeh Valley	Pine Valley (within HSA)	Entire HSA
Ground Water Inflow[2] (afy)					
Precipitation Recharge[4]	4,100	21,400	13,200	34,900	73,600

Budget Component	Antelope Valley	Diamond Valley	Kobeh Valley	Pine Valley (within HSA)	Entire HSA
Subsurface Inflow[5]	0	7,800 (5,800 from Pine Valley and 2,000 from Kobeh Valley)	4,800 (1,600 from Monitor Valley, 2,700 from Antelope Valley, and 500 from Pine Valley)	0	1,600 (from Monitor Valley to Kobeh Valley)
Total Inflow	**4,100**	**29,200**	**18,000**	**34,900**	**75,200**
Ground Water Outflow[2] (afy)					
Evapotranspiration[3,5]	1,400	14,700	15,900	17,100	49,100
Net Ground Water Pumping[6]	negligible	55,800	2,900	negligible	58,700
Subsurface Outflow[5]	2,700 (to Kobeh Valley)	0	2,000 (to Diamond Valley)	17,600 (5,800 to Diamond Valley, 500 to Kobeh Valley, and 11,300 to northern Pine Valley)	11,300 (from southern to northern Pine Valley)
Total Outflow	**4,100**	**70,500**	**20,800**	**34,700**	**119,200**
Inflow - Outflow	**0**	**-41,300**	**-2,800**	**200**	**-44,000**

[1] Estimation based on sources of data and methods described in Montgomery et al. (2010), including results from the calibrated numerical ground water model.
[2] Values rounded to nearest 100 afy.
[3] Includes ET from phreatophyte areas and evaporation from playas and spring discharge.
[4] Source: Montgomery et al. (2010), Table 4.1-5.
[5] Source: Montgomery et al. (2010), Table 4.4-4.
[6] Source: Montgomery et al. (2010), Figure 4.4-2.

Another source of inflow to the ground water system of the HSA is subsurface flow that enters Kobeh Valley from the adjacent North Monitor Valley to the south. The amount of subsurface flow from North Monitor Valley to Kobeh Valley is estimated to be approximately 1,900 afy under existing (2009) conditions (Montgomery et al. 2010), as shown in Table 3.2-5.

As shown in Table 3.2-4, ET is the primary mechanism of ground water loss from the HSA. Evaporation takes place from soil, wet plant surfaces, and open water bodies, whereas transpiration occurs by the action of plants. ET of ground water happens in areas where the water table is shallow, including areas near springs and seeps and along the valley floors of the HSA basins. Plants that send their roots to the water table and depend upon a constant supply of ground water are termed phreatophytes. Some phreatophytes, such as greasewood (*Sarcobatus* spp.), commonly send their roots as deep as 50 feet to the water table, although depths of up to 80 feet were reported by Eakin et al. (1951). **Rabbitbrush (*Chrysothamnus* and *Ericameria* spp.) is also considered a phreatophyte, although it has a dimorphic root structure with fine roots in the upper soil profile and woody tap roots that extend to near the water table at greater than 13-foot depths, however, depths of up to 48 feet have been reported**

(McLendon 2011). The existing phreatophyte areas in the HSA are mainly found along the axial drainages of Antelope, Kobeh, and Pine valleys and surrounding the playa areas in the northern part of Diamond Valley. The depth to water, vegetation type and density, soil characteristics, and climatic factors all influence the amount of ground water that phreatophytes transpire. Including evaporation from playa areas and spring and seep discharges, the total ET for the HSA under pre-development (circa 1955) conditions is estimated to be approximately 62,300 afy (Table3.2-4), and is approximately 49,100 afy under existing (2009) conditions (Table 3.2-5), as described in Montgomery et al. (2010).

Other sources of natural ground water outflow include subsurface flow from the southern part of Pine Valley across the northern boundary of the HSA. The amount of subsurface flow from the southern part of Pine Valley across the northern boundary of the HSA is estimated to be approximately **11,300** afy under existing (2009) conditions (Montgomery et al. 2010), as shown in Table 3.2-5.

3.2.2.6.6 Ground Water Uses

Pumping withdrawals for irrigation, municipal, domestic, and mining uses account for the greatest amount of the ground water discharges from the HSA. Available data indicate that the distribution and amount of ground water pumping within the HSA has increased over time.

Development of ground water resources in Diamond Valley began in 1949, when two wells were installed along the eastern boundary of the valley (Eakin 1962). Additional wells installed prior to 1960 were located primarily along the periphery of the valley to augment flows from springs. An estimated 238 wells had been drilled in Diamond Valley by the end of 1965, with over 150 of those wells drilled between 1960 and 1965. Although numerous, the wells were not heavily pumped until 1972, when electrical power became available in Diamond Valley to supplement wind and diesel power (Arteaga et al. 1995). This change in technology, coupled with the increased price for alfalfa and the development of center-pivot irrigation, eventually caused a shift away from row crops and resulted in a significant increase in ground water withdrawals. Currently, the majority of irrigation is centered in south-central Diamond Valley and along the eastern portion of the valley

On a much smaller scale, irrigation development in Kobeh Valley followed a similar progression, and by 2005, approximately 1,000 acres of alfalfa were being irrigated along the basin's western border. Existing ground water resources in the basin are still considered to be largely undeveloped (Tumbusch and Plume 2006) because of the limited scale of ground water withdrawals in Kobeh Valley.

Montgomery et al. (2010) summarized ground water pumping withdrawals from the HSA basins on the basis of published estimates of ground water withdrawals from Diamond Valley (Arteaga et al. 1995; Eakin 1962; Harrill 1968); detailed crop surveys and basin-estimate aggregates from the NDWR (1961-2005) for Diamond and Kobeh Valleys; estimates of public water-system requirements based on population for Nevada public water systems (Lopes and Evetts 2004); and pumping records from the Ruby Hill Mine. In the year 1955, under pre-development conditions, Montgomery et al. (2010) report that a total of approximately 800 afy of ground water was being pumped from the Diamond Valley basin, with negligible amounts being pumped from the other HSA basins at that time (Table 3.2-4). Under existing (2009) conditions, total consumptive use of ground water for agricultural purposes (minor mining and municipal uses) is estimated to be approximately 55,850 afy from the Diamond Valley basin and approximately 4,500 afy from the Kobeh Valley basin, with negligible amounts being pumped from Antelope Valley and the southern portion of Pine Valley within the HSA (Table 3.2-5).

3.2.2.6.7 Land Subsidence Due to Ground Water Withdrawals

Prolonged ground water withdrawals in the southern part of Diamond Valley have resulted in depressurization and some consolidation of the basin-fill aquifer, which in turn, has produced land surface subsidence in that area. Estimates of the cumulative subsidence in Diamond and Kobeh Valleys for the years 1992 to 2000 were made based on satellite-derived Interferometric Synthetic Aperture Radar (InSAR) data. The methodology consists of utilizing two satellite radar scenes acquired over the same area at different times to determine radar phase changes produced by small displacements of the ground surface (Bell 2008). In the case of land subsidence due to ground water withdrawals, aquifer consolidation results in centimeter-scale changes of the ground surface that are detectable with InSAR data. A detailed description of the methods used to estimate land subsidence in Diamond Valley is presented in Bell and Arai (2009).

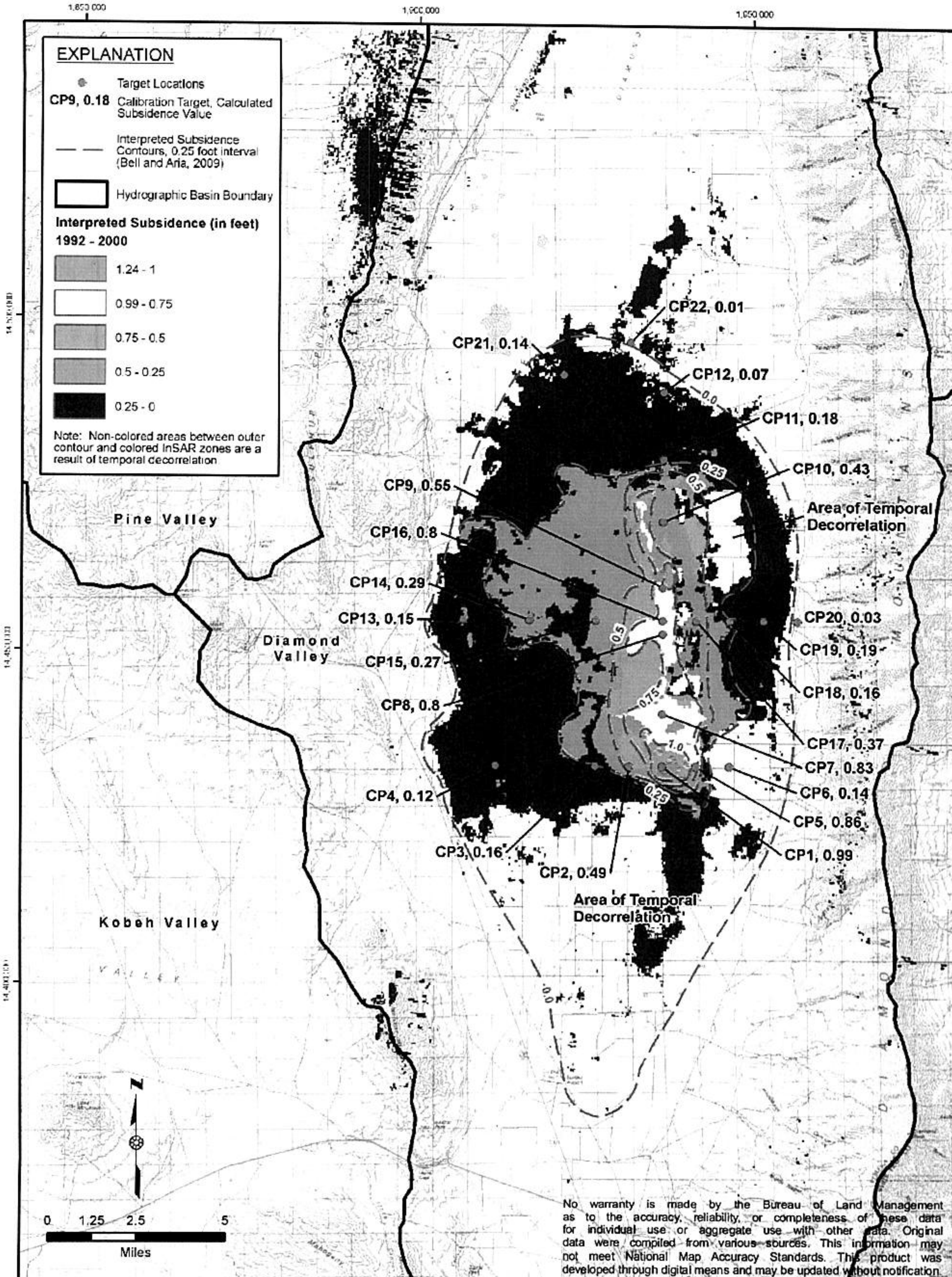
Based on the InSAR data analysis, at least 1.2 feet of land subsidence was estimated to have occurred in the south-central part of Diamond Valley between 1992 and 2000 (Figure 3.2.13). No measurable land subsidence was observed in Kobeh Valley during that time period (Montgomery et al. 2010).

The hydrogeological characteristics of Diamond and Kobeh Valleys are very similar (Harrill 1968; Tumbusch and Plume 2006). Both valleys contain thick (>3,000 feet) accumulations of basin-fill materials, much of which were derived from repeated cycles of lacustrine deposition during the late Cenozoic. It is reasonable, therefore, to expect that the aquifer system's response to pumping in Kobeh Valley would be similar to that observed in Diamond Valley in terms of land subsidence for a given amount of ground water drawdown.

3.2.2.7 Water Rights

In 1926, a carte blanche Public Water Reserve (PWR) was created through an EO by President Coolidge entitled "Public Water Reserves No. 107" (PWR 107). PWR 107 ended the site-specific system of reserving springs and water holes. The purpose of PWR 107 was to reserve natural springs and water holes yielding amounts in excess of homesteading requirements. This order states that "legal subdivision(s) of public land surveys which is vacant, unappropriated, unreserved public land and contains a spring or water hole, and all land within one quarter of a mile of every spring or water be reserved for public use". There was no intent to reserve the entire yield of each public spring or water hole, rather reserved water was limited to domestic human consumption and stockwatering. All waters from these sources in excess of the minimum amount necessary for these limited public watering purposes is available for appropriation through state water law. To date, many of these PWRs have not been registered with the state and/or are not adjudicated.

Water rights and applications for water rights were reviewed by Interflow and are summarized in Montgomery et al. (2010, Appendix C). These data were collected from the NDWR records in January 2010. The summary identified all water rights and applications for water rights for



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MOUNT HOPE PROJECT

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Land Subsidence in Diamond Valley Interpreted From 1992-2000 InSAR Data

Figure 3.2.13

points of diversion within the HSA and within a 30-mile radius of Mount Hope, including those owned by EML or any of its subsidiaries. Of the 1,000 water rights and applications for water rights within the inventoried area, 472 were associated with surface water sources (e.g., streams and springs) and 528 were associated with underground sources (e.g., ground water wells). The primary uses for water in the area are stock watering, irrigation, mining and milling, and municipal. Since water rights are not necessary for most domestic wells in Nevada, this summary may not include all wells that exist within the inventoried area that are used for domestic water. An example of this is the domestic water well at the Roberts Creek Ranch. Additional vested water rights and subsisting rights for stockwater and future PWRs that are reserved for stockwatering (and domestic) purposes could exist within the Project Area and within the ten-foot ground water drawdown contour.

For the purpose of the EIS analysis, all underground water rights and pending applications for underground water rights owned by EML or its subsidiaries were excluded from the assessment of potential impacts; however, the actual streams and springs associated with any of EML's surface water features were not excluded. The boundary of the inventory area and locations of the points of diversion for the remaining (i.e., non-EML controlled) water rights and applications for water rights that were included in the assessment of potential impacts are shown in Figure 3.2.14; the owner, beneficial use, and annual duty for each water right are listed in Montgomery et al. (2010, Appendix C). Table 3.2-6 lists the non-EML controlled water rights and application for water rights that may be affected by Project activities, as discussed in Section 3.3.3.2.

Table 3.2-6: Non-EML Water Rights That May be Affected by Project Activities

Permit/ID Number/ Well Number	Basin	Source	Manner of Use	Duty (Af/Year)	Spring Number	Owner
2732	Kobeh Valley	STR	IRR	120.00	--	Etcheverry Family LTD Partnership
11188	Kobeh Valley	UG	STK	1.69	--	A C Florio
12748	Kobeh Valley	SPR	STK	10.86	721	Etcheverry Family LTD Partnership
16802	Kobeh Valley	STR[1]	IRR	117.00	--	Etcheverry Family LTD Partnership
43025	Kobeh Valley	UG	STK	5.16	--	BLM
43321	Pine Valley	SPR[2]	STK	7.24	--	Etcheverry Family LTD Partnership
44774	Kobeh Valley	UG	STK	6.51	--	BLM
44775	Kobeh Valley	UG	STK	5.77	--	BLM
48684	Kobeh Valley	UG	STK	8.68	--	Etcheverry Family LTD Partnership
71594	Kobeh Valley	UG	STK	0.00	--	Roy Risi
R06940	Diamond Valley	SPR	OTH	10.65	619	BLM
R06942	Pine Valley	SPR	OTH	10.65	597	BLM
R06944	Diamond Valley	SPR	OTH	10.65	612	BLM

Permit/ID Number/ Well Number	Basin	Source	Manner of Use	Duty (Af/Year)	Spring Number	Owner
R06951	Kobeh Valley	SPR	OTH	3.93	742	BLM
R06952	Kobeh Valley	UG[3]	OTH	3.93	--	BLM
V01953	Kobeh Valley	STR	IRR	350	--	Bernard Damele
V02781	Pine Valley	STR	IRR	112.33	--	Eureka Livestock Company
204*	Kobeh Valley	UG	STK	Unk	--	Unk
310*	Kobeh Valley	UG	STK	Unk	--	Unk

SPR=Spring, STR=Stream, STK=Stockwater, UG=Underground (well), IRR = Irrigation, OTH = Other (wildlife), Unk=Unknown
[1] - The water right is associated with Roberts Creek; however, NDWR identified the right as a spring in their database.
[2] - The water right is associated with a gravel pit that has water within the pit.
[3] - The water right is associated with a well; however, NDWR identified the right as a spring in their database.
* - Wells 204 and 310 appear to be used for stock watering and there are no water rights associated with these wells.

3.2.3 Environmental Consequences and Mitigation Measures

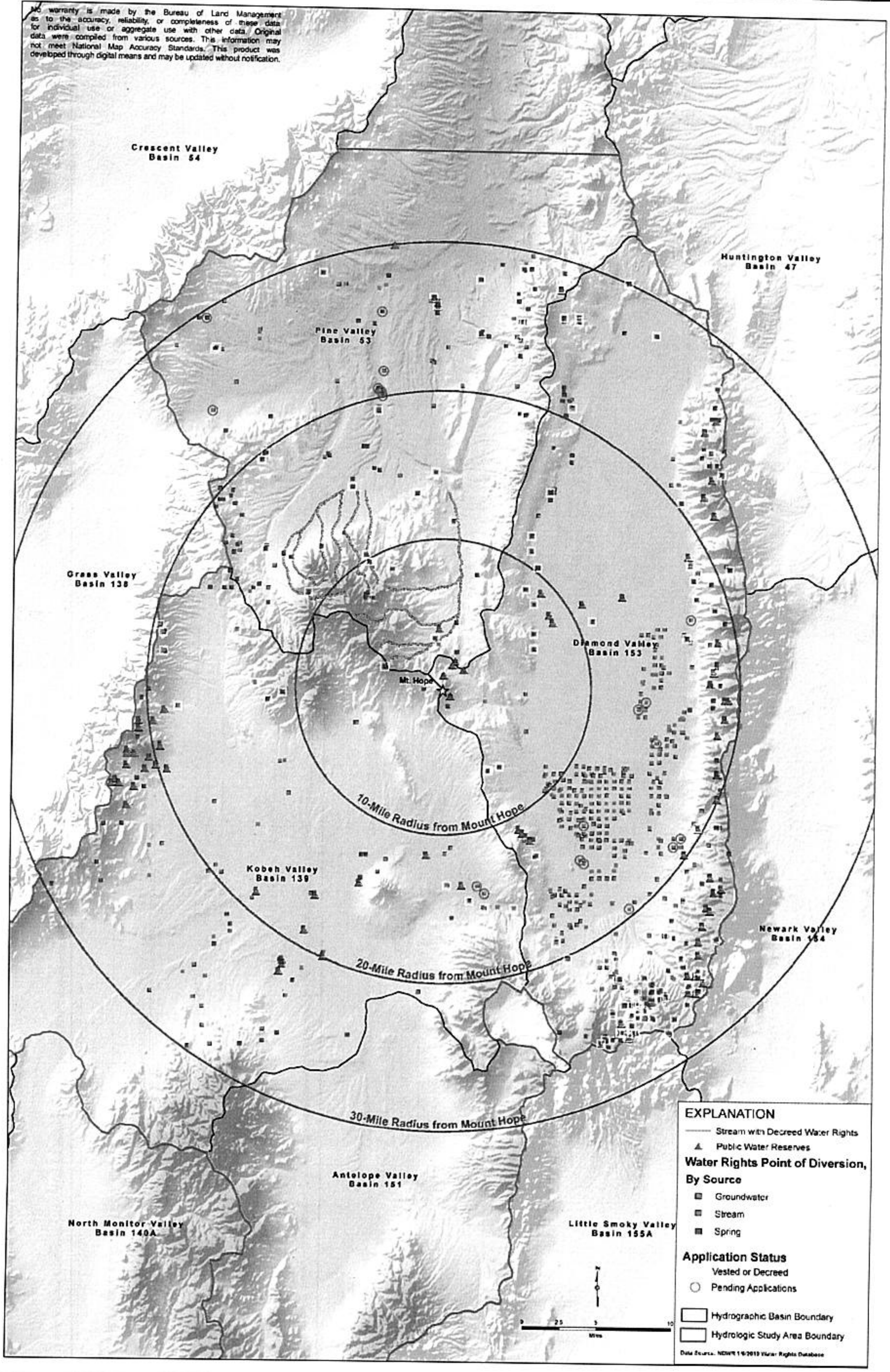
The Proposed Action and alternatives have the potential to impact surface water and ground water in the HSA. Potential water quantity impacts that may be associated with mining operations include the following: 1) reduction in surface and ground water quantity for current users and water-dependent resources from pit dewatering and production well withdrawals; 2) impacts from flooding, erosion, and sedimentation associated with mine construction, operation, and closure activities; and 3) changes in aquifer productivity or surficial drainage patterns or the creation of open fissures at the land surface related to dewatering-induced subsidence. The analysis of the magnitude and significance of these potential water resource impacts in relation to the Proposed Action and alternatives are addressed in this section. Potential water quality impacts are discussed in Section 3.3.3.

3.2.3.1 Significance Criteria

Criteria for assessing the significance of potential impacts to the quantity of water resources in the HSA are described below. Impacts to water resources are considered to be significant if any of these criteria are predicted to occur as a result of the Proposed Action or the alternatives.

3.2.3.1.1 Surface Water Quantity

- Modification or sedimentation of natural drainages resulting in increased area or incidence of flooding.
- Reduction in the flow of springs, seeps, or streams. Impacts are considered to be significant where the predicted ten-foot water table drawdown contour encompasses a spring, seep, or stream and where the surface water feature is determined to be hydraulically connected to the aquifer affected by drawdown.
- Diversion or consumptive use of ground water that adversely affects other (non-EML) water rights holders. This criterion includes flows to springs, seeps, or streams where existing beneficial water uses, as defined by state law, may be affected.



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MOUNT HOPE PROJECT

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Non-EML-Controlled Water Rights and PWRs within HSA and 30-mile Radius of Mount Hope

Figure 3.2.14

3.2.3.1.2 Ground Water Quantity

- Reduction of ground water levels that adversely affect water-supply, municipal, domestic, agricultural, or industrial wells caused by Project dewatering or post-mining pit lake development. Impacts are considered to be significant where the predicted ten-foot water table drawdown contour encompasses an existing well with an active water right and the well is hydraulically connected to the aquifer affected by drawdown.
- A long-term consumptive use of a water resource that does not provide for a beneficial use.
- Lowering of ground water levels that result in substantial land subsidence. For the purposes of this EIS, significant impacts are indicated where hydraulic parameters of the aquifer are substantially changed (such that aquifer productivity may be affected), where differential subsidence results in open fissures at the land surface, or if subsidence is great enough to change drainage directions or cause ponding.

For this impact analysis, the area that is predicted to experience a decline in ground water elevation of ten feet or more as a result of mine dewatering and water production activities was selected as the area of **primary focus** regarding impacts to water resources. This is a commonly used approach for EISs in Nevada, in part because changes in ground water levels of less than ten feet generally are difficult to distinguish from natural seasonal and annual fluctuations in ground water levels.

3.2.3.2 Assessment Methodology

This section provides a summary of the methods used to evaluate the following: 1) the expected mine pit dewatering rates, 2) changes in ground water elevations and hydrographic basin water balances due to mining-related production well withdrawals and pit dewatering, and 3) the development and ultimate hydrologic conditions of the post-mining pit lake.

3.2.3.2.1 Numeric Ground Water Flow Modeling

A pair of nested three-dimensional numerical ground water flow models have been developed, calibrated, and utilized to estimate potential effects to ground water and surface water resources from the Proposed Action and No Action Alternative, and from the cumulative effects of historical dewatering and projected future dewatering and water production activities for this EIS. The nested models consist of a larger, regional-scale model (the Regional Model) that encompasses the entire HSA and a smaller, imbedded local-scale model (the Local Model) that is focused on the vicinity of the proposed open pit. The two models are "coupled" by representation of the same time-varying ground water stresses (boundary conditions) in both model domains. Interflow, Inc., prepared the Regional Model, and Montgomery & Associates, prepared the Local Model. A detailed explanation of the conceptual hydrogeologic model, numerical modeling approach and setup, steady-state and transient calibrations, sensitivity analyses, optimization, model coupling, and predictive usage of both the Regional and Local Models is presented in the technical report by Montgomery et al. (2010, Chapter 4). Additional supporting data, analysis, and documentation for the numerical models are presented in Bell (2008), Bell and Arai (2009), Interflow (2010), Montgomery & Associates (2010), and SRK (2008a).

Interflow and Montgomery & Associates conducted the ground water flow modeling using an enhanced version of the USGS numerical code MODFLOW (McDonald and Harbaugh 1984). The enhanced version, known as MODFLOW-SURFACT (HydroGeoLogic 1996), contains many improvements over MODFLOW, including more robust and accurate simulation capabilities for handling complex field conditions (such as large ground water elevation fluctuations, which result in drying and wetting of model grid cells). MODFLOW originally was designed to simulate flow through porous media. However, it is common practice for MODFLOW models to be used to simulate ground water flow in bedrock aquifers where flow through the rock mass is primarily controlled by interconnected fracture or solution networks that behave similarly to porous media flow at the scale of the model grid cells (D'Agnese et al. 1997; Prudic et al. 1995). MODFLOW packages that were utilized in this analysis include the Interbed-Storage Package (Leake and Prudic 1991) to evaluate subsidence effects of dewatering and the LAK2 Package (Council 1999) to evaluate filling of the pit lake after mining.

The Regional Model encompasses the entire HSA as shown in Figure 3.2.1. The Regional Model contains eight variable-thickness layers to simulate the vertical range extending from over 10,000 feet amsl at the peaks of some of the HSA's mountain ranges to zero feet amsl (mean sea level) at the base of the model. To provide better resolution where ground water stresses would be greatest, the model grid cell dimensions vary horizontally from 5,000 feet by 5,000 feet at the outer margins of the model to 1,000 feet by 1,000 feet in the vicinity of the proposed well field and open pit areas. The Regional Model was calibrated to include the following: 1) historic (circa 1955, presumed steady-state) water levels in each of the HSA basins, 2) the estimated agricultural pumping and observed changes in ground water levels in Diamond Valley between 1956 and 2006, and 3) the results of six aquifer pumping tests conducted in carbonate bedrock and basin-fill deposits in Kobeh Valley as part of the baseline studies for this EIS (Interflow 2010).

The Local Model domain is nested within the Regional Model and covers a rectangular area of approximately 28 square miles, which includes Mount Hope and extends roughly two miles to the north, west, and south and five miles to the east of the proposed open pit, as shown in Figure 3.2.1. The Local Model consists of 19 horizontal layers of different thickness spanning the vertical range from the top of Mount Hope (8,411 feet amsl) to zero feet amsl (mean sea level) at the base of the model. Horizontal grid cell dimensions range from 100 feet by 100 feet in the proposed open pit area to 800 feet by 800 feet along the edges of the Local Model. These refined grid cells in the Local Model, relative to the Regional Model, allow the Local Model to more accurately represent hydrologic features, such as fault zones and steep hydraulic gradients, well locations, open pit geometry, and ground water levels, in the proposed mining area. The Local Model was calibrated to observed 2009 water levels in the proposed open pit area, which were assumed to represent steady-state conditions, and to the measured transient responses to three aquifer pumping tests conducted in the open pit area dewatering test wells as part of the baseline studies for this EIS (Montgomery & Associates 2010).

Transient, predictive Regional and Local Model simulations were developed to assess the potential water quantity impacts of the Proposed Action, No Action Alternative, and cumulative effects of historic dewatering and projected future dewatering and water management activities. Potential water quantity impacts due to the Partial Backfill Alternative were evaluated in a modeling assessment using the same methodologies as used for the Proposed Action, except modifying those parameters that would reflect the backfilling of the open pit (Montgomery &

Associates 2011). The Off-Site Transfer of Ore Concentrate for Processing Alternative would require the same mining-related production well pumping, pit dewatering, and water production activities, and would result in the same development of the pit lake, as the Proposed Action; therefore, the potential water quantity impacts of the Off-Site Transfer of Ore Concentrate for Processing Alternative and the Proposed Action are considered to be the same. Potential water quantity impacts due to the Slower, Longer Project Alternative were evaluated in a modeling assessment using the same methodologies as used for the Proposed Action, except modifying those parameters that would reflect a doubling of the mining and pumping time frames and a one-half decrease in the production field pumping rate (Interflow 2011).

3.2.3.2.2 Modeling Scenarios

The calibrated Regional Model was used to simulate a "No Action Alternative Scenario" and a "Cumulative Action Scenario," both of which are identical for the historical time period from 1955 through 2009, but differ for the predictive time period beginning in 2010. The modeling assumptions regarding anthropogenic ground water withdrawals during the predictive time period for the two scenarios are summarized as follows:

No Action Alternative Scenario

The No Action Alternative Scenario includes all of the relevant existing ground water withdrawals within the HSA, as outlined below.

- Consumptive use of ground water for agricultural irrigation in Diamond Valley continues at 2009 rates (34,630 gpm or 55,850 afy) through 2106, and then is reduced by 60 percent (to 13,850 gpm or 22,340 afy) for the remainder of the simulated time period to constrain the drawdown to approximately 300 feet bgs (Figure 3.2.15). The modeling of the future agricultural consumptive use in Diamond Valley as a step function is a more conservative assumption than using a monotonically declining curve, in terms of water consumption. It is entirely possible that future ground water use could continue at rates similar to the present until the currently available water supply (in the upper part of the aquifer tapped by the agricultural wells) is depleted.

- Consumptive use of ground water for agricultural irrigation in Kobeh Valley continues at 2006 rates (1,800 gpm or 2,900 afy, at the Bobcat Ranch) through 2011 and then increases to 2,330 gpm (3,750 afy) at the Bobcat and 3F Ranches for the remainder of the simulated time period.

- Town of Eureka municipal water-supply pumping continues at 2006 rates (190 gpm or 300 afy) throughout the simulated time period.

- Consumptive use of ground water at the Ruby Hill Mine continues at 2006 rates (280 gpm or 450 afy) through 2012 and then ceases.

Cumulative Actions Scenario

The cumulative actions scenario includes all of the assumed consumptive uses listed above for the No Action Alternative Scenario plus the following ground water withdrawals related to the Proposed Action.

- Mine construction water supply is pumped from two wells in the proposed mining area at a combined rate of 300 gpm (480 afy) for one year (2011).

- Production well pumping for the proposed mining and milling operations in the Kobeh Valley Central Well Field (KVCWF) continue for 44 years; the amount of water extracted at the KVCWF varies yearly depending on the volume of water derived from open pit dewatering during mining, with the sum of the two water-supply sources equaling the total process-water demand of 7,000 gpm (11,300 afy) on an annualized average basis.

- Pit dewatering **would** continue **for** 32 years; **and** pit lake formation begins in **Year 32**.

Historic pumping rates and projected future ground water withdrawals are summarized in Table 3.2-7 and shown on Figure 3.2.15.

The Local Model was coupled to the Regional Model simulation of the Cumulative Action Scenario for the predictive time period beginning in 2010. Lateral boundary conditions for the Local Model (specified hydraulic heads) were derived from the Regional Model via an iterative process that is explained in Montgomery et al. (2010). The Local Model was used to estimate the following:

- Passive ground water inflow rates to the mine open pit during the 32-year mining period;

- Pit lake formation (filling time, final lake stage) after dewatering ceases;

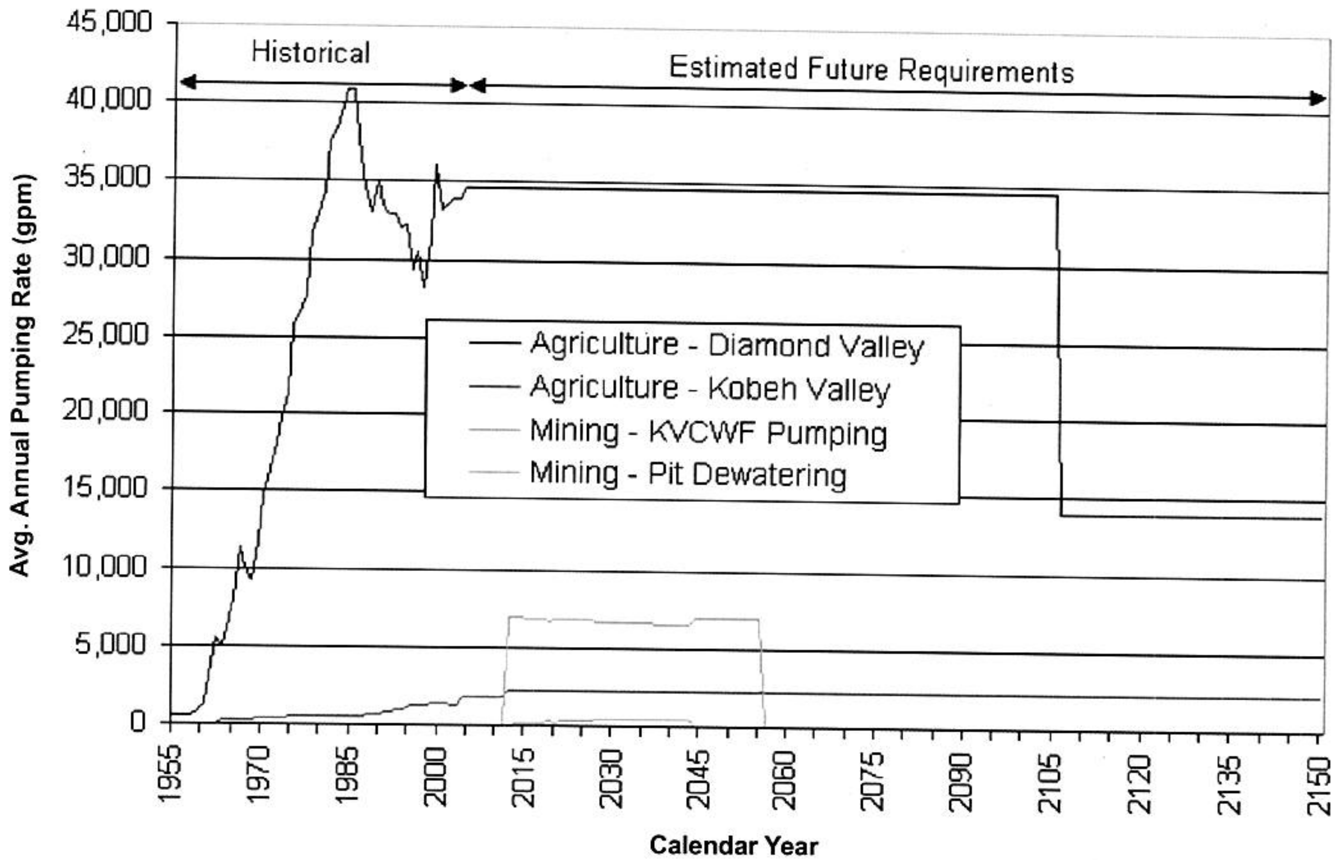
- The ground water inflow and outflow component(s) of the pit lake water balance;

- Whether the pit lake would act as a hydrologic sink for ground water or as a through-flow system; and

- Ground water stresses from open pit dewatering and pit lake development, which feed back into the Regional Model to complete the model coupling process.

3.2.3.2.3 Pit Dewatering and Water Supply Pumping

The open pit excavation is planned to commence late **in the construction phase**, with one year of pre-production followed by 32 years of production. Upon completion, the open pit would extend downward approximately 2,550 feet bgs and would cover an area of approximately 730 acres. Existing ground water levels near the center of the proposed open pit are approximately 300 feet bgs; therefore, a ground water drawdown of approximately 2,250 feet would be required during mining operations to lower the ground water level to below the ultimate open pit bottom. Inflowing ground water would be pumped from sumps in the pit and removed for consumptive use in the mining and milling process. The results of the numerical ground water modeling indicate that the open pit dewatering requirements under the Proposed Action (and the Partial Backfill Alternative and the Off-Site Transfer of Ore Concentrate for Processing Alternative) would range from approximately 60 to 460 gpm (100 to 750 afy) on an average annual basis, as listed in Table 3.2-7 and shown on Figure 3.2.15.



Note: Agricultural pumping is the annual net agricultural pumping, which is not the consumptive loss when referring to irrigation withdrawals.

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DESIGN: EMLLC	DRAWN: GSL	REVIEWED: RFD
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FILE NAME: p1635_Fig3-2-X_Hydro_8i11i.mxd		

BUREAU OF LAND MANAGEMENT

MOUNT HOPE PROJECT

DRAWING TITLE:

Historical Pumping and Estimated Future Pumping and Dewatering Requirements

Figure 3.2.15

Table 3.2-7: Summary of Historic Pumping and Estimated Future Pumping and Dewatering Requirements

Project Year	Calendar Year[1]	No Action Alternative				Proposed Action		Partial Backfill Alternative	
		Net Agricultural Pumping (gpm)[2]			Other[3] (gpm)	KVCWF Pumping (gpm)	Pit Inflow[4,5] (gpm)	KVCWF Pumping (gpm)	Pit Inflow[4] (gpm)
		Diamond Valley	Kobeh Valley	Total					
	1955	510	0	510	0	0	0	0	0
	1956 - 2009	510 - 40,830	0 - 1,800	510 - 41,450	70 - 470	0	0	0	0
	2010	34,630	1,780	36,410	470	0	0	0	0
0	2011	34,630	1,780	36,410	470	0	300	0	300
1	2012	34,630	2,330	36,960	470	6,940	60	6,940	60
2	2013	34,630	2,330	36,960	190	6,910	90	6,910	90
3	2014	34,630	2,330	36,960	190	6,930	70	6,930	70
4	2015	34,630	2,330	36,960	190	6,820	180	6,820	180
5	2016	34,630	2,330	36,960	190	6,860	140	6,860	140
6	2017	34,630	2,330	36,960	190	6,850	150	6,850	150
7	2018	34,630	2,330	36,960	190	6,840	160	6,840	160
8	2019	34,630	2,330	36,960	190	6,690	310	6,690	310
9	2020	34,630	2,330	36,960	190	6,800	200	6,800	200
10	2021	34,630	2,330	36,960	190	6,780	220	6,780	220
11	2022	34,630	2,330	36,960	190	6,750	250	6,750	250
12	2023	34,630	2,330	36,960	190	6,750	250	6,750	250
13	2024	34,630	2,330	36,960	190	6,750	250	6,750	250
14	2025	34,630	2,330	36,960	190	6,750	250	6,750	250
15	2026	34,630	2,330	36,960	190	6,750	250	6,750	250
16	2027	34,630	2,330	36,960	190	6,640	360	6,640	360
17	2028	34,630	2,330	36,960	190	6,640	360	6,640	360
18	2029	34,630	2,330	36,960	190	6,640	360	6,640	360
19	2030	34,630	2,330	36,960	190	6,640	360	6,640	360
20	2031	34,630	2,330	36,960	190	6,640	360	6,640	360
21	2032	34,630	2,330	36,960	190	6,610	390	6,610	390
22	2033	34,630	2,330	36,960	190	6,610	390	6,610	390
23	2034	34,630	2,330	36,960	190	6,610	390	6,610	390
24	2035	34,630	2,330	36,960	190	6,610	390	6,610	390
25	2036	34,630	2,330	36,960	190	6,610	390	6,610	390
26	2037	34,630	2,330	36,960	190	6,540	460	6,540	460
27	2038	34,630	2,330	36,960	190	6,540	460	6,540	460
28	2039	34,630	2,330	36,960	190	6,540	460	6,540	460
29	2040	34,630	2,330	36,960	190	6,540	460	6,540	460
30	2041	34,630	2,330	36,960	190	6,540	460	6,540	460
31	2042	34,630	2,330	36,960	190	6,580	420	6,580	420
32	2043	34,630	2,330	36,960	190	6,580	420	6,580	420
33	2044	34,630	2,330	36,960	190	7,000	180	7,000	0

Project Year	Calendar Year[1]	No Action Alternative				Proposed Action		Partial Backfill Alternative	
		Net Agricultural Pumping (gpm)[2]			Other[3] (gpm)	KVCWF Pumping (gpm)	Pit Inflow[4,5] (gpm)	KVCWF Pumping (gpm)	Pit Inflow[4] (gpm)
		Diamond Valley	Kobeh Valley	Total					
34	2045	34,630	2,330	36,960	190	7,000	180	7,000	0
35	2046	34,630	2,330	36,960	190	7,000	180	7,000	0
36	2047	34,630	2,330	36,960	190	7,000	170	7,000	0
37	2048	34,630	2,330	36,960	190	7,000	170	7,000	0
38	2049	34,630	2,330	36,960	190	7,000	170	7,000	0
39	2050	34,630	2,330	36,960	190	7,000	160	7,000	0
40	2051	34,630	2,330	36,960	190	7,000	160	7,000	0
41	2052	34,630	2,330	36,960	190	7,000	160	7,000	0
42	2053	34,630	2,330	36,960	190	7,000	160	7,000	0
43	2054	34,630	2,330	36,960	190	7,000	150	7,000	0
44	2055	34,630	2,330	36,960	190	7,000	150	7,000	0
	2056 - 2105	34,630	2,330	36,960	190	0	150 - 120	0	0
	2106 - end	13,850	2,330	16,180	190	0	120 - 60	0	0

[1]Calendar years used for numerical ground water flow model simulations; actual startup dates for the Proposed Action or Partial Backfill Alternative would depend on BLM and NDEP authorizations.
[2]Net agricultural pumping means net consumptive loss when referring to irrigation withdrawals. Average annual flow rate in gpm, rounded to nearest ten gpm.
[3] Includes Town of Eureka municipal water-supply pumping and Ruby Hill Mine pumping.
[4] Pit inflow value for Project Year Zero is local mine-area pumping for construction water.
[5] Pit inflow values after Project Year 32 are passive ground water inflows permanently lost to pit lake storage and/or evaporation from the lake's surface.

In addition to open pit dewatering, the Proposed Action (and the Partial Backfill Alternative and the Off-Site Transfer of Ore Concentrate for Processing Alternative) would also involve pumping from the KVCWF for mining and milling water supply starting in 2012 and continuing for 44 years. The water-supply pumping was simulated from ten wells located along the well field corridor in central Kobeh Valley, as shown in Figure 3.2.1. Approximately ten percent of the total well field production was withdrawn from simulated wells in carbonate bedrock, whereas the remaining 90 percent was withdrawn from simulated wells in the basin-fill aquifer (Montgomery et al. 2010). The simulated KVCWF total production during the planned 44 years of operation ranged from 6,540 to 7,000 gpm (10,550 to 11,300 afy) on an average annual basis, as listed in Table 3.2-7 and shown on Figure 3.2.15.

The assessment of cumulative impacts associated with the proposed mine dewatering and KVCWF pumping include an evaluation of the total drawdown from all past, present, and reasonably foreseeable future mine dewatering, production well pumping, and other withdrawals of ground water for consumptive use. This includes the following: 1) historic pumping for agricultural irrigation in Diamond and Kobeh Valleys and continuing through the present; 2) projected future ground water withdrawals for agricultural irrigation, municipal water supply and mining and milling uses by other mines within the HSA; and 3) projected future dewatering and KVCWF pumping requirements for the Proposed Action.

3.2.3.2.4 Evaluation of Impacts to Ground Water Levels

The method used for calculating ground water drawdown for the Proposed Action, No Action Alternative, and cumulative effects assessment are described in detail in Montgomery et al. (2010). Briefly, the predicted water-table drawdown for the No Action Alternative was calculated by subtracting the No Action Alternative Scenario predicted water-level elevations at a certain time in the future (approximately 2055) from the simulated water-level elevations at the end of 2009 (Figure 3.2.16), thus illustrating only the predicted future drawdown relative to existing conditions. The predicted water-table drawdown for the cumulative effects assessment was calculated by subtracting the Cumulative Action Scenario predicted water-level elevations at a certain time in the future from the simulated water-level elevations in 1955, thus relating the simulated historic drawdown and the predicted future drawdown to pre-development conditions (Figure 3.2.11). The predicted water-table drawdown for the Proposed Action was calculated by subtracting the simulated No Action Alternative Scenario water-level elevations from the Cumulative Action Scenario water level elevations at the same point(s) in time in the future. By using this methodology, the predicted results for the Proposed Action do not include the simulated changes to ground water elevations that have occurred in the HSA due to the historic pumping and ground water consumption that occurred between 1955 and the end of 2009, which are shown in Figure 3.2.17. Hence, the baseline condition used as the reference for comparison of the Proposed Action and the alternatives is the simulated existing ground water elevations at the end of 2009, whereas for the cumulative analysis the baseline condition is the estimated pre-development steady-state ground water elevations that existed in 1955.

A ten-foot drawdown contour has been used in the analysis as the reference point for determining potential impacts. The use of a numeric flow model to project potential drawdown at magnitudes of less than approximately ten percent of the local magnitude of drawdown becomes progressively uncertain as the threshold for drawdown prediction decreases. While the numeric model produces values of drawdown to small fractions of a foot, extrapolated over vast distances (the entire model domain), the numbers at this level of precision become an artifact of numeric processes rather than a representation of a physical reality. This is due to physical and mathematical simplifications necessary to model the regional flow system. While there is no standardized way of determining a reporting threshold, the value of ten feet is believed to be commensurate with the predictive qualities and uncertainties associated with this particular model. It is acknowledged that lesser degrees of drawdown can have impacts, however, modeling in this complex geologic setting has its limitations, and to report modeling results to very small thresholds would project a false level of model utility.

In addition, the magnitude, timing, and areal extent of drawdown was evaluated by analyzing the model simulation results at eight selected time intervals that represent the projected conditions at the end of the proposed mining/milling operations (in 2055) and at ten, 30, 50, 100, 200, 300, and 400 years after KVCWF pumping ceases under the Proposed Action.