in the central parts of the basins. The results of regional geophysical studies published by the NBMG and the USGS provide information on the depth of the alluvial deposits on a regional scale. The estimated elevation of the pre-Tertiary basement in the region is illustrated on **Figure 3.1-8** and defines a number of prominent troughs of valley fill deposits. The basins in the flow system also share a number of similar tectonic characteristics and features, such as faults, folds, and intrusions that have important implications with respect to groundwater flow. Through aerial photo interpretation and ground reconnaissance, Dohrenwend et al. (1996) mapped young (latest Tertiary and Quaternary) faults in the region (**Figure 3.1-8**). These faults may be significant as they may serve as conduits for large flows of groundwater, especially where present in carbonate rocks that have been subjected to a high degree of secondary dissolution. Dissolution channels associated with young faults may also hydraulically link the basin flow systems and to flow systems of adjacent basins.

Groundwater resources are mainly contained within the extensive valley fill deposits within the hydrographic basins and, to a lesser extent, in the consolidated rocks that form the mountain blocks and underlie the valley fill groundwater systems of the valley floors.

3.4.1 Well Network

Water level data for Antelope, Diamond, Kobeh, Pine, and North Monitor Valleys were assembled from published and unpublished sources. The majority of water level records were retrieved from the USGS National Water Information System database (NWIS, 2007). Additional records were obtained from exploratory wells (Montgomery & Associates, 2010b) and data published in USGS/Nevada Department of Natural Resources Reconnaissance Series Reports (Eakin, 1961, 1962; Rush and Everett, 1964). Harrill (1968) provided a considerable amount of water level data acquired during the course of a field study with the objective of investigating the relationship between water level responses and groundwater pumping in Diamond Valley. Although Harrill (1968) provided a comprehensive dataset for Diamond Valley, data were not collected outside of Diamond

Valley. Additional historic and modern data (2005) were recently published for Antelope, Diamond, Kobeh, Pine, and North and South Monitor Valleys by Tumbusch and Plume (2006), who included interpretations of the regional flow system, historic and recent water levels, and an overview of regional and local hydrogeologic units.

Depths to groundwater are also reported on many NDWR drillers' logs for the Study Area. The potential error associated with these data is not defined but is greater than for wells that have been measured and reported in scientific studies. The well logs also provide information on geology and productiveness of the aquifer, as reported by the well driller.

In all, for this study, approximately 4,000 water level measurements were assembled into an electronic database which includes data from 1900 to 2009 for approximately 454 wells, as well as time-series water level data for 14 wells (**Appendix F**). **Appendix F** is comprised mostly of data reported in referenced reports, NDWR, and the USGS NWIS database. The data in **Appendix F** were supplemented with data from drillers' logs (**Appendix G**) where data were sparse, most notably in Pine Valley.

3.4.1.1 WELL NUMBERING SYSTEM: Each well in this investigation was assigned a unique number, and the well numbers are provided electronically on the CD that accompanies this report along with a digital location map (**Appendix F**). Where applicable, the USGS name and site number are provided to allow the reader to cross-reference and verify water level information. In addition, a separate column is provided that references a unique numbering system used by Tumbusch and Plume (2006) and can be cross-referenced to recent and historical data presented in their report on the Diamond Valley flow system.

3.4.1.2 FLOWING, ARTESIAN WELLS: The presence of flowing (artesian) wells was historically common in every valley in the Study Area in locations such as:

- Kobeh Valley near Lone Mountain
- Bean Flat, and the Bartine Ranch
- Antelope Valley at Kitchen Meadows
- Klobe Hot Springs
- Diamond Valley in northwest part and historically in the southwest and southeast parts
- Diamond Valley, along the mountain fronts

Flowing wells identified through field reconnaissance measurements are listed in **Table 3.4-1** with corresponding USGS author and appear on the basin detail maps on **Figures 3.4-2 through 3.4-5**. Additional data on flowing artesian wells were added to **Table 3.4-1** from the Great Basin Center for Geothermal Research (2007), which presents the locations of wells that were flowing at the time they were drilled but not discharge data. The majority of these wells could not be correlated with known well locations and may or may not still be present. Data from flowing wells presented in the Reconnaissance Series Reports are deemed the most reliable information regarding flowing wells in the Study Area.

3.4.2 Groundwater Movement

Regional groundwater movement to Kobeh Valley is from the north end of Monitor and Antelope Valleys through the alluvium to the groundwater system in Kobeh Valley. It is unknown to what degree any of this water moves through the underlying volcanic or carbonate rocks. Rush and Everett (1964) surmised that there is groundwater inflow into Kobeh Valley from Monitor Valley but not from Antelope Valley. Local areas of recharge to Kobeh Valley are in the surrounding mountains and to some extent in the ephemeral drainages on the valley floor. In general, groundwater flows similarly to the topographic gradient; however, flow directions can be influenced by complexities of the geologic environment. Groundwater flow in mountain blocks moves through fractures, faults, and porous media. Springs are abundant in the mountain blocks and represent groundwater discharge (**Section 3.3.1**).

Prior to groundwater development, the potentiometric surface for the valley fill aquifers was controlled in large part by climate, topography, geology, proximity to springs or streams, and the degree of confinement by fine-grained strata. Once anthropogenic groundwater development began, additional variables such as pumpage locations and amounts strongly affected the configuration of the water table. These changes introduced a transient nature to the groundwater flow regime and interrupted the dynamic equilibrium of the local hydrologic cycle, resulting in lowered water levels and, in places, reversal of flow direction. Because of the strong relationship between withdrawals and water level declines, a dataset was assembled to document both withdrawals from the valley fill aquifers and the aquifer response to those withdrawals.

3.4.2.1 POTENTIOMETRIC DATA AND PRE-DEVELOPMENT CONDITIONS: A water level database, as described in **Section 3.4.1**, was compiled for the Study Area (**Appendix F**). From this database, a pre-development dataset was compiled to best approximate the head distribution in the valley fill aquifer, prior to initiation of major pumping activities in the Study Area. This was accomplished by compiling well data from the years prior to 1960 in Diamond Valley and other basins. Quasi-steady state conditions were assumed for the available period of record, excepting southwestern Kobeh Valley in the vicinity of the Bobcat Ranch, where pumping for agriculture has occurred since the 1960s.

Groundwater levels in the valley fill aquifers prior to major agricultural development are presented on **Figure 3.4-6**. Water level elevations range from above 6,700 feet in Garden Valley and north of Mt. Hope to less than 5,300 feet. Flow direction is generally from areas of higher elevations to areas of lower elevations, and hydraulic gradients are usually the greatest at the upper portions of alluvial fans. The general configuration of the potentiometric surface indicates groundwater flow from North Monitor and Antelope

Valleys, through Kobeh Valley, to the terminus of the flow system in Diamond Valley. In the area north of Mt. Hope, the general direction of groundwater flow is northward through Garden Valley, westward into Pine Valley, and northeastward through Pine Valley.

Within North Monitor Valley, the hydraulic gradient along the basin axis is fairly low, about 0.15 percent, and averages 8.8 to 9.4 feet per mile near the eastern boundary of Kobeh Valley.

Flow within Antelope Valley is similar to other valleys in the area, with flow paths originating in the mountain block and converging toward the valley center. The average gradient from northern Antelope Valley to southeastern Kobeh Valley is approximately 0.26 percent or 13.5 feet per mile.

Within Kobeh Valley, flow from the Simpson Park Mountains, the Roberts Mountains, and the Monitor Range as well as flow from the North Monitor and Antelope valleys converges near the center of the basin. A large and extensive series of phreatophytes marks the location of shallow depths to groundwater. The occurrence of shallow groundwater at this location may be attributable to a decrease in the cross-sectional area of the valley fill aquifer west of Lone Mountain at this point of convergence (Tumbusch and Plume 2006). The shallow groundwater levels west of the Devils Gate also suggest that the mountains separating Kobeh and Diamond Valleys are of sufficiently low permeability to preclude significant drainage into Diamond Valley.

The hydraulic gradients under pre-agricultural development conditions in Diamond Valley were markedly lower than in Pine, Kobeh, North Monitor, and Antelope Valleys. This is probably caused by several factors, including higher transmissivity of the valley fill materials (Buqo, 2008) and Diamond Valley's terminal position in the flow system, where a nearly flat gradient occurs beneath the playa. Diamond Valley receives some amount of inflow from Kobeh and Pine (Garden) Valleys, and possibly from Antelope Valley and Stevens Basin.

3.4.2.2 CURRENT (2005) WATER LEVEL CONTOURS: The most comprehensive compilation of water level data was obtained in 2005 by the USGS (Tumbusch and Plume, 2006). Over much of the Study Area, current flow conditions reflect dynamic equilibrium conditions due to the lack of groundwater development in most of the basins. The exception is southern and central Diamond Valley, where historic pumping has resulted in 30 to 80 feet of drawdown in the pumping area and lesser degrees of drawdown propagating outward from the pumping center (**Section 3.4.3.3**). Water level contours in southern and central Diamond Valley have been modified by pumping as depicted on **Figure 3.4-7**, for 2005 conditions, based on the work of Tumbusch and Plume (2006).

3.4.3 Hydrographic Basin Summaries

This section details the hydrologic setting and groundwater conditions for the basins within the Study Area. In addition, figures detailing the locations of wells and springs are provided for reference (**Figures 3.4-2 through 3.4-5**). A detailed inventory of springs visited within the Study Area is presented in **Appendix E**, and well data are provided in **Appendices F and G**.

Aquifer systems in southern Diamond Valley are the best defined in the Study Area due to the number of wells that have been drilled. However, because most wells in Diamond Valley are less than 600 feet deep, data exist primarily for the uppermost aquifer systems in the valley fill. As observed in well logs (**Appendix G**), the uppermost valley fill is primarily composed of interbedded strata of sands, silts, and clays.

Elsewhere in the Study Area, the data available to characterize aquifer systems are limited at present. Drilling and aquifer testing was completed in 2006 through 2009 by

EMLLC (Montgomery & Associates, 2008 and 2010b; Interflow, 2010). Aquifer testing by Hydro-Search (1982) provided some data for parts of Kobeh Valley. Mine-related drilling and testing data are supplemented by irrigation wells and petroleum exploration wells drilled in Kobeh Valley.

A shallow water table condition is present under the valley floors of Kobeh, Antelope, Diamond, and Pine Valleys from which phreatophyte vegetation discharges (transpires) groundwater. **Figures 3.4-8 through 3.4-10** show the distribution of phreatophyte vegetation in these four basins. Occupying the northern valley floor of Diamond Valley is an extensive playa of approximately 50,000 acres. Playas are absent in other basins in the model area as these basins are internally drained.

Flowing artesian wells exist in all basins in the model area. In Kobeh and Antelope Valleys, flowing wells discharge on the valley floor and are believed to be completed to relatively shallow depths (**Appendix G**). This may indicate the presence of a shallow confining unit. Alluvium in the basins is derived in part from Pleistocene lake deposits. Lake Diamond occupied Diamond Valley during the last glacial period (approximately 15,000 years before present) and encroached into a small portion of Kobeh Valley near Devils Gate (**Section 3.1 and Figure 3.1-7**). Older Quaternary and Tertiary lakes occupied the basins, and sedimentary units deposited in these environments (claystone, siltstone, and fine-grained, weakly cemented sandstone) are exposed at numerous locations in the Study Area (QTg and Ts on **Figure 3.1-1**; Childress and Ferdock, 2008). More recent lacustrine environments resulted in clay deposition and are most likely responsible for the shallow valley floor aquitards. Older valley fill deposits tend to be tuffaceous in nature throughout the Great Basin and can weather to clayey sedimentary units. Often, these units also become indurated, whereby the sediments become compressed and hardened over time, thus lowering the permeability. The deeper valley fill deposits also includes volcanic rocks from the Tertiary era, as exposed in some locations in the model area and extensively encountered in deep petroleum exploration drilling in the model area (**Section 3.1**). As a general rule, the younger Quaternary alluvium tends to be more permeable than older valley fill units.

The presence of geothermal springs and wells in the Study Area indicates deep, structurally-controlled flow systems (**Section 3.3.1.3**). In Kobeh Valley, geothermal wells are located southwest of Lone Mountain (**Plate 3**), and geothermal and artesian conditions have been reported in deep mineral exploration drill holes on the northern flank of Lone Mountain. Other geothermal springs include Klobe Springs in northern Antelope Valley, springs on the east side of central Pine Valley, and springs along the northwestern edge of Diamond Valley.

Deep drilling for petroleum exploration and geophysical surveys of the basins (**Section 3.1; Figures 3.1-4 and 3.1-5**) also provide data from which deep basin structure and potential aquifer systems may be characterized. Taken together with geomorphologic processes common to basins in the Great Basin, the nature of valley fill deposition and subsequent formation of aquifers and deep flow systems is conceptually presented in the groundwater model (**Section 4.1**).

"Bedrock" aquifers are also important in the Study Area, as some of the near-surface and much of the deeper bedrock lithology consists of carbonate rocks. Carbonate rock aquifer systems are extensive throughout eastern and central Nevada, where extensional tectonics have created regional structures through which water can flow, and when enhanced by dissolution of carbonate minerals, created highly permeable carbonate rock environments.

3.4.3.1 KOBEH VALLEY: The mountains that surround Kobeh Valley are composed of volcanic rocks (shown in red and orange on **Figure 3.1-1**), Paleozoic sedimentary rocks, including carbonate rocks (shown in blue on **Figure 3.1-1**), and clastic sedimentary rocks (shown as shades of green on **Figure 3.1-1**). The valley floor of Kobeh Valley resides at elevations ranging from approximately 6,100 to 6,200 feet, amsl.

Surrounding mountains are the Simpson Park Range to the west (elevation 8,146 feet, amsl); Roberts Mountains to the north (10,134 feet, amsl); Sulphur Spring Range, including Mt. Hope (8,411 feet, amsl), to the east; and Whistler Mountain (8,147 feet, amsl) and the Monitor Range to the south (10,463 feet, amsl). Lone Mountain protrudes from the central-eastern side of the Kobeh Valley floor at approximately 7,986 feet, amsl (**Figure 3.4-2**).

Coils Creek, Rutabaga Creek, and Roberts Creek are the largest perennial streams in the basin (**Figure 3.4-2**), although these streams generally do not produce flow past the mountain fronts in Kobeh Valley. No perennial streams exist on the valley floor; however, seasonal runoff and storm events can produce significant runoff at times. The Stoneberger Creek drainage enters the southwestern side of Kobeh from North Monitor Valley and crosses southern Kobeh Valley in a west to east direction through Bean Flat (**Figure 3.4-8**). Antelope Wash discharges from Antelope Valley to the south, and these ephemeral drainages join on the southeastern side of Kobeh Valley to form Slough Creek. Slough Creek, also ephemeral, drains east through Devils Gate to southern Diamond Valley. Channel geomorphology and a lack of vegetation scour indicate that outflow through Devils Gate is a rare occurrence related to low frequency, high volume runoff events.

As evidenced by petroleum exploration drilling and geophysical surveys, the Kobeh Valley basin contains approximately 5,000 feet of valley fill composed of alluvial, lacustrine, volcanic, and other sedimentary deposits and is deepest near the central-western part of the valley (**Figure 3.1-1**). By contrast, neighboring Diamond Valley contains approximately 8,000 feet of valley fill.

Groundwater flow in Kobeh Valley is toward the valley floor and eastward toward Devils Gate (**Figures 3.4-1 and 3.4-8**). Groundwater is shallow beneath the central valley floor, within 50 feet of ground surface, and, in some areas, within 10 feet of ground surface, such as at the Risi Ranch near Devils Gate and at Bean Flat. Springs and seeps discharge in the vicinity of Bean Flat and the Bartine Ranch, where flowing artesian wells also provide recharge to meadow areas southwest of Lone Mountain. Springs and seeps are estimated by Rush and Everett (1964) to discharge approximately 2,500 AF/yr on the valley floor. The mountain blocks have numerous small springs which feed streams and support local meadows.

The shallow groundwater at the valley floor supports substantial areas of phreatophyte vegetation, with roots that tap groundwater (**Figure 3.4-8**). Primary phreatophytes observed in Kobeh Valley are greasewood, rabbitbrush, and salt grass. ET of groundwater by phreatophytes is the primary groundwater discharge component in the basin. The water budget for Kobeh Valley presented by Rush and Everett (1964) is estimated at 17,000 AF/yr of combined recharge from infiltration of precipitation falling in the basin and from subsurface inflows from North Monitor Valley. Minor (equal to or less than 40 AF/yr) groundwater is reported to discharge from Kobeh Valley as subsurface outflow to Diamond Valley in the vicinity of Devils Gate (Eakin, 1962; Rush and Everett, 1964; Harrill, 1968). Computations of the potential range of outflow to Diamond Valley in this study are 12 to 270 AF/yr (**Section 3.4.3**). It is also conceptually possible that deep flow through carbonate rocks north of Whistler Mountain (a granite intrusive) provides a conduit for subsurface flow from Kobeh Valley to Diamond Valley. Existence or magnitude of this conceptual flow cannot be determined or verified with existing data. However, given that Kobeh Valley functions primarily as a hydrologically closed basin with substantial groundwater discharge from the central valley floor, the magnitude would not be expected to be large as compared to the total water budget for the basin.

Some groundwater development has occurred in Kobeh Valley, primarily for small-scale agriculture. Flood and sprinkler irrigation occurs at several smaller ranches in the basin, the largest of which is the Bobcat Ranch on the western side of the valley (**Figure 3.4-8**). Historic agricultural water use in Kobeh Valley has been minor compared with that in Diamond Valley and is estimated at approximately 3,400 AF/yr (**Section 3.5.3**).

Current groundwater resources are not fully committed by underground water rights **(Table 2.0-1)**.

3.4.3.2 ANTELOPE VALLEY: Antelope Valley is a V-shaped valley, open on its northern end to Kobeh Valley. Antelope Valley is bounded by the Monitor Range (10,463 feet, amsl) on the west, by the Antelope Range (10,105 feet, amsl) to the south, and by Fish Creek Range (10,378 feet, amsl) to the east **(Figure 3.4-8)**. Surface and groundwater move northward **(Figure 3.4-1)** and, in part, are consumed by phreatophytes on the valley floor **(Figure 3.4-8)** and, in part, by discharges to Kobeh Valley. Rush and Everett (1964) speculated that a fault barrier to subsurface flow existed between Antelope and Kobeh Valleys; however, little supporting evidence exists today to support this hypothesis. From a hydrogeologic perspective, Antelope Valley appears to be a connected tributary to Kobeh Valley. As noted previously, there may be some small quantity of groundwater that flows from northeasternmost Antelope Valley to the east toward Diamond Valley.

Recharge to Antelope Valley was estimated by Rush and Everett (1964) at 4,100 AF/yr, and discharge by phreatophyte vegetation was estimated at 4,200 AF/yr, with effectively no outflow from Antelope Valley to Kobeh Valley. However, water level maps published for Antelope Valley (Robinson et al., 1967; Fiero, 1968; Tumbusch and Plume, 2006) show a northern gradient, implying some degree of subsurface outflow. Calculations of subsurface outflow in this study range from 150 to 3,000 AF/yr **(Section 3.4.4.2)**.

Previous investigators have suggested the possibility of southeastward subsurface outflow from Antelope Valley to the Fish Creek Springs in Little Smoky Valley (Rush and Everett, 1966; Lopes et al., 2006; Tumbusch and Plume, 2006). These interpretations are not consistent with the potentiometric maps cited above, but the difference may be a result of the loss of access to a well that was measured in the older studies but subsequently backfilled. The water budget estimate by Rush and Everett (1964) for Antelope Valley does not accommodate additional subsurface outflow. However, water budget imbalances for north

Little Smoky Valley and the Fish Creek Springs do support a source of inflow from outside the local watershed (Rush and Everett, 1966). Additional data are required to substantiate and quantify this possible connection between Antelope Valley and Little Smoky Valley, and an adjustment in the Antelope Valley water budget would be required to support outflow of any substantial magnitude.

Flowing artesian wells producing both geothermal and non-geothermal waters, are located in the north-central part of the valley (**Figures 3.4-3 and 3.4-8**). Springs at the western side and central portion of the valley floor (Klobe Springs and Kitchen Meadow) were estimated by Rush and Everett (1964) to discharge 1,000 AF/yr.

Some agriculture occurs on the valley floor along Antelope Wash (**Figure 3.4-8**); however, to date, Antelope Valley is not fully committed with regards to groundwater rights (**Table 2.0-1**).

3.4.3.3 DIAMOND VALLEY: Diamond Valley is elongated in a north-south orientation and bound by the Diamond Range to the east (10,614 feet, amsl); the Diamond Hills to the north; the Sulphur Spring Range, Mt. Hope, and Whistler Mountain to the west; and the Fish Creek Range to the south (**Figure 3.4-4**). The valley floor is approximately 10 miles wide by 42 miles long. Diamond Valley is a topographically closed basin with no surface water outflow or known groundwater outflow.

Groundwater flow in Diamond Valley is toward the valley floor and northward toward an extensive playa which occupies approximately 50,000 acres in the northern valley floor (Harrill, 1968). Phreatophyte vegetation consisting primarily of greasewood, rabbitbrush, salt grass and meadow grass surrounds the playa (**Figure 3.4-9**). Springs situated near the eastern and western mountain fronts and at the periphery of the playa support salt grass and meadow grass vegetation. ET from the northern playa and phreatophyte areas comprised the primary groundwater discharge under natural conditions.

However, Diamond Valley has been extensively developed for agriculture since the 1950s, and current pumping is another large groundwater discharge component in the basin. In fact, more groundwater is pumped for irrigation in Diamond Valley than any other basin in Nevada (Lopes and Evetts, 2004). The basin has been subdivided into northern and southern subareas for purposes of computing water budgets (Harrill, 1968). The playa and most of the phreatophyte discharge occurs in the northern subarea, while most of the agricultural pumping occurs in the southern subarea (**Figure 3.4-9**).

Groundwater recharge was estimated by Harrill (1968) to be 21,000 AF/yr, and an additional 9,000 AF/yr is interpreted as subsurface inflow from Garden Valley, a subarea of Pine Valley, through the Sulphur Spring Range. Groundwater inflow from Kobeh Valley at Devils Gate was estimated by Harrill (1968) to be less than 40 AF/yr. As presented in **Section 3.4.3.1**, conceptual inflow from Kobeh Valleythrough deep carbonate rocks north of Whistler Mountain is identified as a possibility for this study. Ephemeral surface water flow through Devils Gate to Diamond Valley was estimated at 100 AF/yr, as a long-term annual average (Harrill, 1968).

ET discharge was estimated by Harrill (1968) at 30,000 AF/yr; however, during the period of that study, groundwater storage was also being depleted by agricultural pumping and water levels were declining in the vicinity of the irrigation wells. Since the Harrill (1968) study, groundwater pumping has both continued and increased to approximately 70,000 AF/yr in 1995 (Arteaga et al., 1995), and the resultant cone of depression has continued to expand, as water levels in southern and central Diamond Valley continue to decline. Total decline in water levels in the agricultural area since the 1950s ranges from approximately 30 to 90 feet (Tumbusch and Plume, 2006), and the ramifications of this drawdown are discussed further in **Section 3.5.3**.

The agricultural pumping center is asymmetrical with regards to the natural flow system, with the pumping occurring in the southern portion, while the natural discharge primarily occurs in the northern portion of the basin. Drawdown has undoubtedly captured some of the southern phyreatophyte and playa discharge and will slowly progress northward. Springs on the southern end of the playa, such as Sulphur Spring, have ceased to flow, as observed by the study team in 2007 and 2008. Thompson Ranch Spring was observed by Harrill (1968) to discharge approximately 2.17 cfs (975 gpm) in 1965-66 (**Tables 3.3-1 and 3.3-2**). Arteaga et al. (1995) reported flow at 4.23 cfs in 1980, decreasing to 0.11 cfs by 1990. Currently, the spring has no surface flow, as observed by the study team in the spring of 2007. Depth to water at Thompson Spring was measured at 6.1 feet below the spring box discharge rim on April 13, 2007. Drawdown at these springs situated in the southern part of the north subarea is attributed to pumping in the south-central part of Diamond Valley.

Numerous springs and several flowing artesian wells were known to exist on the northwestern side of the valley (**Figure 3.4-9**), most of which produced warm waters (Harrill, 1968). Shipley Spring, the most significant of these springs, was reported by Harrill (1968) to discharge 6.20 to 7.19 cfs (2,783 to 3,227 gpm) (**Tables 3.3-1 and 3.3-2**). The water temperature of Shipley Spring was observed to be approximately 103.0 °F in April 2007, and in May 2008, the discharge was measured at 3.56 cfs, indicating that Shipley Spring flows may also be reduced from historic levels (**Section 3.5.3**).

If estimates of recharge by Harrill (1968) are accurate, a significant overdraft condition exists in Diamond Valley and an equilibrium discharge-recharge condition may never be reached. Under this overdraft condition, the drawdown would continue to propagate to the north, capturing additional phreatophyte, playa, and spring discharge. Water level declines would continue in the vicinity of the wells until the portion of the aquifer tapped by the pumping wells has been effectively dewatered, at which point the magnitude of pumping could not be supported without progressive deepening of wells and pumps.

3.4.3.4 PINE VALLEY: Pine Valley is elongated in a north-south direction and narrows to the north (**Figure 3.4-5**). Surface water from Pine Creek and tributaries flows northerly to the Humboldt River located on the northern edge of the hydrographic basin. The basin is approximately 55 miles long and is bounded on the south by the Roberts Mountains, on the east by the Sulphur Spring Range, northwest by the Cortez Mountains, and southwest by the Simpson Park Mountains. Garden Valley is a sub-basin of Pine Valley and is situated between the Roberts Mountains and the Sulphur Spring Range, with the watershed divide about two miles north of Mt. Hope. Henderson Creek drains Garden Valley, discharging to Pine Valley on the western-central edge of Garden Valley (**Figure 3.4-10**).

Groundwater in Pine Valley flows northward and toward the valley floor, although some researchers believe there is groundwater discharge from Garden Valley into Diamond Valley (see below and **Section 3.4.4.4**). Phreatophyte areas are observed along Pine Creek and tributaries Willow Creek and Henderson Creek (**Figure 3.4-10**). Mapping of phreatophyte vegetation areas was not presented in the Reconnaissance Report by Eakin (1961), but were mapped by Berger (2000a) as the Valley Lowland. This geographic area was intended by Berger to represent the zone of phreatophytes but is not specifically mentioned in his report (Dave Berger, 2008, personal communications). Berger's phreatophyte distribution was electronically digitized and is shown on **Figure 3.4-10**. The northern portion of Pine Valley is outside the Study Area defined for this study.

Basin-wide recharge to Pine Valley is estimated at 46,000 AF/yr by Eakin (1961), and discharge was estimated at 24,000 AF/yr, being in part ET and in part groundwater discharge to Pine Creek in the northern portion. Subsurface outflow to the Humboldt River was estimated by Eakin (1961) to be approximately 300 AF/yr. A considerable imbalance in the water budget is presented in Eakin (1961). The subsurface outflow from Garden Valley to Diamond Valley of 9,000 AF/yr estimated by Harrill (1968) was not acknowledged by Eakin (1961) but lessens the imbalance.

Berger (2000a) further reviewed water budgets for Pine Valley, presenting an estimated range of recharge between 52,500 to 79,300 AF/yr and suggesting higher ET rates in the range of 0.5 to 2.5 ft/yr versus 0.1 to 1.25 used by Eakin (1961). Berger (2000a) includes an examination of the distribution of recharge in Pine Valley between major geographic regions, being the mountain blocks, piedmont (alluvial fans), and the valley floor (phreatophyte discharge areas). The work of Berger (2000a) is similar to that of Nichols (2000) in that he used climate data in combination with satellite images to develop a vegetation index for estimating ET.

Agriculture occurring along Pine Creek and its tributaries subsists on both surface and groundwater resources. The basin is not presently fully committed with regard to underground water rights (**Table 2.0-1**). Oil and gas have been developed in the central-eastern portion of the basin.

3.4.4 Inter-basin Flow

3.4.4.1 NORTH MONITOR VALLEY TO KOBEH VALLEY: Subsurface inflow to the Study Area occurs from north Monitor Valley into Kobeh Valley. Rush and Everett (1964) estimated the inflow from Monitor Valley to be approximately 6,000 AF/yr, using a Darcy's Law computation (form Q = TIW) with assumed values of transmissivity (T) of 100,000 gallons per day per foot (gpd/ft), a gradient (I) of 10 feet per mile, and an effective flow width (W) of 6 miles, converted to equivalent units in feet and days. In review of these assumptions, additional data are available to refine the supposition; however, no transmissivity values are available at the location of inflow. Using transmissivity values ranging from 5,150 to 54,450 gpd/ft, as estimated from reported specific capacity data from wells in the Bobcat Ranch area (Driscoll, 1986, and **Table 3.4-2**), an updated gradient of 8.8 to 9.4 feet per mile, and an estimated effective width of 3.8 to 6 miles results in an estimated subsurface inflow to Kobeh Valley ranging from 200 to 3,450 AF/yr, using the lowest and highest T, I, and W values, respectively. Utilizing an average value for gradient, width, and transmissivity, an overall average of 1,500 AF/yr is obtained. While existing data suggest subsurface inflow to Kobeh Valley exists, it may be a little less than presented by

Rush and Everett (1964); however, data are presently lacking to quantify the magnitude of inflow more precisely

3.4.4.2 ANTELOPE VALLEY TO KOBEH VALLEY: Groundwater outflow from Antelope Valley to Kobeh Valley is supported by potentiometric gradients and suitable permeability materials for outflow. Using the form of Darcy's Law, Q = TIW, where T ranges from 1,000 to 20,000 gpd/ft, I is an average 0.0026 feet per foot (ft/ft), or 13.6 feet per mile, and W is approximately 10 miles, the range of possible outflow from Antelope Valley to Kobeh Valley is estimated to be 150 to 3,060 AF/yr.

3.4.4.3 KOBEH VALLEY TO DIAMOND VALLEY: Flow from Kobeh Valley into Diamond Valley has been postulated based on potentiometric gradients near Devils Gate and the likely connectivity of alluvial cover between the basins at Devils Gate. Harrill (1968) suggested the subsurface flow was no greater than 40 AF/yr.

In this study, Darcy's Law (form Q = KIA) was applied to compute estimated outflow using the following assumptions and potential range of parameters:

1. Outflow could occur in both the shallow alluvium and underlying fractured bedrock (Devils Gate limestone at the center of Devils Gate with clastic sedimentary rocks along the east and west side [**Figure 3.1-1**]).
2. The alluvial area (A) in cross-section at the narrowest point in Devils Gate canyon is approximately 100 feet wide and 50 to 100 feet thick (Harrill, 1968).
3. Hydraulic conductivity (K) of the alluvium is approximately 60 ft/d, and the gradient (I) as estimated by differences in water level elevations between nearby alluvial wells is 0.0024 to 0.0037 ft/ft (EMLLC 9211R on the Risi Ranch, USGS Devils Gate well, and NWIS 153 N20 E53 30ABCC in Diamond Valley).
4. A conductive bedrock fracture zone exists and is 50 to 100 feet wide and 50 to 1,000 feet deep, with a hydraulic conductivity ranging from 1 to 100 ft/d and a gradient of 0.003 ft/ft. This fracture is consistent with an inferred right-lateral

west-east-striking structure suggested by offset in rock elevations from geologic mapping of Devils Gate (**Figure 3.1-1**).

The range of potential outflow is computed as 6 to 18 AF/yr in the alluvium and 6 to 252 AF/yr in the bedrock, with a combined range of approximately 12 to 270 AF/yr. It should also be acknowledged that there is potential for groundwater flow between Kobeh Valley and Diamond Valley at depth through bedrock north of Whistler Mountain, particularly the deep portions of the range composed of carbonate rocks. This may be in part driven by the increasing head differential between these valleys as a result of pumping-associated drawdown occurring in Diamond Valley. It should be noted that water level data for the upper 1,000 feet of Kobeh Valley fill and rocks in the Whistler Range north of Whistler Mountain do not indicate the presence of shallow subsurface groundwater between basins.

3.4.4.4 PINE VALLEY (GARDEN VALLEY SUB-BASIN) TO DIAMOND VALLEY: Harrill (1968) estimated subsurface outflow from Garden Valley to Pine Valley to be 9,000 AF/yr based on water budget computations for Garden Valley and the quantity of thermal spring discharge on the western side of Diamond Valley. Conceptually, it is difficult to envision 90 percent of the estimated recharge to Garden Valley resulting in outflow to Diamond Valley, and Eakin (1961 and 1962), in his work in Pine and Diamond Valleys, did not identify any subsurface flow between the basins. For purposes of this study, it was assumed that a significant outflow from Garden Valley to Diamond Valley may exist, but perhaps not as large as the 9,000 AF/yr estimated by Harrill (1968).

3.4.4.5 STEVENS BASIN TO DIAMOND AND/OR ANTELOPE VALLEYS: Stevens Basin may contribute 200 AF/yr of inflow to Diamond and/or Antelope Valleys (Rush and Everett, 1964). However, for purposes of this study, outflow from Stevens Basin is assumed to be negligible.

3.4.5 Discharge by Evapotranspiration

ET is the process that returns water to the atmosphere through evaporation and transpiration. Evaporation occurs from soil, wet plant surfaces, and open water bodies, while transpiration occurs from plants. ET from groundwater is a principal variable for developing water resource budgets in Nevada, but evaporation from surface water is also important from a total water resource budget. Plants that commonly use groundwater are termed phreatophytes, first defined by Meinzer (1927) as "plants that habitually grow where they can send their roots down to the water table or the capillary fringe immediately overlying the water table and are able to obtain a perennial and secure supply of water."

Early USGS ET investigators (Lee, 1912; Blaney et al., 1930, 1938; White, 1932; Gatewood et al., 1950; and Robinson, 1970) were based generally on ET-tank experiments. Maxey and Eakin (1949) developed their recharge estimates based on groundwater discharge by phreatophytes and bare soil referencing the early investigators mentioned above. USGS investigators from the 1940s through the 1970s utilized the earlier studies to estimate ET from groundwater in nearly all the basins in Nevada. These results are published in the State's Reconnaissance Series Reports.

The phreatophytes of interest in the Study Area are mainly the greasewood-rabbitbrush-meadow grass plant community. This community may include greasewood, saltbush, spiny hopsage, winter fat, rabbitbrush, and sagebrush. Saltgrass, part of the salt desert plant community, is also a major water user.

Some phreatophytes, such as greasewood, commonly send their roots as deep as 50 feet to the water table, and depths up to 80 feet were reported by Eakin et al. (1951). Rabbitbrush is found where the depth to water is generally less than 30-35 feet, and saltgrass grows where the depth to water ranges from near surface to 10 feet bgs. There are numerous parameters that determine the water use rate of phreatophytes, such as the depth to water, type of vegetation, density, soil characteristics, and climatic factors.

The ET estimates given in published reports for basins within the Study Area are listed in **Table 3.4-3**. The footnotes reference the various authors.

By the time Berger (2000a) worked in Pine Valley, many studies had been undertaken to determine ET other than utilizing ET tanks. This work primarily solved the energy budgets to determine the amount of ET from various types of vegetation including phreatophytes. Notable studies include Tanner (1960), Monteith (1965), Businger et al. (1967), Weeks et al. (1987), Duell (1990), Malek et al. (1990), Nichols (1992, 1993, 1994), Nichols and Rapp (1996), Nichols et al. (1997), and Nichols (2000). Berger (2000a) applied the Penman-Monteith (Monteith, 1965) equation to climatic data from remote automatic weather stations at numerous sites throughout his Study Area. Using remote sensing techniques described by Nichols (2000) and based on Landsat imagery, a vegetation index resulting from the reflectance from vegetation cover was correlated to ET.

The results of Berger's (2000a) work in Pine Valley show about a two- to threefold increase in the amount of ET compared with the work of Eakin (1961).

3.5 WATER BUDGETS AND PERENNIAL YIELD

3.5.1 Summary of Previously Established Water Budgets

The water budget (or water balance) concept is commonly used in hydrologic sciences and can be viewed as an accounting system. For a groundwater system that is in a state of dynamic equilibrium, inflows of water to the system are equal to outflows. In a disequilibrium system, outflows are not in balance with inflows, resulting in depletion or addition to groundwater in storage in the aquifer. Consequently, water levels in the aquifer are either rising or falling in elevation. Common inflows to a groundwater system include recharge by infiltration of precipitation and subsurface inflows from adjacent basins. Common outflows include: ET by phreatophytes; evaporation of groundwater from a playa with a shallow underlying water table; subsurface outflow to adjacent basins; evaporation of open surface water directly fed by groundwater; spring discharge; and pumping from wells. The water budget equation can be written as follows:

Sum of Inflows – Sum of Outflows = Change in Storage
where:

Change in Storage equals zero for a condition of dynamic equilibrium

Using Diamond Valley as an example, the inflows are recharge from precipitation falling on the basin, subsurface inflows from Garden Valley and Kobeh Valley, infiltration of unused irrigation water (termed secondary recharge or return flow), and, at times, recharge of surface runoff which enters the basin through Devils Gate via Slough Creek. Outflows from Diamond Valley are natural ET of groundwater by phreatophyte plants; evaporation from the playa; discharges of groundwater at springs as subsequent evaporation of spring water; and pumping by wells for agriculture, mining, municipal, and domestic purposes. The system is in disequilibrium, as evidenced by declining water levels in the agricultural use area, which indicates a net depletion from groundwater stored in the aquifer.

An overview of water budgets in the Diamond Valley regional flow system and peripheral basins, as presented in USGS-NDWR Reconnaissance Series Reports, is presented in **Table 3.5-1**. With the exception of Pine Valley and the northern portion of Little Smoky Valley, the basins of interest in and adjacent to the Study Area have presently defined pre-development water budgets that balance, meaning interpreted outflows equal interpreted inflows to the system.

A summary of the conceptual water budget for the Study Area, including water sources and sinks, is in **Table 3.5-2**. For the most part, water budgets are derived from published USGS Reconnaissance Series Reports for the numerical model area, with the following modifications:

1. The total recharge by precipitation to Kobeh Valley was increased over the Reconnaissance Series Report estimate to approximately 13,300 AF/yr based on the updated Maxey-Eakin computation (**Table 3.2-6**).
2. Some subsurface inflow from Antelope Valley to Kobeh Valley is expected, at a magnitude to be established at 150 to 3,060 AF/yr (**Section 3.4.4.2**). The estimated recharge to Antelope Valley remains the same reported in the USGS Reconnaissance Series Report. Some of the outflow component must be subtracted from the ET discharge in Antelope Valley to maintain the water balance.
3. Outflow from Kobeh Valley to Diamond Valley has been estimated in the USGS Reconnaissance Series Reports to be minor, no greater than 40 AF/yr at Devils Gate. Outflow from Kobeh Valley to Diamond Valley was assumed to be 12 to 270 AF/yr (**Section 3.4.4.3**) by interpreted deeper subsurface hydraulic connection at Devils Gate, with a possible additional outflow source north of Whistler Mountain.
4. Subsurface inflow to Kobeh Valley from North Monitor Valley was estimated in the USGS Reconnaissance Series Report to be approximately 6,000 AF/yr. Data from which to calculate subsurface inflow are sparse, and, in this study, the range was estimated at 790 to 5,950 AF/yr, with an average value of 2,830 AF/yr (**Section 3.4.4.1**). The water balance and perennial yield of Kobeh Valley is approximately the same total as determined in the USGS Reconnaissance Series Report (16,000 AF/yr), and the deficit of inflow from North Monitor Valley will be offset by increased recharge by precipitation (see item 1 above) and inflow from Antelope Valley (see item 2 above).

5. Harrill (1968) estimated that 90 percent of the recharge derived in the Garden Valley subbasin of Pine Valley resulted in outflow to northern Diamond Valley. This represents a rather large quantity of water, 9000 AF/yr, and conceptually is difficult to envision given the geologic composition of the intervening Sulphur Spring Range. Eakin (1962) did not recognize any subsurface inflow from Garden Valley. To the degree that the inflows may be less than Harrill, some compensation may occur by inflow from Kobeh Valley greater than estimated by Harrill (1968). However, a deficit may still result which will be reflected in lower total ET and playa discharge in Diamond Valley.

Distribution of recharge in the Study Area is divided into three landform zones for each basin, those being: 1) the mountain blocks, 2) piedmonts (alluvial fans), and 3) major ephemeral drainages crossing the piedmonts (**Section 3.2.2.1**). This distribution is based in part on work by Berger (2000a) in Pine Valley and is supported by ephemeral stream loss estimates made in this study for Kobeh Valley (**Section 3.3.2.3**). The three major zones of recharge distribution adhere to a general scientific understanding of the primary occurrence of recharge by precipitation in Great Basin valleys.

Distributions of discharge through phreatophyte and playa ET are based on mapping presented in the USGS Reconnaissance Series Reports except for Pine Valley, where satellite images were used in conjunction with work by Berger (2000a) to make preliminary interpretations of phreatophyte distributions (**Section 3.4.5**).

Except in Diamond Valley, present-day conditions are similar to pre-development conditions in all basins. Some ranching and mining has occurred, but pumping stresses are not observed to have caused extensive or persistent water level declines. Hydrologic conditions in Diamond Valley are not presently in equilibrium as a result of significant pumping for agriculture (**Section 3.5.3**), which is manifested as declining water levels.

Consumptive use of groundwater by pumping is currently estimated at 55,000 AF/yr, which is offset somewhat by capture of spring and ET discharge in the central portion of the basin.

3.5.2 Summary of Perennial Yields for the Study Area

Table 3.5-3 shows established perennial yields for basins in the Study Area. The perennial yield of Kobeh Valley, based on the Rush and Everett (1964) Reconnaissance Series Report, is approximately 16,000 AF/yr. Adding estimated groundwater inflow from northern Monitor Valley of 6,000 AF/yr and 11,000 AF/yr of recharge derived from estimated in-basin recharge from precipitation over upland areas results in a recharge total of 17,000 AF/yr. Rush and Everett (1964) estimated ET discharge to be 15,000 AF/yr based on reconnaissance-level mapping of phreatophyte areas and estimated ET rates derived from observations on the ground and values determined elsewhere in the Great Basin. These recharge and discharge estimates were averaged to derive a perennial yield estimate of 16,000 AF/yr. **Table 3.5-1** summarizes the assumed basin inflows and outflows. Mt. Hope process water pumping of 11,300 AF/yr will be within the presently defined perennial yield of Kobeh Valley.

Based on available data, relying on the published perennial yield values appears to be a conservative assumption for purposes of evaluating project pumping.

3.5.3 Water Use (Anthropogenic)

Within the Study Area the vast majority of water that is received by the basins as precipitation is lost to evaporation and transpiration from vegetation. However, groundwater pumping within Diamond Valley is approximately double the presently defined perennial yield. Anthropogenic groundwater use within Kobeh Valley has been more limited but not insignificant, particularly in the southwestern portion of the basin.

3.5.3.1 ESTIMATED WATER USE: Available data indicate that spatial distribution and magnitude of groundwater withdrawals has varied considerably over time. Development of groundwater resources in Diamond Valley began in 1949, when two wells were installed along the eastern boundary of the valley (Eakin, 1962). Many wells installed prior to 1960 were located 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 plentiful, 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 heralded a significant increase in groundwater 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 somewhat similar pattern, and by 2005, approximately 1,000 acres of alfalfa were irrigated along the basin's western border. Because of the limited scale of groundwater withdrawals in Kobeh Valley, groundwater resources in the basin are considered largely undeveloped (Tumbusch and Plume, 2006).

Groundwater pumping distribution from the valley fill aquifers is based on published estimates of groundwater withdrawals from Diamond Valley (Arteaga et al., 1995); reports of pumping distributions from Nevada basin Reconnaissance Series Reports (Harrill, 1968; Eakin, 1962); detailed crop surveys and basin estimate aggregates from the NDWR (1961-2005) for Diamond and Kobeh Valleys; additional estimates for public water systems using an interpolation method based on population for Nevada public water systems (Lopes and Evetts, 2004); and pumpage reports for the Ruby Hill Mine.

NDWR crop inventories for Diamond Valley were conducted from 1961 to 1965, 1975 to 1989, 1992 to 2000, and 2002 to 2005. Crop inventories and crop consumptive water use estimates for Kobeh Valley were provided by NDWR for 1983, 1985, 1986, 1993, 1999, 2001, and 2002 to 2004. Additional data on pumping estimates for Kobeh Valley are found in Rush and Everett (1964). For years lacking any data (1970-1974, 1991, and 2001) linear interpolation of the years prior to and after the missing record were used to estimate total annual withdrawals.

For Diamond Valley pumping distribution between the years of 1992 and 2005, this study relied heavily on the crop survey data provided by NDWR, which were provided on a township and range scale. The NDWR township and range aggregates summarize the acreage of crops grown by type and assigns a consumptive use (not a pumping total) rate based on crop type for each irrigated field. In general, irrigation-intensive crops such as alfalfa were assigned a consumptive use rate of 3.0 feet per acre per year. Other crops and pasture were assigned a use of between 1.0 to 2.0 feet per acre per year. Throughout the NDWR crop inventories, these consumptive use rates were constant, with the exception of surveys conducted in Diamond Valley in the mid 1970s. During these years, grains were assigned a rate of 3.0 feet per acre, which was reduced to 2.0 feet per acre in 1976. This discrepancy was not altered from the reported data because it is uncertain if the change reflects actual changes in crop type or an arbitrary change in the crop surveyor's estimation method. In several of the crop surveys, some minor computational errors in arithmetic were noted where values from each township and range were incorrectly tabulated to create a valley-wide total. These errors were corrected but resulted in only a very small change in the total reported water use. The difference between the NDWR-reported water use based on crop summaries and that calculated for this report differs by only a fraction of a percent (0.08 percent), and reported versus estimated values are shown in **Table 3.5-4** and on **Figure 3.5-1**.

It is important to note that NDWR crop inventories reflect consumptive water use and not the total water right duty or total water pumped. The actual pumped amounts are greater, including both the crop water use and return flows, i.e. infiltration past the crop root zone and back to the aquifer.

The NDWR has recently updated crop consumptive use estimates on a basin scale throughout Nevada (Huntington and Allen, 2010). The Penman-Monteith (Monteith, 1965) method was used, along with consideration of local and regional meteorological data. Computations by Huntington and Allen (2010) suggest that the consumptive use assumption in the NDWR crop inventories for alfalfa (3.0 AF/yr) is high and should be adjusted down to 2.5 AF/yr in Diamond Valley. **Figure 3.5-1 and Table 3.5.4** show recomputed consumptive use in Diamond Valley based on an adjusted consumptive use rate of 2.5 AF/yr for alfalfa, while maintaining consumptive use rates for other crops. Use of the reduced consumptive use value suggests that approximately 55,000 AF/yr are currently being consumed for agriculture in Diamond Valley.

3.5.3.2 AQUIFER RESPONSE TO WATER USE: Water level response to groundwater withdrawals in the Study Area is generally related to the level of agricultural development in the individual basins. The transient response to pumping over time is illustrated on **Plate 3** and consists of data gathered from the USGS and NDWR. Hydrographs for all water level data points can be viewed in **Appendix F**, with an automated hydrograph function established in the Excel spreadsheet.

3.5.3.2.1 Kobeh Valley: Within Kobeh Valley, groundwater levels have not substantially changed over time, due in part to the lack of any major groundwater withdrawals in the basin. Groundwater resources are considered by the USGS to be "largely undeveloped" (Tumbusch and Plume, 2006). Within Kobeh Valley, water levels in most wells have fluctuated less than 10 feet in 40 years and appear to be stable (**Appendix F; Plate 3**).

Agricultural water use (consumptive use) in Kobeh Valley was estimated at approximately 3,500 AF/yr in 2004 and 2005 (**Table 3.5-4**). Water levels have undoubtedly declined to some extent in response to pumping at the Bobcat Ranch; however, historic water level data in the immediate vicinity are sparse. In May 2008, the water level was at 86 feet bgs on the west side of the farm. Irrigation had just begun for the season. Depth to groundwater reported on a well log in close proximity (perhaps the same well) was 60 feet in 1972, suggesting about a 26-foot water level decline at the farm although some of this decline is likely due to the seasonal pumping immediately before the reading. Two miles southeast of the Bobcat Ranch, long-term records for well 139 N19 E47 36BBBA (Well 28) indicate that water levels in 2005 were within the range seen in the 1960s and 1970s (**Plate 3**).

Near Devils Gate, between Kobeh Valley and Diamond Valley, water levels have also varied very little in the shallow alluvium and do not appear to have responded to pumping from Diamond Valley (**Plate 3**, well 100). No data exist for deep potentiometric water levels in this area.

3.5.3.2.2 Diamond Valley: Diamond Valley, with the greatest level of agricultural development in the Study Area, has likewise experienced the largest changes in groundwater levels. Water levels in the center of the southern Diamond Valley subarea have experienced 80-90 feet of decline, while wells along the periphery of the main pumping center have experienced declines of 30-80 feet (**Figure 3.5-2**). As a result of the lowering of the potentiometric surface in Diamond Valley, groundwater flow directions have reversed in the central part of the basin, as is apparent from comparison of **Figures 3.4-6 and 3.4-7**.

The rate of groundwater level decline in southern Diamond Valley for wells with historic records ranges from approximately 1.3 to 3.3 feet per year using data from the USGS (**Appendix F**). Historically, Townships 21 and 22 north and Ranges 53 and 54 east have displayed the largest amount of drawdown, as shown on **Figure 3.5-2**. Assuming that an average rate of decline of 2 feet per year will continue into the future, groundwater levels will drop below the bottom depths of most wells in 70 to 100 years (**Table 3.5-5**). Before this situation occurs, water levels will fall below current pump intakes, rendering the wells unusable unless deepened.

As groundwater levels in the valley fill aquifer in Diamond Valley have declined, flow from springs and seeps south of the playa and along the mountain-front have also declined. In some cases, historic springs no longer flow and have been replaced by wells or augmented by spring boxes. However, spring discharge also responds to variations in precipitation. The annual precipitation recorded at Eureka is compared with the spring discharge of Shipley Spring and Thompson Ranch Spring (also referred to as Taft Spring) on **Figure 3.5-3**. The data show a mild decline in spring discharge from the mid 1960s to the early 1980s that corresponds to an average precipitation condition of approximately 12 inches, plus or minus 5 inches. Both springs increased in discharge during the wet years of the early 1980s when precipitation was considerably above average. As precipitation fell closer to the normal range from the early 1990s to present, spring discharges did not resume post-1980s flows, and Thompson Ranch Spring (Taft Spring) ceased flowing around 1990. Although data are limited, Shipley Spring discharge also appears to have declined from about 6 to 7 cfs in the mid-1960s to 3.5 cfs observed in 2007-2009.

At Thompson Ranch Spring, it is believed that the spring flow, as likely derived from a carbonate-rock flow system from the Diamond Mountains, still exists, but because of water level declines, no longer reaches ground surface. A similar "capture" condition may be occurring at Shipley Spring.

<u>3.5.3.2.3 Other Study Area Basins:</u> Agricultural development and groundwater withdrawals are largely absent in North Monitor Valley, and water levels from the basin show a steady, unchanging water level (Tumbusch and Plume, 2006), as shown on **Plate 3**.

Antelope Valley, to the south of Kobeh Valley, has also experienced stable water levels. Data on historic water level trends in Pine and Garden Valley are sparse and not sufficiently comprehensive to make any trend observations.

3.6 AQUIFER HYDRAULICS

This section discusses the available hydraulic property data from Kobeh Valley and other basins in the Study Area. The data were assembled from published and unpublished sources including the USGS, consultants working on behalf of EMLLC, and previous owners of the Mt. Hope project.

Some common aquifer testing and hydraulic terms used to define aquifer characteristics are provided below. References with greater discussion of aquifer coefficients include Todd (1980), Freeze and Cherry (1979), Driscoll (1986), Walton (1987), and Heath (1989).

Transmissivity (T) is defined as the rate of flow in gallons per minute through a vertical section of an aquifer 1 foot wide and extending the full saturated height of the aquifer under a hydraulic gradient of 1. Transmissivity values are reported in units of gallons per day per foot, which in turn can be converted to units of square feet per day (ft^2/d), or other equivalent units. The transmissivity of a homogenous and isotropic aquifer divided by the aquifer thickness is the hydraulic conductivity (K), reported in feet per day (ft/d).

Specific Yield (Sy) is defined as the volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in the water table. Sy typically ranges from 0.01 to 0.30 for alluvial materials.

Storativity (S) (or the storage coefficient) is used for confined aquifers and is defined as the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface area, and commonly ranges from values of 10-3 to 10-5.

Specific Storage (Ss) is the storativity divided by the confined aquifer thickness.

Aquifer coefficients are normally determined by aquifer testing in which the aquifer is stressed by pumping a well. Determination of S and Sy requires measurable drawdown in observation wells a known distance from the pumping well. T and K can be calculated using data from the pumping well; however, observation well data improve the reliability of calculated T and K values and eliminate a typically unknown variable of pumping well efficiency. In a fractured rock setting, it is possible to estimate fracture hydraulic conductivity and fracture-specific storage and to differentiate these values from matrix (unfractured rock adjacent to fractures) hydraulic conductivity and matrix specific storage, using dual porosity solutions (Moench, 1984).

3.6.1 Hydraulic Properties for Valley Fill Sediments

Hydraulic conductivity values for valley fill sediments in Nevada generally average from 0.2 ft/d to 30 ft/d (Mauer et al., 2004) depending on composition and association with geomorphic features as well as position within a basin. Maurer et al. (2004) evaluated a wide range of published data from Nevada and concluded that sediments associated with dune sands, alluvial slopes, and stream channel deposits provided the highest range in hydraulic conductivity with floodplain, lake, and playa deposits providing the lowest range in hydraulic conductivity, as provided in **Table 3.6-1**. Within the Study Area, it is likely that most, if not all, of the geomorphic features (or equivalent) may be present in the subsurface, though the hydrostratigraphy of basins within the Study Area is not precisely defined.

Relative position with respect to valley centers (playas) also plays a role in hydraulic conductivity distribution for valley fill sediments (Plume, 1996). Hydraulic conductivity data collected from a variety of geomorphic features between the upper slopes of alluvial fans and the valley floor indicate that permeability tends to decrease toward the valley center (Plume, 1996; Maurer et al., 2004), as illustrated in **Table 3.6-2**. Fluvial deposits, those sediments deposited directly from rivers and streams, can display very high hydraulic conductivities when compared with other alluvial deposits (deposits transported and deposited by water over any surface, including fans).

In addition to unconsolidated sediments affecting hydraulic conductivity, depth plays a role in hydraulic property distribution within basins because tuffaceous sediments, tuff, lacustrine sediments, and other semi-consolidated sediments of pre-Pleistocene age or older are most likely to be present at depth below younger unconsolidated alluvium. These pre-Pleistocene units are of low horizontal conductivity (Maurer et al., 2004). Plume (1996) referred specifically to sequences of older valley fill throughout Nevada and noted that they probably occur at depth in most basins in Nevada. In an evaluation of petroleum exploration logs from Kobeh Valley, Buqo (2008) noted units described as tuff, siltstone, and claystone comprising large sequences (up to 6700 feet) of valley fill deposits below younger sand and gravels and above the pre-Cenozoic "basement."

Within the Study Area, the first attempt at an assessment of hydraulic properties of the alluvial materials south of Mt. Hope appears in a report on exploratory drilling in Kobeh Valley (Hydro-Search, 1982). **Figure 3.6-1** is a map of aquifer test locations from that investigation. KCE#2 through KCE#6 were drilled west of the Whistler Range in preparation for a test-production well, KCT#1. All of the wells were terminated in alluvium to their respective total depths and did not encounter "bedrock." According to the Hydro-Search report, geophysical logs indicated a multi-layered aquifer system with several producing zones of sand and gravel separated by less permeable zones of clay and silt. The authors of the Hydro-Search report indicate that the upper 100 feet of saturated aquifer is the most productive, followed by a deeper zone at approximately 600-800 feet bgs in KCT#2 that exhibits similar geophysical log response (Hydro-Search, 1982).

Based on the data obtained from the exploration wells, a test-production well, KCT#1, was installed 50 feet to north of KCE#2. The well was drilled and then later reamed in several stages. Well completion activities encountered frequent difficulties with drilling equipment. The associated delays to the project required numerous additions to the borehole's drilling fluids. In all, over 11,600 lbs of bentonite, lignite, CMC gel, and other additives were used during the construction of KCT#1. A step-drawdown test was performed subsequently at KCT#1 with discharge ranging between 299 and 456 gpm. Analysis of the data, according to the Hydro-Search report, indicated that small increases in pumping rates resulted in very large increases in drawdown—an indicator of an inefficient well. According to Hydro-Search, several producing zones were invaded and plugged with drilling fluids. The authors concluded that the data produced from the test were probably poor because of well inefficiency at the pumped well (KCT#1) and because calculated transmissivity values varied by about 85,000 gpd/ft (~11,300 ft^2/d), with storativity ranging over two orders of magnitude. The authors stated that the estimated hydraulic properties derived from the test should be used with caution. A summary of values obtained with well information is presented in **Table 3.6-3**.

Montgomery & Associates recently tested existing Exxon Minerals Corporation wells (EW1 and EW2, also referred to as Atlas wells), and two test wells drilled at the request of EMLLC (Montgomery & Associates, 2008). The Atlas wells are located to the west of Roberts Creek and northwest of Lone Mountain. Additional aquifer tests were performed on KV11 and 9211R (west of Devils Gate). Results of the aquifer testing are presented in **Table 3.6-4**.

In summary, from the geophysical logs and the aquifer test data from the Hydro-Search (1982) report, it appears that the aquifer system in the valley fill aquifer south and southwest of Mt. Hope contains upper alluvial sediments with an average transmissivity of at least 25,000 gpd/ft (~3,300 ft^2/d). Deeper producing sediments noted on the logs from well 9211R may provide additional flow to wells.

EMLLC has conducted additional test well drilling and aquifer testing in northern Kobeh Valley that includes three wells (222T, 228T, and 229T) completed in the valley fill sediments (Interflow, 2010). The estimates of transmissivity for the three wells ranges from 2,700 to 3,000 ft^2/d for two of the wells and nearly 13,000 ft^2/d for one of the test wells. Based on the thickness of the aquifer, hydraulic conductivity ranged from 5 to 19 ft/d (**Table 3.6-5**). Other estimates of transmissivity for valley fill materials are reported in Buqo (2008), which evaluated specific capacity data for 61 wells in Diamond Valley as reported on drillers logs obtained from NDWR. Estimated transmissivity ranged from a low of 74 ft^2/d to 36,000 ft^2/d. It is assumed that the transmissivity values derived from specific capacity may be skewed low because the data include poorly-efficient domestic and stock water wells in addition to high-capacity irrigation wells.

Basin-wide estimates of the specific yield of valley fill materials are available only for Diamond Valley (Harrill, 1968). Harrill estimated the specific yield distribution of the upper 100 feet of saturated sediments for Diamond Valley in 1968 based on drillers logs for the many wells drilled throughout the basin; a map of Harrill's specific yield distribution is provided on **Figure 3.6-2**. The range of specific yield spanned from approximately 5 percent to 25 percent. Areas with the highest specific yield are in southern Diamond Valley and along the eastern margin of the basin. Zones of lower specific yield are located in areas in and adjacent to the playa and in an area extending south from the southeastern margin of the playa.

CERTIFICATE OF SERVICE

Pursuant to NRAP Rule 25(1)(c), I hereby certify that I am an employee of ALLISON, MacKENZIE, PAVLAKIS, WRIGHT & FAGAN, LTD., Attorneys at Law, and that on this date, I caused a CD-ROM version of same to be served to all parties to this action by:

______	Placing a true copy thereof in a sealed postage prepaid envelope in the United States Mail in Carson City, Nevada
______	Hand-delivery - via Reno/Carson Messenger Service
______	Facsimile
______	Federal Express, UPS, or other overnight delivery
X	E-filing pursuant to Section IV of District of Nevada Electronic Filing Procedures

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DATED this 21st day of December, 2012.

/s/ Nancy Fontenot

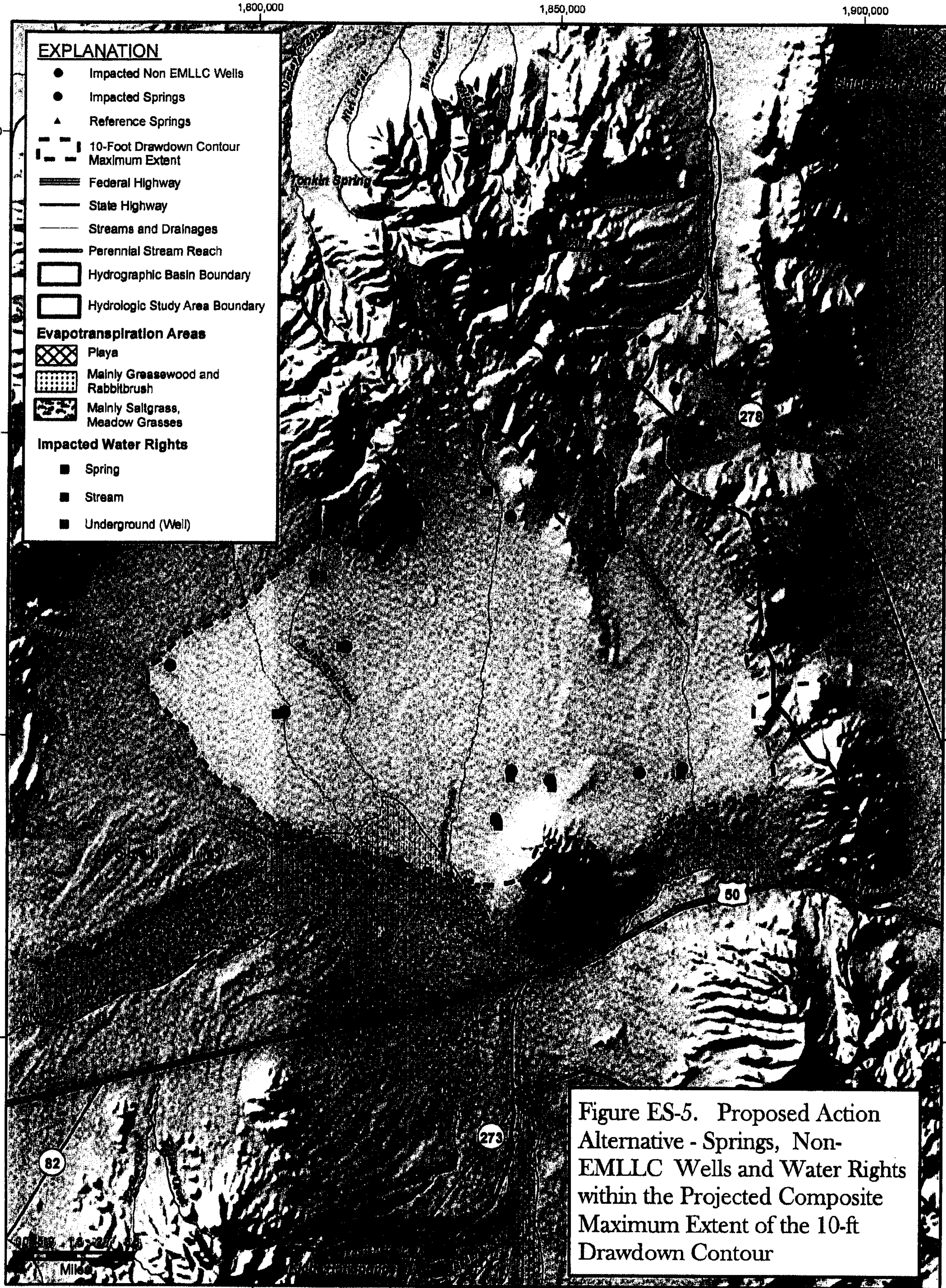

Figure ES-5. Proposed Action Alternative - Springs, Non-EMLLC Wells and Water Rights within the Projected Composite Maximum Extent of the 10-ft Drawdown Contour

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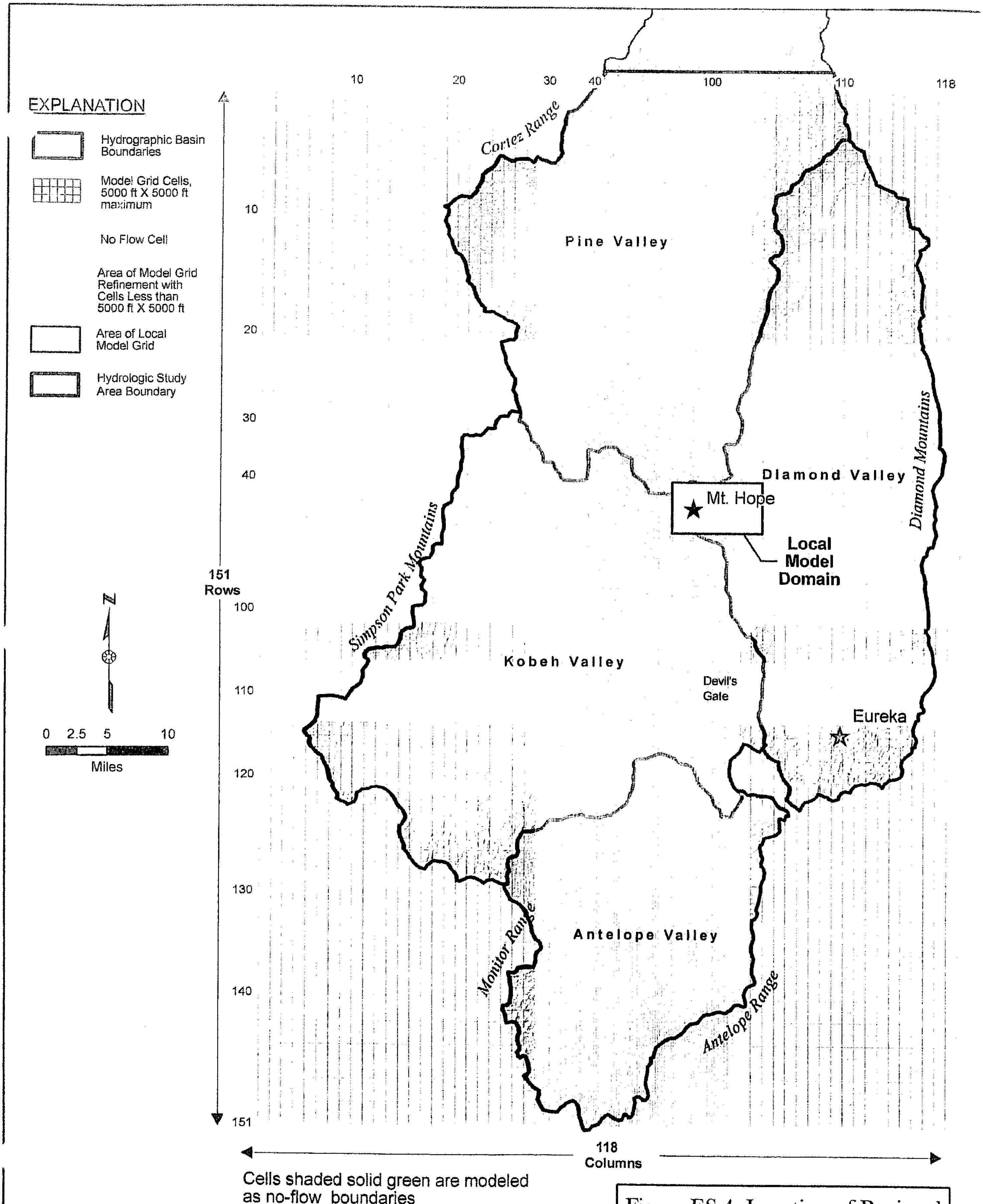

Figure ES-4. Location of Regional Model and Local Model Domain

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July 2010
REPORT

HYDROGEOLOGY AND NUMERICAL MODELING
MT. HOPE PROJECT
EUREKA COUNTY, NEVADA

CHAPTER 1 – INTRODUCTION

Eureka Moly, LLC (EMLLC) is developing the Mt. Hope molybdenum project (the Mt. Hope Project or "the Project") northwest of the town of Eureka in Eureka County, Nevada. To meet project needs, a reliable water supply of approximately 7,000 gallons per minute (gpm) [approximately 11,300 acre-feet per year (AF/yr)] is required. The sulfide flotation concentrator will process 60,675 t/d (tons per day). The project has a 44-year life.

General Moly, Inc. (GMI) owns 80 percent of EMLLC through its wholly owned subsidiary, Nevada Moly, LLC. POS-Minerals own a 20 percent interest through a joint-venture agreement. For the purposes of this report, GMI and EMLLC are one and the same and used interchangeably.

This report incorporates information from several other supporting studies designed to characterize hydrology in the project area and to report the results of numerical simulations that were developed to estimate the project's potential impacts on water and other resources. These supporting studies include the following:

- "Baseline Surface Water and Groundwater Report", (SRK Consulting, 2008a), BLM review draft
- "Kobeh Valley Well Field Data Summary Report" (Interflow, 2010), a summary of geology and hydrogeology data for the Kobeh Valley Central Well Field area of the Mt. Hope project, Eureka County, Nevada
- "Regional Spring and Seep Inventory", (SRK Consulting, 2008b), BLM review draft
- "Hydrogeologic Characterization of Pit Area, Mt. Hope Project, Eureka County, Nevada" (Montgomery & Associates, 2010b), a summary of pit area piezometer installation, hydraulic testing, pump testing, water quality analysis, and water level evaluation
- "Evaluation of Potential for Groundwater Subsidence in Kobeh Valley", (Bell, 2008), Nevada Bureau of Mines and Geology, University of Nevada, Reno

The data compiled for these reports were used to develop a conceptual model of groundwater in the region and the mine pit area. From the conceptual model, coupled numerical models were developed and calibrated for the pit area ("Local Model"), and the surrounding region ("Regional Model"). The calibrated models were then used to run various pumping scenarios at the proposed supply wellfield. Model development and simulation results are found in **Chapter 4** of this report.

This study identifies and provides analysis of the potential impacts from the proposed Mt. Hope mine. The alternatives studied and scenarios examined are summarized as follows:

- The Proposed Action Alternative consists of the development of the Mt. Hope mine and the associated groundwater pumping in Kobeh Valley and dewatering of the proposed open pit mine
- The No Action Alternative consists of Diamond Valley agricultural pumping and lesser amounts of industrial and municipal pumping
- The Cumulative Action Scenario consists of the combined impacts of the Mt. Hope Mine water supply and pit dewatering; and Diamond Valley agricultural pumping and lesser amounts of industrial and municipal pumping

Because significant groundwater pumping and aquifer drawdown has occurred in Diamond Valley beginning in the mid-1950s, it is important to understand the impacts resulting from this agricultural activity to fully assess the Cumulative Action Scenario. Designation of the No Action and Proposed Action Alternatives and the Cumulative Action Scenario was determined as the result of discussions with BLM personnel (**Appendix A**).

This introductory chapter provides a brief overview of the Mt. Hope Project and the area of study and presents the purpose, objectives, scope, and methodology of the investigations summarized in this report. **Chapter 2** provides an overview of water rights in the project area. **Chapter 3** characterizes the groundwater and surface water resources, precipitation, phreatophytes, water use, and geology. **Chapter 4** evaluates potential impacts on water resources as projected by numeric flow modeling (i.e., conceptual model development and construction, calibration and pumping simulations). **Chapter 5** provides a listing of all references cited in the report.

This report addresses permitting requirements by the U.S. Bureau of Land Management (BLM) and contributes to the development of the Environmental Impact Statement (EIS) being prepared by the BLM as required under the National Environmental Policy Act (NEPA) and BLM regulations.

1.1 LOCATION AND STUDY AREA

Mt. Hope is located approximately 23 miles north-northwest of the town of Eureka, the county seat of Eureka County, Nevada (**Figure 1.1-1**). The project site is accessible via Nevada Highway 278.

Mt. Hope resides on the topographic divide separating Kobeh Valley on the southwest from Diamond Valley on the east. Garden Valley (a sub-basin of Pine Valley) is situated approximately 2 miles to the north. The summit elevation of Mt. Hope is approximately 8,411 feet above mean sea level (amsl), and the base of the mountain is at approximately 6,500 feet, amsl. Mt. Hope is an isolated peak near the confluence of the Roberts Mountains to the west and the north-south-trending Sulphur Spring Range to the northeast.

The Hydrologic Study Area includes the entire hydrographic basin of Kobeh Valley, the southern portion of Pine Valley including the Garden Valley sub-basin, Diamond Valley, and Antelope Valley (**Figure 1.1-1**). To a limited extent, data from neighboring valleys were also included in the investigation to gain a more complete understanding of the hydrologic systems.

The proposed Mt. Hope project area includes the mine pit, processing facilities, tailings impoundments, and ancillary facilities and shown on **Figure 1.1-2**. Within the project area is the Kobeh Valley Central Well Field (KVCWF), which is the planned water supply area for the mine. The Project Boundary is shown on **Figure 1.1-2** and is defined as the Plan of Operations Project Boundary. This includes the physical mine and process facilities where the preponderance of disturbance is created and the rights-of-ways for the water supply corridors and the 230-kV power line. The Hydrologic Study Area is much larger than the area included within the Plan of Operations Project Boundary.

1.2 PURPOSE AND SCOPE

The purpose of this investigation is twofold: 1) to define the hydrologic conditions of Kobeh Valley and the surrounding region, including the proposed open pit area, and 2) to identify and assess the potential impacts of the groundwater production and mine dewatering on water resources, existing water rights, and the environment. To achieve these objectives, the following scope of work was completed:

- Review of existing published and unpublished data and reports for the Study Area;
- Compilation of datasets on groundwater levels, surface water flows, water chemistry, water rights, geology, and hydraulic properties of the aquifers present from national and state agency databases, published sources, and unpublished reports by EMLLC, its predecessors, and other mining interests in the region;
- Field reconnaissance studies and field measurements of spring and stream discharge and of water levels in wells;
- Collection of water samples from springs, streams, and wells for field determinations of key water quality parameters and laboratory analyses for a comprehensive set of water chemistry data;
- Development of a hydrogeologic framework model and conceptual hydrologic model to serve as a guide in the development of a numerical groundwater flow model of the Study Area;
- Development of a wellfield design, supported by pumping tests, to provide a reliable source of water for the project while minimizing adverse environmental impacts;
- Development of a regional-scale numerical groundwater flow model for the Study Area to assist in the evaluation of likely and possible impacts of the existing and proposed water resources development on natural resources and adjacent water rights holders;
- Development of a local-scale groundwater flow model for the proposed Mt. Hope mine to incorporate the effects of mine pit dewatering and pit lake development; and
- Development of a model to evaluate potential topographic subsidence in Kobeh Valley, which may result from groundwater withdrawals.

The work conducted has resulted in the characterization and understanding of the hydrologic conditions present in the Study Area. New baseline data have been collected and compiled with pre-existing data. Identification and quantitative evaluation of potential drawdown impacts have been developed from the dataset using numerical groundwater flow models.

1.3 MINE WATER NEEDS

The Mt. Hope Project will require approximately 11,300 AF/yr for mining and ore processing, which equates to a continuous flow of 7,000 gpm. Most of the water will be consumed by storage in tailings and evaporation from the surface of the tailings pond. This water demand will continue for approximately 44 years, after which water demands will effectively become zero, although some post-project water will be needed for reclamation. An estimated 500 acre feet of construction water supply will be needed in years prior to Mine Year 1 (start of commercial production).

The mine water supply will be withdrawn from the KVCWF located in the north-central part of the basin (**Figure 1.1-2**). Model simulations used ten water supply wells (**Appendix B**). Exploration wells have been constructed and tested at five of these locations.

Pit dewatering will be required for the 32-year mining period. Dewatering may be required as overburden materials are removed (prestripping). Water produced from dewatering will augment the water supply produced from the KVCWF. Projected long-term pit dewatering quantities average 580 AF/yr. Dewatering rates will vary over time. EMLLC owns mining water rights in Diamond Valley to allow dewatering from that hydrographic basin.

1.4 PROJECT BACKGROUND

1.4.1 Previous Mining Activity Mt. Hope

Mining operations at Mt. Hope date from 1871, when zinc-rich ore was discovered from skarn along the eastern side of Mt. Hope, and continued sporadically until the late 1940s (BLM, 1985). Four areas were the main targets of exploration activities and resulted in the driving of the Lorraine shaft, the No. 1 and No. 2 adits, and the Whim shaft. The Lorraine workings were opened in 1886, with the other adits and shafts opening in the 1890s (BLM, 1985). Ore was partially milled and concentrated on site and shipped offsite for further processing. Ore production ceased in 1947 when the process facility was destroyed by fire. By 1949, most structures built on the property to house miners were removed. Some of the shafts and adits that were developed in the 1800s remain open. Effects of early mining activities on hydrologic resources of the area are largely unknown. A small amount of water flows from the zinc adit located along the eastern margin of Mt. Hope.

The Mt. Hope property was evaluated by various mining companies between the 1950s and the 1970s, though exploration activity was relatively modest. In the early 1970s, the Mt. Hope Mining Corporation and Phillips Petroleum's mineral division engaged in a drilling program and identified copper and molybdenum mineralization. The Exxon Corporation continued the exploration efforts and defined a separate high-grade zone of molybdenum mineralization not previously identified. In addition, the Exxon Corporation began permitting the project and initiated exploration activities for sources of mine water supply (Hydro-Search, 1982). In 2004, Idaho General Mines obtained a 30-year renewable lease on the mining claims from Mt. Hope Mines, Inc., and began project development. In 2004 Idaho General Mines initiated hydrologic studies for securing water rights and other environmental permitting. General Moly, Inc. is a successor of Idaho General Mines through a reincorporation in October, 2007. General Moly, Inc. now owns 80 percent of Eureka Moly, LLC through a wholly owned subsidiary, with the remaining 20 percent owned by

POS-Minerals Corporation through the Mt. Hope Joint Venture Agreement of February 2008.

1.4.2 Regional Mining Activity

Mining has been regionally significant in Eureka County. Inactive and currently active mines within the Hydrologic Study Area are located in Kobeh Valley and nearby Diamond and Pine Valleys. These mining operations generally follow the Battle Mountain/Eureka Trend, comprising bands of northwest- to southeast-oriented precious metal deposits. Within Kobeh Valley the most visible mining operation is the Gold Bar Property and its satellite open-pit operations (historic) within the Roberts Mountains west of Roberts Creek. The property occupies approximately 17 square miles. The mine operation was active between 1989 and 1999.

The Tonkin Spring Mine in southern Pine Valley operated for two short periods from 1985 to 1988 and again in 1989 – 1990. An existing carbon-in-leach plant is currently in mothball status (Noble, 2008). The property covers 37 acres on BLM managed lands. During the 1980s, an Environmental Assessment was developed for the mine operations but did not address or model impacts to nearby spring resources (Mallory, 2007).

The Ruby Hill Mine, located 1 mile west of Eureka has operated intermittently. Mine water supply and dewatering activities, as predicted in 2005, anticipated an impact of 10 feet of water table decline to a distance of approximately 2 miles from the mine (BLM, 2005).

1.4.3 Previous Water Resources Investigations

In the vicinity of the Mt. Hope project a number of investigations have been conducted on the hydrogeology and water resources at various scales including site-specific studies, flow system studies, and regional evaluations. Both the United States Geological

Survey (USGS) and the Nevada Division of Water Resources (NDWR) maintain databases containing water level records for the area, and the USGS datasets also include stream flow and water chemistry data. Because of the location of the Mt. Hope Project within the Battle Mountain/Eureka Trend, and the mineralization of the region, a number of investigations have been completed on many aspects of the geology at a wide range of scales. In this section, a brief overview of the most significant previous investigations is presented. Other reports and data used in this investigation are cited in the appropriate sections of this report.

1.4.4 Hydrology and Water Resource-Related Investigations

The hydrogeology of Kobeh Valley was investigated by the USGS in 1964 as part of the Groundwater Resources Reconnaissance Series reports prepared in cooperation with the Nevada Department of Conservation and Natural Resources (Rush and Everett, 1964). This reconnaissance report also includes Monitor Valley to the southwest of Kobeh Valley and Antelope Valley to the south of Kobeh Valley. In 1962, the USGS Groundwater Resources Reconnaissance Series report for Diamond Valley was published as Report No. 6 (Eakin, 1962). At the time of that investigation, agricultural development was ongoing, and in 1968 the USGS in cooperation with NDWR published a more detailed hydrogeologic evaluation of the basin entitled, Hydrologic Response to Irrigation Pumping in Diamond Valley, Eureka and Elko Counties, Nevada, 1950 – 1965 (Harrill, 1968). This work was used by the NDWR in establishing the perennial groundwater yield of the basin at 30,000 AF/yr.

Eakin (1961) produced the Groundwater Resources Reconnaissance Series Report for Pine Valley that established the perennial yield for that basin at 24,000 AF/yr. However, Eakin's work produced a considerably large water budget imbalance which was not resolved.

While the above published hydrogeologic studies form the basis for defining the basic hydrogeologic components of the hydrographic basins, subsequent studies have continued to contribute to regional understanding of the flow systems, aquifers, and water budgets. Some of the more relevant studies are summarized below.

From the mid-1960s through the early 1980s, the BLM conducted detailed watershed data collection at 12 areas in the Great Basin (Houng-Ming et al., 1983). One of the areas included in the BLM project was the Coils Creek watershed in northwestern Kobeh Valley. Precipitation data were collected at 20 locations, along with stream flow data, and are available for 1963-1980. In 1967, the Atomic Energy Commission sponsored a regional USGS data collection effort that extended as far north as Township 21 North, including southern Kobeh and Diamond Valleys. Water level, water chemistry, and spring and stream discharge records were collected and published (Robinson et al., 1967). The Commission also sponsored a study by the Desert Research Institute on the regional groundwater flow systems of central Nevada as part of Project Faultless, an underground atomic bomb detonation in Hot Creek Valley to the south of the Study Area. The results of this investigation, published by Fiero (1968), included an inventory of wells and springs in the region including the Diamond Valley flow system. Both of the Atomic Energy Commission studies included regional potentiometric maps.

Between 1979 and 1981, Kobeh, Antelope, and Monitor Valleys were under consideration as deployment basins for the MX-Missile System, an inter-continental ballistic nuclear missile capable of delivering a nuclear warhead across the globe. As part of the water resources investigations for constructing the proposed (but never built) missile deployment system, water level monitoring, stream and spring gaging, water sampling and analysis, and exploratory drilling were conducted in each of the basins. Five water monitoring borings were drilled in Kobeh Valley, eight in Antelope Valley, and thirteen in Monitor Valley. Most of the data collected during these field studies were compiled by the USGS and are available as an open-file report (Bunch and Harrill, 1984).

Exxon Corporation commissioned hydrogeologic studies for the Mt. Hope project in the early 1980s. As part of this effort, Hydro-Search, Inc. (1982) produced a hydrogeology report for the project that reviewed potential wellfield locations and pit dewatering requirements with a presentation of baseline hydrologic data and impact analyses related to the mining project.

In 1995, the USGS published a data report for Diamond Valley quantifying pumping, irrigated crop land, and water levels in the valley, which were continuing to decline as a result of agricultural water uses in excess of perennial yield (Arteaga et al., 1995).

Berger (2000a) published a review of water budgets for several basins along the Middle Humboldt River, including Pine Valley. This work included a conceptual review of the magnitude and distribution of recharge in Pine Valley and presented water budget estimates for the basin.

John C. Halepaska and Associates (2005) produced a scoping-level report for the Mt. Hope project entitled Geological, Geochemical and Hydrological Investigations for Phase I Feasibility Study, Mount Hope Project. This report included wellfield hydraulic parameter estimations and a review of estimated mine pit dewatering requirements. The hydraulic properties provided in this report include a compilation of earlier work but did not include any new testing or investigations.

In 2006, the USGS published a report entitled, Hydrogeologic Framework and Groundwater in Basin-fill Deposits of the Diamond Valley Flow System, Central Nevada (Tumbusch and Plume, 2006). The study area of that report extends from South Monitor Valley to Diamond Valley and includes Kobeh and Antelope Valleys. This study included updated water level data and a review of historic water level changes, as well as a review of the geologic and hydrologic setting. This study was funded by Eureka County and is part of a three-phase hydrogeologic study program which is ongoing as of 2010. The second phase includes: 1) drilling of monitoring wells in the vicinity of Devil's Gate to more adequately define subsurface outflow from Kobeh Valley to Diamond Valley, 2) drilling monitoring wells in Diamond Valley to the north of Whistler Peak to aid in assessment of possible outflow through this portion of Sulphur Spring Range, 3) operation of micro-meteorological stations in Diamond and Kobeh Valleys, and 4) the detailed mapping of phreatophyte vegetation in order to review and update the water budgets for the basins.

In 2006, exploration drilling and aquifer testing was conducted on the eastern side of Kobeh Valley to assess potential for a wellfield. Aquifer testing was also conducted at one of two existing "Atlas" wells (named after the Atlas Mineral Corporation which drilled the wells for use at the Gold Bar Mine) in northwestern Kobeh Valley (Montgomery & Associates, 2008). Wellfield exploration drilling in eastern Kobeh Valley was conducted at the Risi Ranch, west of the Devil's Gate area, and east of Lone Mountain.

In support of water development for the Mt. Hope Project, Interflow Hydrology, Inc., has prepared the Kobeh Valley Well Field Data Summary Report (Interflow, 2010), which summarizes wellfield exploration drilling and aquifer testing conducted in north-central Kobeh Valley in 2007 through 2009. The Kobeh Valley Well Field Data Summary Report presents an overview of the hydrogeologic framework of Kobeh Valley and the Regional Study Area. The scope of this most recent work included:

- A review of existing geologic and hydrologic conditions in Kobeh Valley,
- Interpretation of existing geologic information and formation of a conceptual model of regional hydrogeology,
- Field reconnaissance and remote sensing to determine likely drilling locations,
- Subsurface geophysical reconnaissance of the northern portion of the Kobeh Valley Well Field area,
- An extensive drilling program that resulted in the drilling of forty (40) test or monitor wells,

- Wireline geophysical logging of test and monitor wells,
- Completion of thirteen (13) pumping tests,
- Analysis of aquifer responses to pumping tests and determination of hydraulic characteristics of the aquifers, and
- Development of geologic cross sections from surface exposures and subsurface data obtained from drilling

Hydrogeologic characterization in the vicinity of the proposed open pit mine area (the focus of the Local Model) conducted during 2007 through 2009 was substantial and broad-ranging in scope and involved the efforts of numerous contractors and consultants. Montgomery & Associates has presented this body of work in a report, Hydrogeologic Characterization of Pit Area, Mt. Hope Project, Eureka County, Nevada (Montgomery & Associates, 2010b). The work conducted is summarized as follows:

- Drilling and logging of 29 boreholes within and near the periphery of the proposed pit
- Completion of 17 boreholes as 2-inch diameter piezometers for measurement and monitoring of groundwater levels and development of an updated groundwater level map for the pit area
- Hydraulic testing of 17 piezometers using slug test methods
- Drilling, logging, and long-term hydraulic testing of four 8-inch pilot dewatering test wells
- Drilling, logging, and construction of five 4-inch diameter monitor wells within and near the proposed pit, including conduct of short-term pumping tests
- Multi-level packer testing of three deep HQ hydrogeologic characterization coreholes
- Drilling, logging, and installation of four multi-level grouted piezometers within the periphery of the proposed pit and one outside the proposed pit

- Analysis of hydraulic test data to determine hydraulic parameters in the vicinity of the proposed pit
- Compilation of existing published and unpublished geologic data, new field geologic mapping, and preparation of an updated geologic map and cross-sections for the pit area
- Collection of groundwater samples obtained from production wells, observation wells, and piezometers, and chemical analysis of these samples by an analytical laboratory.

Water level and chemistry monitoring are on-going for selected wells completed near the proposed open pit mine (SRK Consulting, 2008a) and several draft baseline data documents have been prepared. A regional spring and seep inventory has been prepared (SRK Consulting, 2008b). Results of pit-area well construction and hydraulic testing were compiled in Hydrogeologic Characterization of Pit Area, Mt. Hope Project, Eureka County, Nevada (Montgomery & Associates, 2010b).

Many other studies of regional significance contribute to the overall understanding of the Great Basin and east-central Nevada hydrology and hydrogeology, including regional precipitation mapping, studies of the carbonate-rock aquifer flow systems of eastern, central, and southern Nevada, and investigations of water budget parameters (recharge and evapotranspiration (ET)) in the Great Basin. Of particular note are a number of regional studies by the USGS including investigations by Bedinger et al., (1984), Thomas et al., (1986), Harrill et al., (1988), Plume and Carlton (1988), Prudic et al., (1995), Thomas et al., (1997), Harrill and Prudic (1998), Nichols (2000), Schaefer et al., (2005), and Lopes and Evetts (2004).

1.4.5 Water Resources Related Data Bases

The USGS National Water Information System (NWIS) is a publicly accessible database that contains water level measurements, stream and spring discharge measurements, and water chemistry analyses for sites throughout the United States. NWIS is a primary source for the dissemination of water-related data to the scientific community. Within the Study Area, NWIS contains water level records for 336 sites in Kobeh, Diamond, Antelope, North Monitor, and Pine Valleys.

The NDWR maintains a database of the Well Drillers Reports for every well drilled in Nevada for which records are available. The Well Drillers Reports contain well completion and lithologic data for each well drilled and also include the results of specific capacity tests for some wells. Although the data should be used with caution, the NDWR database provides a valuable source of information. NDWR also maintains a water level database for a few selected water wells in the Study Area that are not included in the NWIS.

1.4.6 Geology, Geophysics, Minerals, Oil and Gas Exploration, and Geothermal Resource-Related Investigations

Because of the extensive history of mining in the region, much information has been published on many aspects of the geology of Mt. Hope, the Roberts Mountains, and the surrounding region. Summarized below are the specific reports, maps, and information that were primary sources of information used in this investigation.

Regional and quadrangle geologic maps are available for the study area. A county geologic map and report based upon the standard nomenclature for geologic formations in central Nevada is available (Roberts et al., 1967). The USGS has published a 1:250,000 scale geologic map of north-central Nevada that portrays the various carbonate, volcanic, and siliceous assemblages and orogenic sequences that comprise one or more individual geologic formations (Stewart and Carlson, 1974). More detailed geologic maps have been published for the following quadrangles: Roberts Creek Mountain (Murphy et al., 1978); Cooper Peak (Murphy et al., 2007); Frazier Creek (McKee and Conrad, 1998); Ackerman Canyon (McKee, 1968); Pinto Summit (Nolan et al., 1974); Diamond Peak (Brew and Gordon, 1971); and Diamond Springs (Larson and Riva, 1963).

Considerable information is available from the Nevada Bureau of Mines and Geology (NBMG) including state-wide maps and detailed information on oil and gas exploration activities and geothermal resources. A series of 1:1,000,000 scale state-wide maps are compiled in Open-File Report 96-2, An Analysis of Nevada's Metal-Bearing Mineral Resources (Singer, 1996). This compendium includes state-wide maps for the thickness of Cenozoic deposits and the isostatic residual over basement rocks (Saltus and Jachens, 1995), indicators of subsurface basin geometry in Nevada (Dohrenwend et al., 1996), and a reconnaissance photographic map of young (Quaternary and late Tertiary) faults of Nevada (Dohrenwend et al., 1992).

Many published and unpublished reports are available on the geology of the Roberts Mountains and the surrounding region that detail many aspects of the geologic history, structural geology, stratigraphy, and mineral resources. Key references used in this investigation include Nolan et al., (1956), Hose et al., (1982), Brew and Gordon (1971), Finney et al., (1993), Sandberg et al., (2001), and Cook and Corboy (2004). The results of a detailed geophysical survey of the Roberts Mountains and Eureka areas are presented by Philbin et al., (1963). State-wide geophysical maps are published by the NBMG and include complete Bouger anomaly, isostatic gravity, and composite magnetic anomaly maps. Information on the extent of Pleistocene lakes in Kobeh Valley and Diamond Valley is presented in Mifflin and Wheat (1979) and Reheis (1999).

The NBMG stores and disseminates subsurface information gathered during oil and gas exploration drilling activities throughout the state. Summary information is presented in

Garside et al., (1988) and NBMG (2009). More detailed information is available on most drillholes including geologist's reports, lithologic logs, and borehole geophysical logs.

The NBMG maintains information on the geothermal resources of the state. Summary information is presented for major energy-producing geothermal resources and hot springs in Garside et al., (1988). Recently, this work has been updated as a new state-wide geothermal resource map and interactive map by Shevenell and Garside (2005). The interactive map is linked to databases that have site descriptions for each geothermal spring, well, and fumarole, and links to spreadsheets with chemistry data.

CHAPTER 2 – WATER RIGHTS

This chapter provides a brief summary of water rights and perennial yields in the four hydrographic basins of interest. The locations of each water right in the vicinity of the proposed Mt. Hope project are shown on **Plate 1** and tabulated in **Appendix C**. The hydrographic basins are:

1. Kobeh Valley
2. Antelope Valley
3. Diamond Valley
4. Pine Valley

Nevada, as in most arid western states with limited fresh water resources, has a highly developed system of water allocation. Nevada applies the doctrine of prior appropriation (also known as the Colorado Doctrine) in granting water rights. The first person or entity that puts water to a beneficial use establishes priority for the use of that water. Any new water rights granted by the State Engineer are carefully examined for impacts to existing water users. Nevada water law further limits issuance of underground water rights to the annual groundwater recharge, also known as the perennial yield of the hydrographic basin. Estimating the perennial yield of a basin considers many factors such as the annual precipitation and recharge, interactions between basins, ET, and an estimate of consumptive water use. The State Engineer reviews each water right application on a case-by-case basis.

EMLLC purchased 16,131 AF/yr of water rights in Kobeh Valley through a GMI subsidiary, Kobeh Valley Ranch, LLC (KVR). Although most rights are held by KVR, some minor holdings are in the name of GMI. Water rights purchases were largely agricultural rights. The intent of these purchases was to own sufficient water for the Mt. Hope project. The fresh water requirements for the project are estimated to be 11,300 AF/yr (about

7,000 gpm). KVR submitted applications to the Nevada State Engineer in 2005-2008 that were a combination of new appropriations and change applications for existing water rights. These applications were made to convert agricultural rights to mining use and change the place of use to the mining project. In March 2009 the State Engineer granted the applications and provided 11,300 AF/yr for mining use to KVR in the Kobeh Valley Basin (NDWR, 2009). The grant was appealed and remanded by judicial decision to the State Engineer for re-hearing. KVR has since submitted change applications to adjust the points of diversion so that they represent the current projected locations of the planned water supply wells. EMLLC anticipates that the State Engineer will grant the applications, which would effectively provide EMLLC with the water it needs for the Mt. Hope project.

In April 2009, KVR submitted new applications to appropriate a projected 3,570 AF/yr of agricultural consumptive use on the Bobcat and 3F ranches. These rights have not yet been granted (no one protested these rights). As these rights are likely to be granted and put to beneficial use by KVR, the amount considered in this study is based on the estimated remaining amount of the perennial yield.

Plate 1 shows current (January 2010) points of diversion for water rights within the Study Area and a 30-mile radius of Mt. Hope. **Table 2.0-1** (written communication NDWR, March 2010) provides a summary of each of the committed underground water rights in the four basins of interest. Estimated perennial yields and the source of the estimates are also shown in this table. The estimated perennial yield in Kobeh Valley is 16,000 AF/yr. Current committed rights for Kobeh Valley (March 2010) are approximately 1,283 AF/yr for irrigation and stock watering purposes. With the anticipated approval of 11,300 AF/yr of mining and milling water rights for the Mt. Hope project, the water right commitment in Kobeh Valley would not exceed the perennial yield.

The estimated perennial yield for Diamond Valley is 30,000 AF/yr, as established by Harrill (1968) in NDWR Water Resources Bulletin No. 35. Committed underground water rights in Diamond Valley total 132,136 AF/yr. NDWR crop inventories, however, suggest that current pumping may be approximately 87,000 AF/yr based on a duty of 4 feet per irrigated acre. Based on existing water level information and pumping data, Diamond Valley is considered to be in a state of overdraft, that is, pumping totals and consumptive water use exceed the perennial yield. Because of the present degree of over-appropriation of groundwater in Diamond Valley, EMLLC's water supply strategy was to avoid additional withdrawals that could impact this basin. Some small quantities of Diamond Valley groundwater will be needed to support open pit dewatering activities (the open pit is partly located in Diamond Valley) and to support minor water uses not sited in Kobeh Valley.

Antelope Valley is contiguous to and south of Kobeh Valley and is defined as a separate hydrographic basin by the NDWR and USGS. Current committed groundwater resources in Antelope Valley total 3,080 AF/yr (written communication NDWR, 2010), and the estimated perennial yield is 4,000 AF/yr (Rush and Everett 1964).

Pine Valley is contiguous to and north of Kobeh Valley. Current groundwater commitments in Pine Valley total 15,361 AF/yr (written communication NDWR, 2010), and the estimated perennial yield is 20,000 AF/yr (Eakin 1961).

One of the main objectives of the modeling efforts described in this report is to determine the potential impact of EMLLC's water use on other water users in the affected basins. Using water rights data from the NDWR website, existing active water rights within a 30-mile radius of Mt. Hope were plotted on **Plate 1**, and water rights data are included in **Appendix C**. The largest concentration of existing water rights within the 30-mile radius is in southern Diamond Valley. Within a 10-mile radius of Mt. Hope, most other water rights are associated with filings at springs for stockwater and federal reserved rights for wildlife purposes. Spring filings for agriculture are also present in western Diamond Valley, as, for example, at Shipley Spring. There are several stream rights in the vicinity of Mt. Hope, on Roberts Creek and Henderson Creek, which are used for agriculture.

CHAPTER 3 – EXISTING CONDITIONS

This chapter describes the baseline resources that may be directly or indirectly affected by the Mt. Hope Project's use of water. Some of the descriptions come from the wealth of published and unpublished studies about the area, many produced during planning efforts for other projects; these studies have been supplemented and/or verified by field research conducted by EMLLC and its consultants for the Mt. Hope Project. They have included re-logging drill cores, drilling test wells, and performing aquifer tests, packer tests, spring surveys, water quality analyses, and other studies.

The area of interest for this report is the Diamond Valley Flow System (as described in **Chapter 1**) and the southern portion of Pine Valley. Tables for each section of this chapter are found in **Volume 1;** figures are found in **Volume 2**.

3.1 GEOLOGY

The geology of Kobeh Valley and the region is complex and reflects a variety of depositional and tectonic histories that have led to the present-day landscape. Geologic conditions in the Study Area are shown on **Figures 3.1-1 through 3.1-3**. **Figure 3.1-1** is a regional geologic map of the Study Area. **Figure 3.1-2** is a generalized geologic map of the Kobeh Valley Central Well Field (KVCWF) area. **Figure 3.1-3** presents simplified geologic cross-sections in the KVCWF area. This section describes the regional structural geology, regional stratigraphy, and the geology of the Mt. Hope mineral deposit. Subsequent sections will tie the geology into the hydrogeology of the Study Area. For reference, a geologic time scale is provided in **Table 3.1-1**.

3.1.1 Regional Geologic History and Structure

During much of the Paleozoic era, central Nevada was occupied by a west-facing continental shelf that was positioned along the western perimeter of North America. The westward-deepening continental slope resulted in a westward-thickening marine sedimentary zone that graded from eastern shallow-water carbonates through a transitional carbonate and silicate sequence to deep-water silicates (Stewart, 1980). These deep-water shales, cherts, and sandstones are referred to as the Western Assemblage, while the carbonates are referred to as the Eastern Assemblage. This depositional pattern continued with little tectonic interruption until the late Paleozoic and resulted in the accumulation of thousands of feet of marine sediments within the passive continental margin of the Great Basin.

In the late Devonian to early Mississippian, an island-arc system was being tectonically emplaced along the western margin of the marine sedimentary basin, which resulted in the development of a highland to the west and a considerable change in the tectonic setting of Central Nevada. Thrust faulting moved deep-water marine rocks over eastern, contemporaneous carbonate strata. This regional thrust fault was first recognized in the Roberts Mountains (Merriam and Anderson, 1942) and is an important geologic and hydrogeologic feature. Within the upper plate of the Roberts Mountains Thrust, early to middle Paleozoic siliceous rocks (most often the Ordovician Vinini Formation and Silurian siltstones and sandstones) are complexly faulted in multiple thrust sheets over the Eastern Assemblage carbonates, in places folding back over themselves. In the Diamond Valley Flow System, the eastern leading edge of the Roberts Mountains Thrust may be approximately located along the west-central portion of the modern-day Diamond Valley with strike roughly north-south in orientation (Stewart, 1980), though small outcrops of shale resembling the Vinini were noted along the western edge of the Diamond Mountains near the Thompson Ranch (Larson and Riva, 1963). It is likely that these outcrops represent the eroded remnants of the upper plate of the thrust sheet, as seen elsewhere, such as near Lone Mountain in Kobeh Valley and in the Fish Creek Range southwest of the town of Eureka.

Following emplacement of the Roberts Mountains Thrust, the depositional patterns in central Nevada shifted from a carbonate-dominated system to a detrital depositional regime. Where exposed, Mississippian rocks reflect terrestrial source areas rather than marine or lacustrine sources. Shale, chert, chert-pebble conglomerates, and limestones are interbedded and are locally represented by the Joanna Limestone, the Chainman Shale, and the Diamond Peak Formation. This heterogeneous, polylithic package is best represented locally in the Diamond Mountains.

Faulting and folding of Paleozoic strata also post-date the Antler Orogeny. Central Nevada during the Mesozoic was predominantly a highland area and thus was principally an erosional rather than depositional environment. However, the Cretaceous Newark Canyon Formation is present in at least Diamond and Pine Valleys; it developed during a period of active folding and thrusting. Mesozoic igneous intrusive rocks are present in the Diamond Valley Flow System and are represented chiefly by the alkali granite (alaskite) of the Whistler Range that separates Diamond and Kobeh Valleys (**Table 3.1-2; Figure 3.1-1**).

As opposed to earlier compressional forces of deformation, the Tertiary is well noted for its multi-phased, episodic extension and volcanism related to the development of the modern Basin and Range Province. The development of the Basin and Range is partially responsible for the current north-south configuration of the mountain ranges and valleys typical of Nevada. The structural basins associated with the Diamond Valley Flow System developed along basin-bounding normal faults, whose displacement allowed thick accumulations of alluvium, colluvium, and lacustrine and volcanic materials. Interpretation of geophysical data provided by the USGS, and of petroleum exploration well logs, confirm the presence of deep structural basins within Antelope, Diamond, Kobeh, and Pine Valleys (Tumbusch and Plume, 2006; Buqo, 2008; Interflow, 2010); (**Figures 3.1-4 and 3.1-5**). Of regional economic importance is the northwest-trending belt of intrusive complexes associated with the Northern Nevada Rift, a Tertiary feature that extends from central Nevada to the Idaho-Oregon Border (Ponce and Glen, 2002). The rift system is associated with an extensive series of industrial and precious metal deposits known as the Battle Mountain-Eureka Trend, which is roughly coincident with the Northern Nevada Rift. The series of roughly northwest-southeast-oriented intrusive bodies associated with the Northern Nevada Rift include extensive mafic dike swarms that are locally present in the Roberts Mountains as shown on **Figure 3.1-6** (Murphy et al., 2007; Childress and Ferdock, 2008).

Early through middle Tertiary deposits within the basins are typically alluvial fan and lacustrine deposits interbedded with air-fall and/or ash-flow tuffs (Gordon, 1990). These units are exposed in the Roberts Mountains as siltstones, mudstones, fanglomerates, and clay (Murphy et al., 2007).

Geomorphic and sedimentary evidence of Pliocene and Pleistocene lakes has been recognized within portions of Antelope, Diamond, Kobeh, and Pine Valleys and reflects a cooler, wetter climate (**Figure 3.1-7**). Lake Jonathan occupied the majority of Kobeh Valley and the northern part of Antelope Valley (Reheis, 1999), while lakes Pine and Diamond occupied their respective basins, with Lake Diamond extending slightly westward into eastern Kobeh Valley (Reheis, 1999).

3.1.2 Regional Stratigraphy

Figure 3.1-1 is a map showing the surficial geology of the KVCWF area, derived primarily from a geologic map of north-central Nevada by Stewart and Carlson (1978). **Figure 3.1-2** is a generalized geologic map of the KVCWF area showing geologic units divided into three major types: 1) valley fill deposits (also known as basin fill deposits); 2) volcanic and igneous rocks of Tertiary and Mesozoic age; and 3) sedimentary and metasedimentary rocks of Paleozoic age. These geologic divisions are described below. **Table 3.1-2** shows the geologic and hydrostratigraphic units in the Study Area.

3.1.2.1 VALLEY FILL DEPOSITS: The uppermost valley fill deposits typically comprise older and younger alluvium. Underlying these alluvial sediments in some areas are thick accumulations of valley fill deposits of Tertiary age (**Table 3.1-2 and Figures 3.1-1 through 3.1-3**). The nature of these sediments is quite variable and is in part based upon three key factors:

1. The configuration of the pre-Tertiary surface on which the sediments were deposited;
2. The sources of sediment; and
3. The environments of deposition.

The configuration of the pre-Tertiary surface (predominantly the top of Paleozoic rock units) can be inferred on the basis of regional scale geophysical studies and logging data from deep oil and gas exploration boreholes. **Figure 3.1-5** shows contours of the elevation of pre-Tertiary rocks based on gravity data from Ponce (1997). In western Kobeh Valley an asymmetric trough in the pre-Tertiary surface extends to depths of more than 5,000 feet below ground surface (bgs). In Diamond Valley, a deep linear trough in the pre-Tertiary surface has accumulated more than 7,000 feet of valley fill deposits in some portions of the basin.

These asymmetric troughs are targets for oil traps, and a number of deep exploration wells have been drilled in Kobeh Valley and Diamond Valley (**Figure 3.1-4**). **Figure 3.1-5** shows summary lithologic logs for the holes drilled in Kobeh Valley, and additional petroleum exploration borehole information is provided in **Table 3.1-3**. The information was obtained from the reports and files of the NBMG, as cited on **Figure 3.1-5**.

As shown, the valley fill deposits are quite variable both in thickness and in lithology. The depth to the pre-Tertiary surface in these oil and gas exploration boreholes ranged from

1,400 to 7,500 feet. The thickness increases in the deeper portions of the basin and decreases near the mountain fronts.

The valley fill sediments in Kobeh Valley are the product of the weathering of the Paleozoic rocks that form the pre-Tertiary surface; the volcanism that created the Monitor Range and the basalt flows and intrusive rocks in the northern and western part of the basin; the erosion of those volcanic rocks; and the chemical processes that altered the source rocks. The lithologies of the valley fill deposits below the recent alluvium include claystone, conglomerate, tuffs and tuffaceous sediments, and occasional freshwater limestones. The claystone, freshwater limestone, and tuffaceous sediments are indicative of lacustrine deposition. These deposits are associated with ancestral (Pleistocene) Lake Jonathan in Kobeh Valley and with Lake Diamond, which covered almost the entire present-day valley floor of Diamond Valley and a small area in southeasternmost Kobeh Valley.

3.1.2.2 VOLCANIC ROCKS: In the Mt. Hope area, Tertiary volcanic rocks are mostly limited to the eastern Roberts Mountains east of Roberts Creek. These volcanic rocks include a rhyolitic tuff and breccia as much as 700 feet thick, andesitic lava flows up to 200 feet thick and massive flows of quartz latite.

While the volcanic rocks are not considered suitable as a target for water development, their presence is important with respect to groundwater flow and boundary conditions in the Roberts Mountains and portions of Kobeh Valley.

Figure 3.1-6 is a portion of the geologic map of the Mt. Hope region by Childress and Ferdock (2008). Of note are the dike swarms that intrude the Paleozoic sedimentary rocks in the north-central part of the Roberts Mountains. These mafic dikes are the manifestation of the Northern Nevada Rift, a north-northwest to south-southeast trending feature related to epithermal gold deposits in the region. The rift is west of Mt. Hope and is not directly associated with Mt. Hope mineralization, but occurs in the central and western

Roberts Mountains. Tumbusch and Plume (2006) place the western boundary of the Northern Nevada Rift as the mountain bounding fault on the west side of the Roberts Mountains, and extend the rift zone southeastward into northern Antelope Valley almost as far east as the Sulphur Spring Range and Whistler Mountain.

3.1.2.3 PALEOZOIC: The Paleozoic sequence comprises more than 12,000 feet of sedimentary rocks and is summarized in **Table 3.1-2** in descending order from youngest to oldest. The uppermost Paleozoic unit, the Garden Valley Formation (Permian age), is present in isolated outcroppings in the Rutabaga Canyon and Lone Mountain areas of Kobeh Valley. It also outcrops in westernmost Diamond Valley in the area east of Mt. Hope and in the eastern part of the Garden Valley portion of Pine Valley.

The Garden Valley Formation has four members including a basal sandy limestone and calcareous sandstone about 500 feet thick. This member is overlain by an 800- to 1,000-foot-thick unit of conglomerate, sandy shale, and carbonaceous sandstone, which is in turn overlain by about 1,000 feet of siliceous conglomerate. The uppermost member comprises about 550 feet of reddish-brown shale and conglomerate.

The Garden Valley Formation is underlain by rocks mapped as undivided Mississippian by Roberts et al. (1967). This undivided Mississippian unit is limited to small outcroppings in the Devils Gate area and includes the Chainman Shale and Diamond Peak Formation (siltstone, sandstone, and conglomerate with lesser amounts of claystone and limestone). The Mississippian Webb Formation is often mapped with the Vinini Formation because of its similarity and the fact that it has, in many locations, been structurally interleaved with the Vinini Formation via complex thrust faulting (Finney et al., 1993). The unit has not been mapped consistently or precisely differentiated from the Vinini Formation throughout Kobeh Valley or the Roberts Mountains.

The Vinini Formation (Cambrian-Ordovician age) outcrops extensively in the Roberts Mountains, at Mt. Hope, and in eastern Kobeh Valley in the Sulphur Spring Range. This formation is more than 2,000 feet thick and comprises a basal member of fine-grained limestone, calcareous sandstone, siltstone and shale with lava flows, tuff, and cherty shales near the top, and an upper member of interbedded layers of chert and black shale. Murphy et al. (2007) divided the formation into three members by breaking the siltstone, shale, and volcanic rocks into a middle member. Throughout most of the Study Area, the Vinini Formation has been thrust over younger Paleozoic rocks and forms the majority of the Roberts Mountains Allochthon (**Figure 3.1-3**). In some areas, multiple thrust faults have resulted in great thicknesses of the Vinini. As noted previously in this section, the formation has been extensively intruded in the central part of the Roberts Mountains by basaltic dike swarms (**Figure 3.1-6**).

The Devils Gate Limestone (Devonian age) outcrops in limited areas in the central Roberts Mountains, in a limited exposure on Lone Mountain, and in the Mahogany Hills and Devils Gate area. This unit is generally a thick-bedded limestone with thinner limestone beds in portions of the middle and upper parts of the formation. The total thickness of the unit is more than 2,000 feet.

The Denay Limestone (Devonian age) outcrops throughout the Roberts Mountains and Kobeh Valley and is composed of dark gray lime mudstones and gray limestones. The unit is often subdivided into an upper and lower member. The upper member is not present throughout the Study Area but has been mapped in the central Roberts Mountains.

The McColley Canyon Formation (Devonian age) comprises dark carbonaceous mudstones and muddy limestones. The unit is present throughout the Roberts Mountains and Kobeh Valley but has not been mapped in detail in the Sulphur Spring Range or the Diamond Mountains to the east.

The Nevada Formation (Devonian age) outcrops in the western Roberts Mountains, at Lone Mountain, and in an extensive area of the southern Sulphur Spring Range. This unit is as much as 2,500 feet thick and comprises primarily well-bedded limestone with some siliceous limestone and dolomitic limestone.

The Lone Mountain Dolomite (Devonian-Silurian age) outcrops only along the southern flanks of Lone Mountain in Kobeh Valley and in the northwestern part of the Roberts Mountains in southern Pine Valley. The unit comprises about 2,200 feet of dolomite and dolomitic limestone; the unit grades laterally into the Roberts Mountains Formation.

The Roberts Mountain Formation (Devonian-Silurian age) in outcrop is limited to a small exposure on the west side of Lone Mountain and two small, isolated blocks in the Pine Valley portion of the Roberts Mountains. The unit is about 1,900-2,200 feet thick and comprises massive dolomite and siliceous bioclastic limestone. The unit grades laterally into the Lone Mountain Dolomite.

The Hanson Creek Formation (Ordovician age) outcrops only in a small area of the Pine Valley portion of the Roberts Mountains and in the southern Mahogany Hills in Antelope Valley. The unit comprises shaly and dolomitic limestone and chert and is about 560 feet thick in the northern Roberts Mountains.

The Lower Eastern Assemblage (LEA) includes a number of individual units of Cambrian to Ordovician age, the Eureka Quartzite, the Pogonip Group, and Hamburg Dolomite. In Kobeh Valley the only occurrence of the LEA is on the southwestern base of Lone Mountain. In other basins, the LEA may be several thousand feet thick.

3.1.3 Geology of the Mt. Hope Deposit

The Mt. Hope molybdenum porphyry deposit is located at the southern end of the northwest-trending Battle Mountain-Eureka mineral belt, 21 miles north of Eureka in central Nevada. The Mt. Hope igneous complex is composed of Tertiary (38 million years ago) rhyolite volcanic-intrusive rocks that intruded and thermally metamorphosed Ordovician age Vinini Formation sedimentary rocks. Molybdenum mineralization and alteration is directly related to rhyolite intrusive events. Surface and drill hole observations and interpretations describe sheeted vein and stockwork molybdenum mineralization symmetrically developed over two separate rhyolite porphyry dome-shaped stocks that intrude host rhyolite quartz porphyry, rhyolite ash flow tuff, and Vinini hornfels. The mineralization forms an inverted tea cup shape. Patterns of high silica and potassium alteration lead outward to argillic alteration on the margins of the Mt. Hope system.

Two dominant structural domains are present at Mt. Hope. One domain, the Corridor Trend, is represented by steeply northeast-dipping, west-northwest-striking faults that are sub-parallel to the regional Battle Mountain-Eureka mineral belt. A second domain, the Cutoff Trend, is represented by steeply southeast-dipping, north-northeast-striking faults. This fault system is younger than, and cuts/displaces, the Corridor Trend; it appears to be the major control responsible for juxtaposing the quartz porphyry mineralized intrusive complex against mostly unmineralized volcanic tuff units.

There is abundant evidence for broad scale and isoclinal folding in Vinini Formation sediments and in the hornfels. Isoclinal and open folds on the south margins of Mt. Hope appear to have axial plane orientations that plunge to the south, while the same scale folds on the north and west margins of Mt. Hope have axial plane orientations that plunge to the north/northwest, suggesting doming of these sedimentary units by the Mt. Hope intrusive complex.

3.1.4 Development of Geologic and Hydrogeologic Base Maps

The geologic base map of the Study Area region (**Figure 3.1-1**) was developed from data included in the Spatial Digital Database for the Geologic Map of Nevada (Raines et al., 2003). The database was digitally assembled and processed from regional mapping of Nevada compiled by Stewart and Carlson (1978). Because of the scale of the mapping (1:500,000), geologic units are represented by general lithology, provenance, and origin rather than detailed formation and member mapping common at larger scales (1:24,000 and above).

Geophysical (gravity) data were obtained from the USGS (Ponce, 1997) and are contoured in 1,000-foot intervals that represent the interpreted elevation of pre-Tertiary bedrock on **Figure 3.1-8**. In addition, faults inferred to have ruptured during the Quaternary have been added to the map because of potentially important controls on not only basin geometry but also groundwater movement in the Study Area.

A geologic base map is provided electronically with this report in **Appendix D** is entitled *Geologic Map of the Mt. Hope and Roberts Mountains Area, Eureka County, Nevada* (Childress and Ferdock, 2008). The geologic base map is a digital compilation of existing USGS and NBMG mapping of the Roberts Mountains portion of the Study Area, as well as a synthesis of existing mapping of the Mt. Hope area and nearby mining claims by exploration geologists. The map was developed by merging one existing digital dataset from the Frazier Creek Quadrangle with other mapped areas that were hand-digitized from scans of hard copy maps. References to previous mapping are provided on the base map (**Appendix D**), as are details regarding scale-appropriate use of the map.

3.1.5 Hydrostratigraphic Units

In order to define, understand, and model the regional hydrogeologic setting, individual lithostratigraphic units were assigned to hydrostratigraphic units. Because of the paucity of hydraulic data defining individual and unique formations, conservative, simplifying assumptions were used to assemble similar formations, based on generalized lithology, into distinct groups that, when considered as an aggregate, behave in a hydraulically similar manner. This section outlines the rationale behind the hydrostratigraphic units used in the numerical flow model.

Ten hydrostratigraphic units were defined initially for Kobeh Valley during water exploration activities (Buqo, 2008) and then expanded to include the entire Study Area (Interflow, 2010). **Table 3.1-2** shows the ten hydrostratigraphic units and their general characteristics. The rationale behind the distribution of units is based on regional observations, inferences, and previous studies of the Study Area and similar flow systems in Nevada by the USGS and others. Carbonates and siliciclastic rocks, such as shales, conglomerates, and sandstones, generally contrast in hydraulic properties and were differentiated as aquifers and aquitards accordingly, although localized faulting and fracturing can play a huge role in the permeability of these units. Aside from young valley fill deposits, the main aquifer unit in the study is represented by the Devils Gate Limestone and equivalent middle to upper Devonian strata. Based on examination of outcrops, this unit was considered permeable and is present throughout the Roberts Mountains. Older carbonate units, such as the Nevada Formation and the Lone Mountain Dolomite, were considered less permeable because of dolomitization, silicification, or presence of interbedded siliciclastics. The Lower Eastern Assemblage rocks contain extensive siliciclastics and dolomites and are considered mainly an aquitard.

In general, the main aquitards in the Study Area are the Vinini Formation and/or the Chainman Shale. The Garden Valley Formation was also included as an aquitard because of its massive nature and shale and conglomerate content in the upper three-quarters of the formation. Transitional and detrital assemblage rocks present in the Diamond Mountains (MDs on **Figure 3.1-1**) were also considered aquitards based on lithology.

Valley fill and volcanic units were delineated based on origin and likely hydraulic properties. Within the Study Area, the valley fill is composed of Tertiary lacustrine, volcaniclastic, conglomerate, and alluvial sediments, as well as Quaternary alluvium, colluvium, and playa deposits. In general, the Quaternary alluvium has higher permeability than older valley fill, volcanics, and volcaniclastics that occur in the basins of the Study Area. A more detailed description of the model parameters is found in **Chapter 4**.

3.2 PRECIPITATION AND RECHARGE

Precipitation is the source of all surface water and groundwater in Kobeh Valley and the surrounding valleys. Most precipitation is lost to evaporation and plant transpiration; some becomes surface water runoff; and a small percentage infiltrates past the root zones of plants and becomes groundwater recharge. Recharge occurs primarily in the mountain block, not only in Kobeh Valley but in all adjacent valleys. Groundwater recharge also occurs along major stream and runoff drainages within the mountains, along zones of fractured bedrock, and on alluvial fans near the mountain fronts where streams discharge from the mountain blocks. Once stream runoff reaches lower parts of the valley floor, downward infiltration of water is less likely because of the low permeability of the finer-grained sediments, such as clay and silt. However, where there is a relatively shallow water table, some precipitation and runoff will infiltrate the soil column and reach the water table. Generally, precipitation at low elevations is lost to the atmosphere through ET.

Many methods for determining annual precipitation and recharge have been developed and applied at different landscape scales and using increasingly sophisticated technologies. Recharge is a critical determinant of aquifer response to changes in water use. This section surveys efforts to quantify annual precipitation and groundwater recharge in the Study Area.

3.2.1 Precipitation

Estimates of average annual precipitation on the valley floor and tributary watersheds of the major hydrographic basins in the Study Area have been determined in the 1960s by USGS Reconnaissance Series Report investigators using the Hardman (1936) and Hardman et al. (1965) regional precipitation map. Precipitation from the Hardman map ranges from approximately 6 to 8 inches/year on the valley floor to 12 to 20 inches/year in mountains surrounding the valleys.

As a quality control check on the total estimated precipitation in the Reconnaissance Series Reports, the areas assigned to watersheds within the basins were evaluated. In order to calculate the precipitation in any given basin, areas must be measured, usually in 1,000-foot elevation zones. A comparison between the Reconnaissance Series Report areas (based on 1:250,000 scale topographic maps), the more modern GIS techniques used by USGS investigators Tumbusch and Plume (2006), and this study is shown in **Table 3.2-1**. There are differences in basin-area estimates between the early investigators and this study, but the only major difference is for Diamond Valley, where the Reconnaissance Series Report estimates are approximately 70,000 acres greater than the current study. The later USGS estimates (Tumbusch and Plume, 2006) are nearly the same for all valleys as determined for this study. Differences between the Reconnaissance Series Report numbers and more recent estimates are probably attributable to the more recent technology used in quantifying area from topographic maps.

The Reconnaissance Series Report estimates of precipitation were further reviewed using long-term precipitation measurements in the Study Area vicinity and more recently published regional precipitation maps (WRCC, 2008; Jeton et al., 2005). Precipitation stations near the Study Area are listed in **Table 3.2-2**. In addition, stations with a computed National Weather Service 30-year normal precipitation record (Jeton et al., 2005) also appear in both **Table 3.2-2 and Figure 3.2-1**.

The data in **Table 3.2-2** and on **Figure 3.2-1** are derived directly from Jeton et al., (2005) and reflect either an average station precipitation over the station's period of record or a computed 30-year normal from the National Weather Service for each station for the years 1971-2000. According to Jeton et al., (2005), the computed normals are considered the most accurate estimation of precipitation at any given station. As indicated on **Figure 3.2-2**, the R^2 values for the precipitation-elevation relationship are weak. Harrill (1968) showed even more regional stations than shown on **Figure 3.2-2**; however, the correlation was no better and was not used by the USGS. Harrill (1968) used the Hardman map but modified it for Diamond Valley by making the northern portion of the valley receive greater precipitation than the southern part of the valley.

The BLM (Houng-Ming et al., 1983) operated 3 recording stations and 20 bulk precipitation collection stations in Kobeh Valley during the time period of 1963-1980 in the Coils Creek watershed, a 50-square-mile area in the northwestern part of Kobeh Valley. Locations of the 20 BLM precipitation collection stations are shown on the inset map on **Figure 3.2-3**. Data from these stations are summarized in **Table 3.2-3**. The local precipitation-elevation relationship is shown on **Figure 3.2-4**. From a statistical standpoint, the Coils Creek elevation-precipitation relationship is also poor, with a very flat trend. The average annual precipitation for the period of record is 11.4 inches. The lack of a clearly defined elevation-to-precipitation relationship is unusual for the Great Basin, which tends to have locally and regionally significant orographic lift effects. The 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 data. It is noted that monthly precipitation values for January–March appear abnormally low in the Houng-Ming et al.

(1983) study (**Figure 3.2-5**), given that winter precipitation is usually dominant over summer precipitation in the Great Basin (WRCC, 2008). Direct relationships between altitude and precipitation quantity are observed throughout Nevada (Jeton et al., 2005) and most likely exist in the Study Area, but cannot be sufficiently defined by existing data.

Precipitation at Mt. Hope (elevations 6,500–8,411 feet, amsl) may be affected by a micro-rain shadow effect from the Roberts Mountains. Regional data and precipitation maps suggest average annual precipitation of 11 to 20 inches for the Mt. Hope elevation range. Local and regional weather stations suggest the actual precipitation is on the lower end of this range, at 11 to 15 inches.

Recently published regional precipitation mapping (OSU, 2006) is available for the Study Area and is shown on **Figure 3.2-3**. The data were developed using the proprietary Parameter-elevation Regressions on Independent Slopes Model (PRISM) algorithm. PRISM mapping was compared with the Reconnaissance Series Report precipitation estimates and local and regional elevation-precipitation relationships. The PRISM estimates (climate dataset 1971-2000), published August 2006, indicate a stronger correlation between elevation and precipitation than station data observations (**Figure 3.2-4**), largely because the relationship is forced by the algorithms used to generate the PRISM precipitation estimates. Basin total precipitation quantities are also approximately -5.8 to +68.7 percent different using the PRISM (Daly et al., 1994; OSU, 2006) mapping than the Reconnaissance Series Report values based on the Hardman (1936) and Hardman et al. (1965) map, as summarized in **Table 3.2-4**. All PRISM-based estimates are greater than the Reconnaissance Series Report values with the exception of the estimate for the Garden Valley subarea of Pine Valley. Ramifications to groundwater budget estimates in the Reconnaissance Series Reports cannot be clearly assessed, but the PRISM data suggest generally greater quantities of water in the overall hydrologic system compared with the Reconnaissance Series Reports.

3.2.2 Groundwater Recharge from Precipitation

Only a portion of the precipitation in hydrographic basins becomes groundwater recharge. Precipitation that infiltrates past the root zone of plants may continue downward under the force of gravity to the water table. Groundwater continues to flow from high to low elevations (**Section 3.4**), where it is eventually discharged by springs, flowing artesian wells, playa evaporation, transpiration by phreatophytes (plants with roots that tap groundwater), and pumped wells. Historically in Nevada and the Great Basin, groundwater recharge has been estimated using the technique of Maxey-Eakin (1949) and Eakin et al. (1951) coupled with precipitation maps prepared by Hardman (1936) and Hardman et al. (1965). It is important to note that the recharge efficiencies developed by Maxey-Eakin are based on estimated groundwater discharge through ET. Maxey-Eakin assumed dynamic equilibrium conditions (groundwater recharge equals groundwater discharge) in the many Nevada valleys they studied.

Nichols (2000) developed new recharge efficiencies using an early PRISM map that was later found to contain errors. However, the real value of Nichols (2000) work was his estimates of ET in 16 valleys in eastern Nevada by establishing micrometeorological stations in four valleys and using data from several micrometeorological sites in Owens Valley. He then developed a relationship between ET and phreatophyte vegetation reflectance measured by LANDSAT images, which he applied to his project valleys. Except for Pine Valley, none of the valleys in the Study Area for the Mt. Hope project were included in Nichols (2000), and the only published ET values presently available are from the Reconnaissance Series Reports. Pine Valley hydrology has subsequently been studied by the USGS (Berger, 2000a), and studies of the Diamond Valley flow system water balance are ongoing by the USGS. The USGS reconnaissance estimates of groundwater recharge, ET, and mountain front runoff for the project valleys are listed in **Table 3.2-5**.

The more recent studies discussed above tend to suggest that water budgets in the basins of interest may have been underestimated in the past. For example, in Pine Valley, situated directly to the north of Kobeh Valley, Berger (2000a) presents an estimated range of recharge to the basin of 52,500 to 79,300 AF/yr, compared with 46,000 AF/yr of recharge using the Maxey-Eakin method as computed by Eakin (1961). Eakin's estimate of basin discharge for Pine Valley was even lower, at 24,400 AF/yr, resulting in a significantly unresolved imbalance in the water budget.

Similar observations are derived from the work of Nichols (2000), who evaluated ET discharge for several basins in central Nevada, including nearby Little Smoky Valley (southeast of Antelope Valley), where his estimate of ET discharge in the northern part is 6,000 AF/yr compared with 1,900 AF/yr in the Reconnaissance Series Report by Rush and Everett (1966). The Maxey-Eakin recharge estimate to northern Little Smoky Valley of 4,000 AF/yr (Rush and Everett, 1966) is closer but still less than the Nichols (2000) discharge estimate.

Also, in review of the Reconnaissance Series Report estimate of recharge to Kobeh Valley, it has been determined that the Maxey-Eakin recharge computation has noticeable error and is more accurately calculated at 13,321 AF/yr (**Table 3.2-6**) versus 11,000 AF/yr reported in Rush and Everett (1964). North and South Diamond Valley also have noticeable error; however, the errors tend to cancel out to reach the previously estimated basin total. The area determinations made today using GIS and digital topography mapping are considerably more accurate than the methods used in the 1960s, which explains the difference. Checks on the computations for other Study Area basins are within acceptable errors, as shown in **Table 3.2-6**.

It is also noticeable in the Maxey-Eakin computations of Rush and Everett (1964) that no recharge is assigned to precipitation below elevations of 7,000 feet, amsl (**Table 3.2-6**). This assumption may be invalid, as precipitation distributions suggest that over three-quarters of the total volume of precipitation in the Kobeh hydrographic area occurs below this elevation. While there is potential for the water budget to have been underestimated in Kobeh Valley, sufficient data are not presently available to redefine the basin water budget with confidence.

3.2.3 Geographic Distribution of Recharge

While precipitation-recharge rate estimation techniques such as the Maxey-Eakin method are useful for deriving estimates of basin-scale recharge, they do not necessarily define the geographic distribution of recharge within a basin. The Maxey-Eakin method is thought to conservatively estimate (and potentially under-estimate) basin recharge (Avon and Durbin, 1994; Watson et al., 1976), and NDWR defines perennial yields for most basins in Nevada using this method. In some basins, other estimation methods and research studies have been applied to estimate water budgets. For almost all basins and regions in the Great Basin, except in the Death Valley Regional Flow System, recent water budget estimates are greater than the Reconnaissance Series Report estimates made by the USGS, which depended on the Maxey-Eakin method (NDWR, 2006).

Many recharge estimation techniques and models have been developed for Great Basin applications, including sophisticated models such as the INFIL model (Hevesi et al., 2003) applied to the Death Valley Regional Flow System and the Basin Characterization Model (Flint and Flint, 2007), recently developed by the USGS as part of the Basin and Range carbonate-rock aquifer system (BARCAS) studies. Statistics-based approaches have also been developed, such as the one developed by Epstein and Huntington (2004). Other recent techniques involve modifications defining elevation-precipitation-recharge efficiency relationships in the form of a modified Maxey-Eakin approach, such as Nichols (2000) or Katzer and Donovan (2003). Geochemical mass-balance methods have also been successfully applied to estimate basin-scale recharge, such as the chloride mass-balance technique described by Dettinger (1989) and the technique employed by Russell and Minor

(2002). However, all recharge estimation techniques contain a degree of uncertainty, and many investigators suggest that quantifying groundwater discharge can provide more accurate definition of basin-scale water budgets (Berger et al., 2004; Laczniak et al., 2006; Moreo et al., 2007). Such studies require several years of field data collection and direct measurement of ET, along with remote sensing techniques (Nichols, 2000; Smith et al., 2007). Geographic distributions of recharge are integrated in modeling approaches; however, many of the empirically derived recharge estimation techniques do not necessarily represent geographic distributions but are more geared toward deriving basin-scale quantities. The Maxey-Eakin method is an example. While the quantification approaches are many, there are several generally accepted concepts regarding spatial distribution in recharge in the Basin and Range and Great Basin province:

- The mountain blocks are an important geographic region in which recharge occurs,
- Recharge quantities and/or rates are related to precipitation quantities, and given that precipitation generally understood to be greater with elevation due to orographic effects, recharge rates will tend to be greater at higher elevations,
- Valley floors tend to receive lower rates of precipitation and are not considered effective geographic areas for significant recharge,
- Infiltration of runoff in ephemeral drainages can be a significant source of recharge, and
- The spatial occurrence of recharge is actually a complex and variable phenomenon, even at local and watershed scales, including many additional variables such as slope angle, aspect, rock type, soil properties, vegetation characteristics, climate trends, and other variables.

Berger (2000a, 2000b) examined spatial distributions of recharge and other water budget components for hydrographic basins along the Middle Humboldt River Basin. Within the Study Area, Berger (2000a) assessed Pine Valley. Three landform types were differentiated within Pine Valley, consisting of the mountain block, piedmont slope, and valley floor lowland. Water budgets for each landform were estimated including the transfer of water between the three landforms. Berger (2000a) identified three zones of significant groundwater recharge in Pine Valley: the mountain blocks; piedmont areas (alluvial fans); and ephemeral streambeds crossing the piedmont areas. Recharge was estimated at 73 to 48 percent of the total recharge (average 58 percent) occurring on the mountain blocks, 21 to 27 percent (average 23 percent) from runoff on the piedmont slopes, and 0 to 31 percent (average 19 percent) from direct precipitation on the piedmont slopes. The recharge distribution percentages differ by hydrographic basin in the Berger (2000a, 2000b) studies, but the general concept of the mountain block being the dominant source area for recharge, followed by contributions from infiltration of runoff on the alluvial fans, followed by direct precipitation on the upland areas between the mountain blocks and valley floors, is consistently represented.

Two other studies are notable in regard to understanding geographic distributions of recharge in the Great Basin. Stone et al. (2001) published a method to estimate recharge distributions in Crescent Valley, west of Pine Valley, using a Soil Conservation Service runoff curve and water balance approach to derive potential recharge by watershed areas. The method was not used to redefine the quantity of recharge estimated by the Maxey-Eakin method but is a method to refine a distribution of the total recharge. The Maxey-Eakin method does not specifically define a recharge distribution, even though it uses an empirical elevation-recharge relationship to derive a total recharge value. As compared with the Maxey-Eakin recharge coefficients, the Stone et al. (2001) approach assigned greater recharge percentages to higher elevation areas and lower percentages to lower elevation areas, resulting in a range of recharge of approximately 4 to 50 percent or precipitation.

A study by Katzer and Donovan (2003) in Spring Valley in east-central Nevada documented a pronounced difference in runoff from watersheds dominated by clastic sedimentary rocks versus watersheds dominated by carbonate rocks. They concluded that watersheds dominated by hydraulically tighter clastic rock types receive lower quantities of recharge from precipitation, and correspondingly greater runoff, compared with watersheds dominated by more permeable carbonate rocks where recharge efficiencies are greater and runoff of precipitation correspondingly less. While runoff was observed to be greater from the clastic rock-dominated watersheds, the runoff has potential to become groundwater recharge on the alluvial fans.

The basic principles and concepts for recharge distribution presented above have been carried forward in establishing a recharge distribution for the Study Area, which was developed and refined during model calibration (**Chapter 4.1.3**).

3.3 SURFACE WATER RESOURCES

Surface water resources within the Study Area include numerous seeps, springs, and streams that occur in the mountain blocks above the valley floors, and to a lesser extent, on the valley floor. The mountain block surface water features contribute flow along the alluvial aprons and valley floors during extremely wet conditions, but generally, they lose all of their flow to ET and groundwater recharge before reaching the valley floors.

On the valley floors of all Study Area basins, most drainages are ephemeral, containing flow only during major runoff events. Springs on the valley floor are typically associated with faults and areas of shallow groundwater. Drainages in the Study Area are tributary to Diamond Valley, ultimately discharging to the playa. Pine Valley is the exception, draining northward to the Humboldt River.

3.3.1 Springs and Seeps

Springs and seeps are numerous within the Study Area, and have been compiled from various sources, including the USGS National Hydrography Dataset, field exploration by mine consultants (SRK, 2008a and 2008b), and digitizing springs from 1:24,000 scale USGS topographic maps. A spring inventory dataset is presented in **Appendix E**; spring and seep locations are shown on **Plate 2**.

SRK Consulting conducted baseline studies of surface and groundwater conditions near Mt. Hope (2008a). Between 2005 and 2007, data were collected from 24 springs and seeps, and 1 mine drainage (the Zinc Adit) (SRK, 2008a). The study provided chemistry and flow data for springs and streams generally within a 5-mile radius of Mt. Hope. SRK (2008a) also noted that nine of the springs and seeps around Mt. Hope were seasonally dry. In the fall of 2007, SRK Consulting conducted a wide-ranging reconnaissance of springs within the Study Area that included chemical analysis, measurement of flow, and assessment of disturbance and beneficial use (SRK, 2008b). These data are incorporated in the **Appendix E** spring inventory dataset.

3.3.1.1 DISTRIBUTION AND OCCURRENCE OF SPRINGS: The majority of springs in the Study Area occur along the contacts between rocks of differing hydraulic properties. This condition can result from a variation in lithology or permeability or can be the result of structural disruption from faulting that juxtaposes differing rock units. Many of the springs in the Study Area are seasonal in nature, with flow occurring during brief periods of time when groundwater levels are temporarily and/or seasonally elevated in response to recharge, while others maintain flow that may be regulated by long-term climatic cycles and anthropogenic water use. Springs in Kobeh Valley occur mostly in the mountains with only a few seeps occurring on the valley floor where the depth to groundwater is shallow.

3.3.1.2 REFERENCE SPRINGS: A subset of springs were selected to orient the reader to the maps in **Section 4.4**. These "reference springs" include Shipley Spring, Tonkin Spring, Klobe Hot Springs, and Bruffey Hot Springs. The selection of these springs was based more on their spatial location than on flow characteristics or ecological importance; in the context of this report, the springs represent landmarks to assist with reading maps, particularly as scales change.

3.3.1.3 GEOTHERMAL RESOURCES: Springs with water temperatures elevated above the mean annual surface temperature are affected by heat from geologic materials at depth. These springs are typically referred to as "geothermal" and in some cases are considered an energy resource where deep reservoir temperatures are high enough to promote economic power generation from steam. Ideal reservoir temperatures for power generation are between 175°F and 350°F (Montana Department of Environmental Quality, 2007). There are presently no geothermal resources developed for this purpose in the Study Area.

In the Great Basin, many geothermal springs with elevated surface temperatures are associated with major range-bounding faults. The conventional explanation for most hot spring flow systems in Nevada is typically cool meteoric waters descending to depth along fault zones with higher permeability than surrounding rocks. The descending water is subject to the prevailing local geothermal gradient and heats with depth. The heated water becomes more buoyant and displaces the cooler, heavier meteoric water, rising to the surface or near-surface. For this model of geothermal convection, the most important factors determining temperatures of springs along these fault zones are depth of circulation and the local geothermal gradient.

The most prominent of these geothermal fault zones in the Study Area is in the southern portion of the Pinyon Range Fault which lies on the east side of Pine Valley along the base of the Sulphur Spring Range (**Figure 3.1-1**). The Pinyon Range Fault in the Study

Area is roughly 22 miles long. Scarps are present on the western flank of the Sulphur Spring Range in Garden Valley, which show that the Pinyon Range fault zone displays little Holocene movement, and may not be a major range-front fault. However, north of Bruffey Canyon, a major range-front setting is shown by an abrupt piedmont angle and pronounced scarp development (Anderson, 2000). Along the eastern side of the Sulphur Spring Range, one or more range-front faults are oriented in a north-south direction.

Another fault zone associated with elevated spring temperatures within the area of study is the Western Diamond Mountain fault zone, which runs along the base of the Diamond Mountains in a north-south orientation for about 40 miles (Redsteer et al., 2000). This fault creates a prominent break from the valley to the steep westward-facing slopes of the Diamond Mountains, which have peaks above 10,000 feet, amsl. 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 seen at Klobe Hot Springs, the Bartine Ranch area, and the Hot Spring Hill complex.

Brief descriptions of warm and hot springs are presented below. Spring inventory ID numbers are included for reference (**Appendix E**). Locations are shown on **Plate 2**.

Klobe Hot Springs (aka Bartholomae Springs, Spring 930, 931): Located at the northeastern end of the Monitor Range (T18N, R50E, Sec. 28), at least two springs are present in this location in Antelope Valley. Water temperatures have been recorded at 156°F in the flowing spring (Fiero, 1968) and 158°F in a water well installed over the spring complex (Rush and Everett, 1964). Estimated reservoir temperatures of 163°F have been made using a Na-K-Ca geothermometer by Mariner et al. (1974). Two wells located 4 miles east of the springs (T18N, R51E, Secs. 18 and 30) have temperatures of 72°F and 74°F taken by Bartholomae Corp. This difference in temperature indicates that the thermal influence of the hot spring complex is geographically limited toward the east.

Bartine Hot Springs (Springs 816, 820, 824, and 826): These springs are located near the west side of Lone Mountain in Kobeh Valley about 2.5 miles north of the Bartine Ranch along U.S. Highway 50 and 11 miles north of, and along the same fault zone, as Klobe Hot Springs (T19N, R50E, Sec. 5). An average temperature for the springs is 106°F. The springs emanate from a tufa mound (Waring, 1965; Reed et al., 1983). This location is locally referred to as "Hot Spring Hill." Discharge is approximately 2 to 3 gpm.

Bruffey's Hot Springs (Springs 74, 75, 76, and 77, 78 and 79): These springs are located on the west side of the Sulphur Spring Range in Pine Valley (T27N, R52E, Sec. 14), along the Pinyon Range front fault. Bruffey's Hot Springs are among the warmest of the hot springs in the Study Area with temperatures recorded as high as 152°F (Stearns et al., 1937). A flow rate of 50 gpm was recorded by Reed et al. (1983). Large, calcareous sinter terraces containing barite and fluorite have accumulated around multiple discharge points (White, 1955).

Flynn Ranch Springs (Springs 187 and 185): These springs are located along the east edge of the Sulphur Spring Range, the Flynn Ranch Springs (T25N, R53E, Sec. 5) include several warm springs discharging into a deep pool. Temperatures have been recorded from 69°F to 70°F with a combined discharge of 10 gpm (Reed et al., 1983).

Shipley Hot Springs (Spring 330): This spring is located on the eastern flank of the Sulphur Spring Range (T24N, R52E, Sec. 23), these springs were reported by Eakin (1962) to have a discharge ranging from 2,900 gpm to about 6,700 gpm. Estimated reservoir temperatures of 109°F were established using silica geothermometers (Mariner et al., 1983). Discharge measured on May 7, 2008, was about 1,600 gpm.

Siri Ranch Springs (Springs 288 and 285): North of Shipley Hot Springs lies the Siri Ranch Spring and well (T24N, R53E, Sec. 6). The reported temperature for the spring is 85°F while the well is reported to be about 95°F (Reed et al., 1983). Stearns et al. (1937) recorded spring discharges of 5,800 gpm while Mifflin (1968) recorded a discharge of 290 gpm. Because of the large discrepancy in reported flow, it is conjectured that Stearns et al. (1937) may have confused Siri Springs with Shipley Springs.

Sulphur Springs (Springs 560, 562, 564, 567, 570): These springs are located along the eastern flank of the Sulphur Spring Range in Diamond Valley (T23N, R52E, Sec. 36), these warm springs are located about 8 miles south of Shipley Hot Springs and were reported to have a temperature of 74°F and a discharge rate of 20 gpm in the 1960s. In 2007, no discharge was observed from Sulphur Springs (SRK, 2008b).

Thompson Ranch Spring (aka Taft Spring, Spring 362): This spring is located on the eastern side of Diamond Valley (T23N, R54E, Sec. 3), this warm spring is reportedly fault-controlled (Harrill, 1968) because it lies along the range-front fault of the Western Diamond Range fault zone (Roberts et al., 1967). The reported water temperatures at this location range from 69°F to 75°F (Mifflin, 1968). Field inspection in 2007 indicated that this spring no longer flows.

3.3.1.4 SUMMARY OF HISTORIC SPRING FLOW CONDITIONS: Besides being important water resources for the semi-arid environment, springs are hydrogeologically significant because they provide information on both geology and subsurface flow conditions in a given hydrologic setting. In the Study Area, springs are commonly at the contacts between rocks of contrasting hydraulic character and in proximity to faults. Within Pine, Antelope, Diamond, and Kobeh Valleys, there are approximately 210 named springs and hundreds of smaller springs and seeps, most of them largely seasonal (**Plate 2**).

Discharge measurements for springs in the Study Area are sparse, but some historic data were provided by Harrill (1968) for Diamond Valley, by Rush and Everett (1964) for Kobeh and Antelope Valleys, and by Eakin (1961) for Pine Valley. During Harrill's reconnaissance of Diamond Valley, he estimated over 8,400 AF/yr (approximately 11.6 cfs) was discharged into the basin from springs, the greatest of which was from Shipley Hot Springs. Some spring flow has been reduced in Diamond Valley as a result of pumping drawdown at the agriculture center, as discussed further in **Section 3.5.3.2.2**. A compilation of historic spring flow data for the Study Area is presented in **Table 3.3-1**, with references provided at the bottom of the table.

3.3.1.5 ADDITIONAL SPRING DISCHARGE MEASUREMENTS OBTAINED AUGUST 2007 THROUGH AUGUST 2009: In addition to the SRK (2008a, 2008b) baseline data and spring reconnaissance efforts, spring discharge measurements were made at Tonkin Spring in Pine Valley and Shipley Spring in Diamond Valley. The recent data are provided in **Table 3.3-2**. These two springs have the largest discharge rates in the Study Area. A continuous flow gage was installed on Tonkin Spring in December 2007, and a rating curve is being developed for the gage.

3.3.2 Streams/Creeks

Surface water resources in the Study Area include numerous streams that include perennial reaches that maintain flow year-round, and additional reaches that are ephemeral or intermittent. In general, the perennial reaches have their sources on the mountain blocks. Much of their base flow (in summer and fall) is provided by groundwater discharge that occurs on the mountain block as spring flow. At higher elevations, spring discharge is likely associated with shallow circulating groundwater that recently fell as precipitation and is likely not directly connected to the groundwater flow system deeper in the bedrock. Within the vicinity of the Mt. Hope project, perennial stream reaches are found in the Roberts Mountains and along the Garden Valley subarea of Pine Valley. The U.S. Bureau of Land Management (BLM, 1997) has identified the mountain block portions of Roberts Creek, Henderson Creek, Vinini Creek, Pete Hanson Creek, Willow Creek, and Cottonwood Canyon as perennial stream reaches (**Figure 3.3-1**). In Pine Valley, the upper segment of

Denay Creek from Tonkin Spring to just below the surface water impoundments located on Denay Creek is classified as perennial by BLM (**Figure 3.3-1**). Birch Creek is not identified as perennial in the BLM dataset, but EMLLC observations and flow measurements support perennial classification. Most of the length of Henderson Creek that is located in the Garden Valley portion of Pine Valley is also classified as perennial by BLM (1997). On the Kobeh Valley floor, a short segment of Stoneberger Wash is classified as perennial, where the Bartine Ranch flowing wells provide a source of surface water. A small segment of U'ans-dame Creek is also classified by BLM as being perennial to the east-northeast of Lone Mountain. However, based on physical observations and review of LandSAT images and USDA's NAIP (National Agricultural Imaging Program) aerial photography, it is believed that this stream segment is in fact non-perennial.

Ephemeral channels, by contrast, primarily carry runoff from rainfall events, including regional and local storms. Rapid snowmelt will infrequently cause runoff in ephemeral channels. In general, the perennial streams that exit the mountain block become ephemeral channels upon reaching the alluvial fans, where they connect with ephemeral washes on the valley floors. Henderson Creek in Pine Valley and Pine Creek in the northern portion of Pine Valley are exceptions that exhibit both intermittent and perennial stream reaches on the alluvial fan and valley floor. Based on field observations in the vicinity of Three Bar Ranch and review of NAIP images, Coils Creek in western Kobeh Valley appears to have some intermittent or discontinuous flow reaches; this may be an artifact of withdrawals for irrigation and/or the presence of springs along the channels. Historic stream flow measurements are summarized in **Table 3.3-3**.

Many surface water impoundments occur throughout the study area, primarily for stock water and irrigation uses. Locations of some of the more substantial impoundments are shown on **Figure 3.3-1**. These impoundments, identified from field inspections, review of USGS 7.5-minute topographic maps, and review of NAIP photography, include the following:

Pine Valley:

Tonkin Reservoir on upper Denay Creek

JD Ranch reservoirs on lower Henderson Creek and Pete Hanson Creek

Alpha Ranch impoundments of Henderson Creek and Chimney Springs

Kobeh Valley:

Roberts Creek Ranch impoundment at the lower perennial reach of Roberts Creek

Diamond Valley:

Shipley Hot Spring pond

Flynn Ranch spring water impoundments

Antelope Valley:

Several reservoirs on the upper Antelope Wash and tributaries near the Segura Ranch

3.3.2.1 SURFACE WATER MEASUREMENTS 2007-2009: Surface water flow into Kobeh Valley occurs from two tributary valleys, as shown on **Figure 3.3-1**. Stoneberger Creek is the axial drainage in North Monitor Valley that is tributary to Slough Creek in southeastern Kobeh Valley. Antelope Wash is the central drainage for Antelope Valley south of Kobeh Valley and is also tributary to Slough Creek. The two main drainages in Kobeh Valley are Coils Creek in the western part of the valley that drains the east side of the Simpson Park Range and the western part of the Roberts Mountains, and the Roberts Creek drainage that drains the central-eastern part of the Roberts Mountains. Intermittent reaches of upper Coils Creek are chiefly fed by spring flow and are used for irrigation. Roberts Creek is perennial near the mountain front, where it is diverted for irrigation.

Evaluation of surface water runoff in this study included chiefly Kobeh Valley, Antelope Valley, and the Garden Valley sub-basin of Pine Valley. Rush and Everett (1964) listed numerous instantaneous discharge measurements made in the Study Area but did not estimate annual runoff. Additional runoff measurements are reported in Hydro-Search

(1982) in the vicinity of the mine for miscellaneous low-flow springs and "Garden Pass" Creek (aka Henderson Creek). Peak flow measurements made by the USGS in Garden Pass Creek from 1965 to 1981 were quite variable, ranging from 0.5 to 650 cfs (Hydro-Search, 1982).

Bunch and Harrill (1984) also reported miscellaneous stream and spring flow measurements made in September and October 1980 in Kobeh Valley. Measurements were made as part of the MX Siting Investigation of basins throughout eastern and central Nevada. Long-term stream gage data for the Monitor Valley were utilized to develop and evaluate the estimation techniques used in the Study Area.

Lamke, in Harrill (1968), has a section on surface water runoff in Diamond Valley. Other than Garden Pass Creek, an ephemeral wash located east of Mt. Hope, surface water resources in Diamond Valley are distant from the proposed mining facilities, and was therefore not investigated in this current study.

During 2007 through 2009 numerous miscellaneous surface water measurements were made at select sites and at two recording stream flow gages. Some measurements were observations of zero flow. A summary of the measurement data is listed in **Tables 3.3-4 through 3.3-7**. Streams and their relations to springs are shown on **Plate 2**. This work was initiated to: 1) establish a base of reference prior to both short-term pumping, such as aquifer testing, and long-term operational pumping; and 2) provide data for estimating water resource budgets. The miscellaneous measurements were made on Roberts Creek and Rutabaga Creek in Kobeh Valley, Henderson and Vinini Creeks in Garden Valley, and Tonkin Springs, Pete Hanson Creek, Birch Creek, and Willow Creek in Pine Valley. Estimates of flow were also made on Allison Creek, Water and Ackerman Canyons, and Ferguson Creek, which all drain the east slope of the Simpson Park Mountains into the extreme west end of Kobeh Valley.

3.3.2.1.1 Roberts Creek: Stream discharge measurements were taken along the course of Roberts Creek from its upstream tributaries to approximately 1 mile north of Roberts Creek Ranch on August 22, 2007, in order to understand the flow characteristics of the stream. Measurement locations are shown on **Figure 3.3-2**. Flow measurements were made from three tributaries of Roberts Creek and progressed downstream at approximately 1-mile intervals with stations named SR-1 (upstream) through SR-6 (downstream). The results of this seepage run are listed in **Table 3.3-4**.

Discharge measurements made on the tributaries of Roberts Creek on August 22, 2007, indicate most flow originates from the east fork, at 0.24 cfs, which in turn receives the majority of flow from springs along the west and south/southeast flanks of Roberts Creek Mountain. The west and middle forks of Roberts Creek contribute little flow, with the west fork being dry and the middle fork discharge estimated at 0.01 cfs. Below the confluence of the three forks, Roberts Creek enters a small incised limestone canyon for approximately 1 mile, at which point the canyon opens and becomes broader where the channel includes incised alluvium within a small, confined floodplain. Discharge measurements made below the confluence of the three forks of Roberts Creek indicate that over its entire course, Roberts Creek is a losing stream, as discharge measurements consistently decreased with distance downstream, as shown on **Figure 3.3-3**. These stream losses are assumed to result in recharge to the local alluvial and carbonate aquifer system. Flow loss due to evaporation and transpiration from riparian vegetation adjacent to the streambed may also be a contributing factor in the consistent decrease in stream flow.

The greatest stream losses per unit stream length occurred in the small limestone canyon below the confluence of the upper forks of Roberts Creek and SR-3, approximately 7,100 feet (stream length) downstream. Between these measurements, Roberts Creek lost approximately 0.08 cfs, or the equivalent of 53 gpm per mile of stream length. Similar loss rates occurred between SR-3 and SR-4. Both of these areas are underlain by carbonate rocks that are exposed at land surface or by carbonate rocks that are covered by only a thin veneer of alluvium.

3.3.2.1.2 Henderson and Vinini Creeks: Stream flow measurements were also made on Henderson and Vinini Creeks, north and northwest of Mt. Hope in the Garden Valley sub-basin of Pine Valley. On August 22, 2007, Vinini Creek was dry, with zero flow observed. Henderson Creek is composed of two main tributaries, the North and South Forks. No stream flow was observed in the North Fork, although perennial (spring-fed) segments exist further upstream of the observation site. Discharge in the South Fork ranged from 0.06 cfs to 0 cfs. Henderson Creek contained observable flow for only approximately 2.3 miles and, like Roberts Creek, was consistently losing stream flow to ET and seepage through the streambed. Discharge measurements obtained in August 2007 are listed below in **Table 3.3-5**, and locations are shown on **Figure 3.3-2**.

Miscellaneous flow measurements and observations of no flow were made on numerous other streams and springs, as listed in **Table 3.3-6 and shown on Figure 3.3-1.**

3.3.2.2 GAGED RECORDS AND RUNOFF ESTIMATION TECHNIQUE COMPARISON: With the exception of Tonkin Spring, at which gaging began in December of 2007, there are no long-term continuous stream flow gages operated in the Study Area; however, there were previously three gaging stations in Monitor Valley operated by the USGS with long periods of record. Because these streams have elevations and topography similar to those of other streams in the Study Area, they were used to recreate some missing records in order to estimate variation in stream flow. For Pine Creek near Belmont, the period of record is 1978-2005; for Mosquito Creek near Belmont, the period of record is 1978-2005; and for Stoneberger Creek North of Austin (the gage is actually southeast of Austin), the period of record is 1978-1996. In order to extend the record of the gaging stations, a regression analysis between Pine Creek and South Twin River near Round Mountain (period of record 1966-2006) was made (**Figure 3.3-4**), and the data regression lines are plotted on **Figure 3.3-4**. Pine Creek was then correlated with Mosquito Creek to extend the Mosquito Creek record, where data were missing (R^2 = 0.87). These two calculations were linear regressions, with a polynomial equation providing the best correlation for Stoneberger Creek and South Twin (R^2 = 0.83). **Table 3.3-7** presents the estimated long-term annual flow at these gage locations as calculated using the regressions on **Figure 3.3-4**.

3.3.2.3 ESTIMATED RUNOFF ON UNGAGED STREAMS: As indicated previously, stream flow has been gaged by the USGS at three stations in Monitor Valley which are no longer active. Some miscellaneous measurements have been made on various streams in the rest of the Study Area, but generally those data serve only to define the flow at one point in time and location. Channel geometry measurements provide a rapid, reasonably accurate method of indirectly estimating mean annual flow from perennial streams. The technique is also applicable, albeit less accurate, for intermittent and ephemeral streams. A second method for estimating runoff from ungaged streams is based on the area of a watershed within various elevation zones.

The hydraulic-geometry concept by Leopold and Maddock (1953) was modified using select channel geometry features by Moore (1968) in Nevada, Hedman (1970) in California, Hedman et al. (1972) in Colorado, and Hedman et al. (1974) in Kansas. The channel geometry technique used for this study was developed by Hedman and Osterkamp (1982) and is a refinement and modification of Hedman et al. 1974.

Hedman and Osterkamp (1982) used an extensive database of stream-flow characteristics from gaging stations in the western United States to correlate with the "active channel" feature and channel sediment characteristics. The resulting statistics provided a series of equations that applied to perennial, intermittent, and ephemeral drainages in regional areas of similar runoff. The caveats, assumptions, and limitations of the technique are discussed in Hedman and Osterkamp (1982).

Two main requirements in determining the appropriate equation to use are the percentage of time there is discharge in the stream and the effectiveness of the sediment that makes up the bed and banks of the stream to armor the channel. The interactions of these two processes are responsible for the development of the "active channel." The "active channel," first used by Hedman et al. (1974) and described by Osterkamp and Hedman (1977), is defined as follows:

The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with lower limit of permanent vegetation so that the two features, individually or in combination, define the active channel reference level. The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge.

To solve the various equations listed by Hedman and Osterkamp (1982) requires a measurement of the width of the active channel.

Moore (1968) developed an estimation technique for average annual runoff in Nevada streams and watersheds based on the area of the watershed within a series of elevation zones. Estimates of annual runoff for Pine, Mosquito, and Stoneberger Creeks, derived by applying Moore's methodology, are shown in **Table 3.3-8**. As shown in **Tables 3.3-8 and 3.3-10**, Moore's method produces noticeably greater estimates of runoff than the gaged record in Monitor Valley.

As an additional technique of estimating annual mean runoff, the channel geometry technique described above by Hedman and Osterkamp (1982) was used to compare with the Monitor Valley gaged record. The Hedman-Osterkamp method produced annual runoff estimates that compare well with the stream gage records (**Tables 3.3-9 and 3.3-10**). Thus channel geometry is believed to provide a useful method for estimating mean annual stream flows in major drainages in the Study Area.

The Hedman-Osterkamp channel geometry method was used to make runoff estimates from individual drainages in the Study Area (**Table 3.3-10**). It has not been applied to every drainage channel in the Study Area, but to the major tributaries, and it is used to gain some understanding of the distribution of runoff among primary drainages as well as the potential runoff infiltration losses which are a component of groundwater recharge. Locations of field measurement of channel width are shown on **Figure 3.3-5**.

Runoff from the mountain block prior to anthropogenic development was partly consumed by ET with an unknown amount infiltrating through the unsaturated zone to the groundwater table. Coils Creek is an example of this process. Site K-10 combines numerous channels in a broad floodplain covered mostly by sagebrush and greasewood. Site K-8, the next upstream site on Coils Creek, is considered to be at the mountain front even though the site is a few miles from the piedmont/mountain front border. The estimated flow at this point is 600 AF/yr. By the time the flow reaches site K-10, about 6 miles downstream, half the flow has been consumed by ET or lost from the channel by infiltration to the unsaturated zone and ultimately to the water table.

In Kobeh Valley, an estimated 2,940 AF/yr of runoff loss occurs in major ephemeral tributaries across the alluvial fans, as determined using the Hedman-Osterkamp method. A portion of this runoff occurs in the winter and spring, before high potential ET rates occur, and it is assumed that a significant portion of this runoff infiltrates the streambeds, becoming recharge to groundwater. Berger (2000a) likewise observed that major drainages in Pine Valley provide a significant source of recharge while flow occurs across the piedmont environment (alluvial fans). Berger (2000a) estimated approximately 21 to 27 percent of the total basin recharge had a source of infiltration from runoff to the piedmont slope.

3.4 GROUNDWATER RESOURCES

Mt. Hope is located in the Diamond Valley Regional Flow System as defined by Harrill et al. (1988), as shown on **Figure 3.4-1**. The basin originates in southern Monitor Valley, with surface and subsurface water flowing northward through the northern Monitor Valley to Kobeh Valley, and then eastward through Devils Gate to southern Diamond Valley. Subsurface inflows into Kobeh Valley also occur from Antelope Valley to the south. In total, the Diamond Valley Regional Flow System encompasses approximately 3,120 square miles.

The extent of the Diamond Valley Regional Flow System, as shown on **Figure 3.4-1**, is modified somewhat from Harrill et al. (1988). Recharge within the upland areas of Monitor Valley and Antelope Valley flows toward the basin axes and northward into Kobeh Valley, comingling with water derived from the upland areas of Kobeh Valley that flows toward the natural discharge area in the valley lowlands. Groundwater not discharged in Kobeh Valley flows eastward into Diamond Valley. Diamond Valley may also receive minor inflows of groundwater from Stevens Basin and the extreme northeastern part of Antelope Valley. Some studies have indicated that there is groundwater flow from the Garden Valley subarea of the Pine Valley into the Diamond Valley (**Section 3.4.4.4**).

On the northern slopes of Mt. Hope and the Roberts Mountains block, groundwater flow is northward into Pine Valley toward discharge areas in the valley lowlands (**Figure 3.4-1**). Groundwater that is not discharged from Pine Valley into Diamond Valley or discharged by pumping or to natural ET in the valley lowlands flows northward, ultimately discharging to the Humboldt River west of Carlin, near Palisade, Nevada.

All of the basins in the Study Area share similarities in their general characteristics. The rocks that crop out in the mountainous areas also occur under the valley fill sediments at depths ranging from only a few feet near the rock-alluvium contacts to thousands of feet bgs

IN THE SUPREME COURT OF THE STATE OF NEVADA

EUREKA COUNTY, A POLITICAL SUBDIVISION OF THE STATE OF NEVADA; KENNETH F. BENSON, INDIVIDUALLY; DIAMOND CATTLE COMPANY, LLC, A NEVADA LIMITED LIABILITY COMPANY; AND MICHEL AND MARGARET ANN ETCHEVERRY FAMILY, LP, A NEVADA REGISTERED FOREIGN LIMITED PARTNERSHIP,

Appellants,

vs.

THE STATE OF NEVADA STATE ENGINEER; THE STATE OF NEVADA DIVISION OF WATER RESOURCES; AND KOBEH VALLEY RANCH, LLC, A NEVADA LIMITED LIABILITY COMPANY,

Respondents.

_______________________________________/

Case No. 61324

Electronically Filed
Dec 27 2012 09:23 a.m.
Tracie K. Lindeman
Clerk of Supreme Court

District Court Case Nos.
CV 1108-15; CV 1108-156;
CV 1108-157; CV 1112-164;
CV 1112-165; CV 1202-170

JOINT APPENDIX
Volume 8

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CHRONOLOGICAL APPENDIX TO APPEAL FROM JUDGMENT

DOCUMENT	DATE	VOL	JA NO.
Partial Motion to Dismiss, Notice of Intent to Defend	09/14/2011	1	136-140
Order Allowing Intervention of Kobeh Valley Ranch, LLC, as a Party Respondent	09/26/2011	1	141-142
Answer to Verified Petition for Writ of Prohibition, Complaint and Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/28/2011	1	143-149
Answer to Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/29/2011	1	150-154
Answer to Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/29/2011	1	155-160
Order Directing the Consolidation of Action CV1108-156 and Action No. CV1108-157 with Action CV1108-155	10/26/2011	1	161-162
Summary of Record on Appeal	10/27/2011	2-26	163-5026
Request for and Points and Authorities in Support of Issuance of Writ of Prohibition and in Opposition to Motion to Dismiss	11/10/2011	27	5027-5052
Order Setting Briefing Schedule	12/02/2011	27	5053-5055
Reply in Support of Partial Motion to Dismiss and Opposition to Request for Writ of Prohibition	12/15/2011	27	5056-5061

DOCUMENT	DATE	VOL	JA NO.
Kobeh Valley Ranch's Reply to Conley/Morrison's Request for and Points and Authorities in Support of Issuance of Writ of Prohibition and in Opposition to Motion to Dismiss	12/15/2011	27	5062-5083
Kobeh Valley Ranch's Joinder in the State of Nevada and Jason King's Partial Motion to Dismiss	12/15/2011	27	5084-5086
Petition for Judicial Review	12/29/2011	27	5087-5091
Petition for Judicial Review	12/30/2011	27	5092-5097
Summons and Proof of Service, The State of Nevada	01/11/2012	27	5098-5100
First Additional Summons and Proof of Service, State Engineer, Division of Water Resources	01/11/2012	27	5101-5103
First Amended Petition for Judicial Review	01/12/2012	27	5104-5111
Opening Brief of Conley Land & Livestock, LLC and Lloyd Morrison	01/13/2012	27	5112-5133
Petitioners Kenneth F. Benson, Diamond Cattle Company, LLC, and Michel and Margaret Ann Etcheverry Family LP's Opening Brief	01/13/2012	27	5134-5177
Eureka County's Opening Brief	01/13/2012	27	5178-5243
Eureka County's Summary of Record on Appeal - CV1112-0164	01/13/2012	28	5244-5420
Eureka County's Supplemental Summary of Record on Appeal - CV1108-155	01/13/2012	29-30	5421-5701

DOCUMENT	DATE	VOL	JA NO.
Transcript for Petition for Judicial Review	04/03/2012	35	6639-6779
Corrected Answering Brief	04/05/2012	35	6780-6822
Findings of Fact, Conclusions of Law, and Order Denying Petitions for Judicial Review	06/13/2012	36	6823-6881
Notice of Entry of Findings of Fact, Conclusions of Law, and Order Denying Petitions for Judicial Review	06/18/2012	36	6882-6944
Notice of Appeal	07/10/2012	36	6945-6949
Petitioners Benson, Diamond Cattle Co., and Etcheverry Family LP's Notice of Appeal	07/12/2012	36	6950-6951
Excerpts from Transcript of Proceedings	10/13/2008	36	6952-6964

ALPHABETICAL APPENDIX TO APPEAL FROM JUDGMENT

DOCUMENT	DATE	VOL	JA NO.
Affidavit of Service by Certified Mail	08/11/2011	1	66-68
Answer to Verified Petition for Writ of Prohibition, Complaint and Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/28/2011	1	143-149
Answer to Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/29/2011	1	150-154
Answer to Petition for Judicial Review by Kobeh Valley Ranch, LLC	09/29/2011	1	155-160
Answer to Petition for Judicial Review	01/30/2012	31	5704-5710
Answer to First Amended Petition for Judicial Review	01/30/2012	31	5711-5717
Answer to Petition to Judicial Review	02/23/2012	34	6398-6403
Answering Brief	02/24/2012	34	6404-6447
Corrected Answering Brief	04/05/2012	35	6780-6822
Eureka County's Supplemental Summary of Record on Appeal - CV1108-155	01/13/2012	29-30	5421-5701
Eureka County's Summary of Record on Appeal - CV1112-0164	01/13/2012	28	5244-5420
Eureka County's Opening Brief	01/13/2012	27	5178-5243
Eureka County's Reply Brief	03/28/2012	34	6566-6638
Excerpts from Transcript of Proceedings	10/13/2008	36	6952-6964

DOCUMENT	DATE	VOL	JA NO.
Order Allowing Intervention of Kobeh Valley Ranch, LLC, to Intervene as a Respondent	09/14/2011	1	134-135
Order Allowing Intervention of Kobeh Valley Ranch, LLC, as a Party Respondent	09/26/2011	1	141-142
Order Directing the Consolidation of Action CV1108-156 and Action No. CV1108-157 with Action CV1108-155	10/26/2011	1	161-162
Order Setting Briefing Schedule	12/02/2011	27	5053-5055
Order Granting Extension	01/26/2012	31	5702-5703
Partial Motion to Dismiss, Notice of Intent to Defend	09/14/2011	1	136-140
Petition for Judicial Review	08/08/2011	1	01-06
Petition for Judicial Review	12/29/2011	27	5087-5091
Petition for Judicial Review	12/30/2011	27	5092-5097
Petition for Judicial Review	02/01/2012	31	5721-5727
Petitioners Kenneth F. Benson, Diamond Cattle Company, LLC, and Michel and Margaret Ann Etcheverry Family LP's Opening Brief	01/13/2012	27	5134-5177
Petitioners Kenneth F. Benson, Diamond Cattle Company, LLC, and Michel and Margaret Ann Etcheverry Family LP's Reply Brief	03/28/2012	34	6542-6565
Petitioners Benson, Diamond Cattle Co., and Etcheverry Family LP's Notice of Appeal	07/12/2012	36	6950-6951

DOCUMENT	DATE	VOL	JA NO.
Record on Appeal, Vol. II, Bates Stamped Pages 217-421	02/03/2012	32	5951-6156
Record on Appeal, Vol. I, Bates Stamped Pages 1-216	02/03/2012	31	5734-5950
Record on Appeal, Vol. III, Bates Stamped Pages 422-661	02/03/2012	33	6157-6397
Reply in Support of Partial Motion to Dismiss and Opposition to Request for Writ of Prohibition	12/15/2011	27	5056-5061
Reply Brief of Conley Land & Livestock, LLC and Lloyd Morrison	03/28/2012	34	6519-6541
Request for and Points and Authorities in Support of Issuance of Writ of Prohibition and in Opposition to Motion to Dismiss	11/10/2011	27	5027-5052
Respondent Kobeh Valley Ranch, LLC's Answering Brief	02/24/2012	34	6448-6518
Summary of Record on Appeal	10/27/2011	2-26	163-5026
Summary of Record on Appeal	02/03/2012	31	5728-5733
Summons and Proof of Service, Kobeh Valley Ranch, LLC	08/11/2011	1	60-62
Summons and Proof of Service, Jason King	08/11/2011	1	63-65
Summons and Proof of Service, Jason King	08/15/2011	1	121-123
Summons and Proof of Service, Kobeh Valley Ranch, LLC	08/15/2011	1	118-120

DOCUMENT	DATE	VOL	JA NO.
Summons and Proof of Service, The State of Nevada	08/17/2011	1	124-128
Summons and Proof of Service, The State of Nevada	01/11/2012	27	5098-5100
Supplemental Petition for Judicial Review	01/31/2012	31	5718-5720
Transcript for Petition for Judicial Review	04/03/2012	35	6639-6779
Verified Petition for Writ of Prohibition, Complaint and Petition for Judicial Review	08/10/2011	1	09-59

CERTIFICATE OF APPENDIX (NRAP 30(g)(1)

In compliance with NRAP 30(g)(1) I hereby certify that this Appendix consists of true and correct copies of the papers in the District Court file.

DATED: December 21, 2012.

/s/ KAREN A. PETERSON
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EXHIBIT 39: Volumes I and II of Hydrogeology and Numerical Flow Modeling Mt. Hope Project Eureka County, Nevada (July 2010)

(BOOKS PREVIOUSLY SUBMITTED)

July 2010
REPORT

HYDROGEOLOGY AND NUMERICAL FLOW MODELING
MT. HOPE PROJECT
EUREKA COUNTY, NEVADA

VOLUME 1: TEXT AND TABLES

Prepared for:

Prepared Cooperatively By:

MONTGOMERY
& ASSOCIATES
Water Resource Consultants

Hydrogeology and Water Resources Consulting

BARRANCA GROUP, LLC
Hydrogeologic Consulting

Copy ex 3001

JA1308

EUREKA MOLY

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September 7, 2010

Mr. Doug Furtado
U.S. Bureau of Reclamation
Battle Mountain Field Office
50 Bastian Road
Battle Mountain, Nevada 89820

Re: Mt. Hope Project NVN 082096; 3809 (NV062)
Revisions to "Hydrogeology and Numerical Flow Modeling, Mt. Hope Project, Eureka County, Nevada" dated July 2010

Dear Mr. Furtado:

Enclosed are two copies of replacement pages, tables, and figures for insertion into the previously submitted report titled *"Hydrogeology and Numerical Flow Modeling, Mt. Hope Project, Eureka County, Nevada, July 2010"*. These documents were revised following discussions with BLM and EMLLC representatives. The amended pages, tables, and figures should be inserted into appropriate places in the July 2010 report binders, in replacement of the corresponding pages, tables, and figures. Below is a listing of the replacement documents summarizing the changes made to each. The revised documents have been incorporated into a revised electronic version of the full report on the attached CD.

The revised documents and a description of the change(s) made are as follows:

PAGE, TABLE, OR FIGURE NUMBERS	DESCRIPTION OF REVISION
Table of Contents	
xv	Figure 3.4-7 noted as an "in pocket" figure. Title of Figure 3.5-3 revised
Report Text	
47	3rd paragraph: Heading changed to indicate Thompson Ranch Spring is also known as Taft Spring, rather than as Diamond Spring. Also, spring numbers 352 and 353 were removed, and spring number 362 was added.
48	Last paragraph: Willow Creek listed as perennial rather than Birch Creek
49	1st paragraph - Sentence added: "Birch Creek is not identified as perennial in the BLM dataset, but EMLLC observations and flow measurements support perennial classification."
59	3rd paragraph: Number of wells in database revised from 475 to 454

PAGE, TABLE, OR FIGURE NUMBERS	DESCRIPTION OF REVISION
Report Text (cont.)	
73	Last paragraph: Range of estimated transmissivity values revised from "22,860 to 94,120 gpd/ft" to 5,150 to 54,450 gpd/ft". Also, groundwater inflow rates revised from "790 to 5,950 AF/yr" to "200 to 3,450 AF/yr", and average inflow revised from "2,830 AF/yr" to "1,500 AF/yr". These values were corrected prior to the most recent modeling, but the report text was not updated accordingly.
86	2nd paragraph: Two instances of "Diamond Spring" changed to "Taft Spring".
Table	
3.3-1	Footnote revised to indicate Thompson Ranch Spring is also known as Taft Spring rather than as Diamond Spring
3.5-2	Table headings revised to clarify Pine Valley vs. Garden Valley water budget amounts
4.1-5	Antelope Valley conceptual water budget recharge rate revised from 4,000 to 4,100 AF/yr.
4.4-1	Initial Post-Mining Pit Dewatering Rate for Cumulative Action Senario and Proposed Action Alternative revised from 460 to 677 AF/yr. The original value of 460 AF/yr is the rate at 1 year after end of mining, whereas 677 AF/yr is the rate at the end of mining.
4.4-10	Spring 719 added to table
Figure	
3.4-4	Thompson Ranch Spring (Taft Spring) label revised
3.4-5	Thompson Ranch Spring (Taft Spring) label revised
3.4-7	Water level data added to contour map; map enlarged for better visibility (New pocket for map included)
3.4-9	Thompson Ranch Spring (Taft Spring) label revised
3.4-10	Thompson Ranch Spring (Taft Spring) label revised
3.5-3	Figure title revised to show Taft Spring rather than Diamond Spring
4.4-20	Outline of 10-ft drawdown revised slightly; Spring 719 added
Electronic Version of Report	
CD	Electronic (PDF) version of the report revised to incorporate revised documents listed above

Please call me if you have any questions.

Sincerely,

Patrick Rogers
Director, Environmental and Permitting

Enclosures

cc: Derek Blazer - Montgomery & Associates, without attachments
Dale Bugenig - Eco-Logic with attachments
Rich DeLong - Enviroscientists with attachments
Steve Drummond - BLM BMFO without attachments
Carrie DuBray - EMLLC with attachments
Brian Hanson - BHW without attachments
Dave Hawkins - Barranca Group, LLC without attachments
Bruce Holmgren - NDEP/BMRR with attachments
Lee Kreutzer - NPS without attachments
Katie Miller - NDOW with attachments
Tom Olsen - BLM NSO with attachments
Angelica Ordaz - BLM MLFO without attachments
Robert Pennington - GMI without attachments
Jon Sherve - BLM MLFO with attachments
Dwight Smith - Interflow without attachments
Daniel B. Stone - ITASCA with attachments
Eric Swanson - AquaLithos Consulting without attachments
Jake Tibbetts - Eureka County with attachments (2 copies)
Ross de Lipkau - Parsons Behl & Latimer with attachments (4 copies)

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July 9, 2010

Mr. Doug Furtado
U.S. Bureau of Reclamation
Battle Mountain Field Office
50 Bastian Road
Battle Mountain, Nevada 89820

Re: Mt Hope Project NVN 082096; 3809 (NV062)
Responses to comments: Review of Mount Hope Project EIS Water Resources Report "Hydrogeology and Numerical Flow Modeling, Mount Hope Area, Eureka County, Nevada" Dated April 2010

Dear Mr. Furtado:

Attached are two copies of amendments to the revised report of "*Hydrogeology and Numerical Flow Modeling, Mount Hope Project, Eureka County, Nevada, April 2010*". The amendments include revised text and tables from Volume 1, and revised figures and Appendices E, F, and M from Volume 2. A new cover page for Volume 2, reflecting the date of these amendments is also provided. The amended Volume 1 (text and tables) is being reissued in its entirety. The amended figures and appendices should be inserted into the April 2010 Volume 2 binder, in replacement of the corresponding figures and appendices from the previous version of the report. We are also providing the attached table that summarizes the changes made to figures to facilitate efficient review of the changes. The amendments have been incorporated into a revised electronic version of the full report, including model documentation.

This letter provides our responses to comments received from Dr. Daniel B. Stone (ITASCA Denver, Inc.), and additional review comments received from Jon Sherve (BLM). In addition, we received written comments from consultants for Eureka County in a memo dated May 28, 2010. EMLLC understands that county written comments included professional modeling opinions/philosophies, such as appropriate drawdown thresholds, uncertainty evaluation, and adequacy of transient calibration of the model in Diamond Valley. Per discussions with Jon Sherve, no further action has been taken on these items. Responses to specific verbal comments provided by Eureka County consultants and personnel during the May 26 meeting are found below.

For clarity and ease of review, we are providing the comments in italics, followed by our response. Where appropriate, each response has been incorporated into the attached report amendments.

Dr. Daniel B. Stone, ITASCA Denver, Inc., Technical Review Memorandum, June 9, 2010:

General Comments:

1. *The report is much improved over previous versions, although it still contains a number of typographical and editorial errors. These should be addressed by the authors prior to the publication of the Draft EIS.*

   We have attempted to correct all typographical and editorial errors in the amended report.

2. *The report should include a more detailed discussion of potential impacts to all water resources within the 10-ft drawdown contour, particularly for the Proposed Action (i.e., Figure 4.4-20). The report does a good job of identifying which specific resources (wells, water rights, springs) lie within the 10-ft drawdown contour under various scenarios and at different times, and it shows the general magnitude and recovery of drawdown at certain regional locations of interest, but it does not discuss the potential degree of impact to a specific resource within the 10-ft drawdown contour, the likelihood of the impact actually occurring, or the anticipated duration of the impact to that resource. For example, shallow, perched groundwater is the likely source of flow of certain springs within the 10-ft drawdown contour, so it may be reasonable to infer that those springs would not be impacted by pit dewatering. Also, the predicted post-project behavior of spring flows and water-levels at wells and water-right locations within the 10-ft drawdown contour should be described and explained, as necessary (see Specific Comment No. 35 below). Similarly, the report should discuss the expected impacts to the surface streams within the 10-ft drawdown contour (e.g., perennial or ephemeral flows in certain sections of creeks may dry up for the duration of drawdown). Whatever the potential impacts may be, they should be thoroughly discussed for each water resource feature (or group of similar features, including streams) within the 10-ft drawdown contour.*

   Page 188: A new section (4.4.4.6) has been added to the report to provide more detail regarding the projected degree, likelihood, and duration of impacts to resources located within the 10-foot drawdown contour.

3. *The Regional Model should be validated using additional water-level data from the time period 2006 (end of calibration) through 2009. This is important because the model is used to simulate groundwater conditions in 2009 as the baseline from which impacts of the No Action and Proposed Action Alternatives are quantified. It is relevant to show how close the simulated baseline conditions are to reality in 2009, and to discuss the reasons for and implications of any notable mismatch.*

   Water level data from 2007 through 2010 has been added to the transient water level hydrographs in Figures 4.1-33 through 4.1-46. These data are generally consistent with transient water levels simulated for this period.

Specific Comments:

1. *Page 21, 2nd paragraph, last sentence – should point the reader to Volume 1 (instead of Volume 2) for the tables of Chapter 3.*

   Page 21, 2nd paragraph: The reference to Volume 2 has been changed to Volume 1.

2. *Page 111, 3rd paragraph, 1st sentence – MODFLOW-SURFACT's handling of dry cells has little bearing on the simulation of lake development in the mine pit, since this is accomplished by using the LAK2 package. Rather, the code's handling of dry cells facilitates the simulation of water-level recovery in the dewatered rock mass outside of the mine pit upon cessation of dewatering. This point of clarification has been made before, but the text remains the same.*

   Page 112, last paragraph: The text has been modified to discuss dry cells in the rock formation rather than in the lake.

3. *Page 118, 2nd full paragraph, last sentence – refers to a specific consultant's advocated ET rates. I suggest removing this sentence, as it is unnecessary.*

   The subject sentence has been removed.

4. *Page 121, 1st full sentence at top of page – refers to Table 4.1-2 and Figure 4.1-6 as summarizing the locations of model boundary conditions used to represent springs and flowing wells. It would be helpful if the ID numbers listed in Table 4.1-2 were shown on Figure 4.1-6 next to their corresponding boundary nodes in the model.*

   ID numbers from Table 4.1-2 have been added to Figure 4.1-6.

5. *Page 122, last sentence – The text should mention how the drain-discharge/well-recharge procedure was implemented (iteratively, presumably).*

   Page 123, last paragraph: A sentence clarifying this point was added to the end of Section 4.1.3.4.

6. *Page 125, 2nd paragraph, 1st sentence – "Recharge rates applied to the Local Model area within the Regional Model utilized a recharge distribution derived from the Local Model on a cell-by-cell basis, with the average recharge from the Local Model input to each Regional Model cell." Can this be restated to clarify the intended meaning?*

   Page 126, 2nd paragraph: The paragraph has been revised to improve clarity.

7. *Pages 136-137, 1st paragraph under heading "Diamond Valley Transient Calibration Targets" – mentions that 414 additional water-level measurements were added for selected years, and references Figure 4.1-30. However, that figure does not show those additional target locations. Appendix F is also referenced, but it does not indicate which*

wells were used as transient targets (for either point or time-series data). The specific well locations and point water-level measurements that were added as transient calibration targets should be clearly identified.

A spreadsheet ("Sorted Data") has been added to Appendix F to identify the referenced water level measurements and to differentiate between the time-series data and the point data. Locations of the point data wells were added to Figure 4.1-30.

8. *Page 138, last paragraph, 2nd sentence – mentions Sulphur Spring as an example of a spring in Diamond Valley that has been affected by drawdown due to agricultural pumping. However, the following sentences describe the observed flows at Thompson Ranch Spring and at Shipley Spring, and say nothing further about Sulphur Spring. A sentence or two should be added to describe what has been observed at Sulphur Spring.*

   Page 140, 2nd paragraph: Text has been added to describe recent conditions observed at Sulphur Spring.

9. *Page 139, last bullet item, last sentence – mentions test well 220P Should this be 220T instead? Same thing on the next page (p. 140, 1st bullet item) – should 206P be 206T instead?*

   Page 141, *3rd bullet item*: Yes, the well identifiers have been changed to 220T and 206T, respectively.

10. *Page 140, last bullet item, last sentence – "Changes to these properties in the steady-state model were removed in an iterative process…" (emphasis added). What does this mean?*

    Page 142, *last bullet item*: The word "removed" was changed to "implemented".

11. *Page 141, last paragraph, last sentence – suggest rewording as: "This achieved the goal of calibrating the model to observed results from the transient aquifer testing."*

    Page 143, 4th paragraph: The sentence was revised as suggested.

12. *Page 142, 2nd paragraph, 3rd sentence – suggest rewording as. "These five lithologies were used to vary horizontal hydraulic conductivity…."*

    Page 144, 1st full paragraph: The sentence was revised as suggested.

13. *Page 164, 1st paragraph after bullet list, 3rd sentence – states that "both [recharge and horizontal hydraulic conductivity] parameters were evaluated using published and field-acquired data." Which field data were acquired/evaluated for recharge?*

    Page 166, 1st paragraph: The sentence was revised. Recharge parameters were derived from published data; hydraulic conductivity parameters were estimated using field data.

14. *Pages 167, 1st paragraph after bullet list, 1st sentence – suggest rewording as: "Overall, the calibrated transient model shows a reasonable representation of local-scale aquifer behavior in the area of the pumping tests, while also maintaining a reasonable steady-state calibration."*

    Page 169, 1st paragraph after bullets: The sentence was revised as suggested.

15. *Page 179, last paragraph discusses simulated groundwater conditions in 2009. How do these results compare with observed conditions? (See General Comment No. 3)*

    Page 181, last paragraph: Text providing a comparison of results to observed conditions has been added to the third paragraph of Section 4.4.3.

16. *Page 180, last sentence – refers to projected water-level contours shown on Figure 4.4-8 for the Cumulative Action Scenario in 2055. The water-level contours shown on that figure look very similar to those shown for the No Action Alternative in 2055 (cf. Figure 4.4-5). Why do the contours on Figure 4.4-8 not indicate drawdown around the pit in the Mount Hope area?*

    The scale of the map is too small to discern detailed drawdown in the vicinity of the pit. A note has been added to Figure 4.4-8 to refer the reader to Figures 4.5-8 through 4.5-12 for greater detail of projected drawdown in the pit area.

17. *Page 181, last paragraph, 1st sentence – refers to projected drawdown shown on Figure 4.4-13 for the Proposed Action Alternative in 2055. The drawdown shown on that figure does not appear to match the results of a visual comparison of Figures 4.4-6 and 4.4-9. The apparent differences (e.g., immediately east of the upper part of Garden Pass Creek) should be explained, even if they are just an artifact of numerical thresholds and the subtraction procedure.*

    The three maps referenced show three different baselines and are therefore not directly comparable.

18. *Page 182, 2nd paragraph, 1st sentence – references Figure 3.4-8 as showing the geographic locations in Kobeh Valley that are plotted in Figure 4.4-14. However, only two of the seven locations plotted in Figure 4.4-14 appear to be labeled in Figure 3.4-8. It would be helpful to show the exact locations on appropriate maps where the hydrograph results presented in Figures 4.4-14 (a and b), 4.4-17, 4.4-18, and 4.4-19 were derived.*

    Locations of the observation points have been added to Figures 3.4-8, 4.4-12, 4.4-13, and 4.4-16.

19. *Page 189, last paragraph, 2nd to last sentence – "The average of the partial-year evaporation rates observed at these sites (51.315 inches) is a conservative assumption with respect to the development of the proposed pit lake." (Is the pit lake proposed, or is*

it just a result of the proposed mining operation?) Justification should be provided as to how/why this is a conservative assumption for simulating pit lake development, or else the sentence should be removed.

Page 195, 2nd paragraph: Text was added to the paragraph to explain the use of the word "conservative".

20. *Page 191, 2nd paragraph, 2nd sentence – states that the historical model simulates the time period from 1955 to present. Should "present" be changed to 2009 instead?*

Page 197, 2nd paragraph, 2nd sentence – The term "present" was changed to "2009".

21. *Page 192, Steps 3 and 4 near top of page – It seems like something important is missing in this description of the mine dewatering coupling procedure. What changes after Step 3 to cause Step 4 to reach closure? After Step 3, aren't the Regional Model drains in the initial simulation replaced with wells in subsequent Regional Model simulations, whose flux rates are determined iteratively with the Local Model?*

Page 198, Steps 1 through 4: The description of the iterative coupling process was revised to improve clarity.

22. *Page 193, 2nd paragraph, last sentence – I think the reference to Figure 4.5-6 should be to Figure 4.5-7 instead.*

Page 199, 1st paragraph: The reference to Figure 4.5-6 was changed to Figure 4.5-7.

23. *Page 200, 1st full paragraph and last paragraph – Precipitation is the only single-variable sensitivity analysis parameter that was not considered in the multivariate analysis. Some discussion should be added to the text explaining why it was excluded (e.g., changes in runoff and evaporation can be used as a surrogate).*

Page 205, last paragraph, and page 206, 3rd paragraph: Precipitation was varied in the multivariate analysis. It was decreased to 12.7 in/yr and increased to 17.18 in/yr for the "lower" and "upper" simulations, respectively.

24. *Page 211, 2nd paragraph – stated values for mean error, absolute mean error, standard deviation and normalized errors are not the same as those listed in Table 4.6-2.*

Page 217, 1st full paragraph: Text has been modified to be consistent with Table 4.6-2.

25. *Page 212, 1st full paragraph, 1st sentence – states that the Regional Model was used to simulate subsidence in Diamond Valley for the No Action Alternative through 2055, with the results shown in Figure 4.6-5. Do these results include the historical 1955 through 2009 time period, or do they just represent the projected subsidence from 2009 onward (the way drawdown was presented for the No Action Alternative)? The next paragraph discusses the simulated future subsidence under the Proposed Action Alternative. How*

was this calculated? Is it the result of subtracting the No Action Alternative subsidence surface from the Cumulative Action Scenario subsidence surface, similar to the way drawdown was calculated for the Proposed Action Alternative? The methodology for the Proposed Action Alternative should be clarified. Also, the simulated future subsidence under the Cumulative Action Scenario should be presented and discussed.

Page 217, last paragraph, et seq.: Section 4.6 text and figures have been revised to address these concerns. The subsidence predictions are processed and presented in a similar format as used for water table drawdown, including results of the No Action Alternative, Proposed Action Alternative and Cumulative Action Scenario.

26. *Table 4.1-5 – should include a footnote to the last column providing a cross-reference for the conceptual water-budget recharge values.*

    The suggested footnote has been added to Table 4.1-5.

27. *Table 4.1-6 – Why does K zone 15 have such a high horizontal conductivity value (45.4 ft/day, the 4th highest value of all units) when it is supposed to represent siliciclastic rocks—an aquitard unit?*

    K Zone 15 is a narrow east-west area north of Whistler Peak, in siliclastic rocks, which represents a higher K faulted zone, a postulated conduit for Kobeh-Diamond Valley flow connection.

28. *Table 4.1-8 – shows storage zone 72 as having a storage coefficient of zero. This should be corrected.*

    The "0" value for storage zone 72 has been replaced with a small positive value (2.96E-07) in Table 4.1-8.

29. *Table 4.1-10 – should include the correlation coefficient (r2), since it is stated on p. 129 that it was one of the primary statistics used in the calibration.*

    The correlation coefficient (R^2) has been added to Table 4.1-10.

30. *Table 4.1-14 – should include the number of observations/target values.*

    The number of observations has been added to Table 4.1-14.

31. *Table 4.2-4 – footnote "b" should read "hydraulic conductivity =" instead of "ft/d =".*

    The footnote in Table 4.2-4 has been modified as requested.

32. *Tables 4.4-4 through 4.4-7 – should include a summation row at the bottoms of the "flow" columns. Also, the various tables appear to use the words "flow" and "flux"*

interchangeably. I suggest the word flow be used (consistently) throughout these tables. (Same with the title for Table 4.4-12.)

As requested, "Total" rows have been added to the bottom of Tables 4.4-4 through 4.4-7. The term "flux" has been changed to "flow" throughout these tables.

33. *Table 4.4-7 – The labels for the 5th and 7th columns should refer to the difference between the No Action Alternative and the Cumulative Action Scenario, rather than between the Proposed Action Alternative and the Cumulative Action Scenario.*

    The columns headings in Table 4.4-7 have been corrected.

34. *Table 4.4-8 -- The footnote indicated by *** does not appear to be attached to anything.*

    The '***' footnote has been deleted from Table 4.4-8.

35. *Table 4.4-10 – Several of the springs listed in this table do not show signs of water-level recovery by 200 years post-project and a few (e.g., 580, 604, 619, 638, 639) exhibit notable fluctuations in drawdown recovery. These predicted behaviors should be discussed in the text. (See General Comment No. 2.)*

    Some spring sites near the pit are not projected to recover to pre-mining levels, due to the fact that water levels will remain suppressed near the pit over the long-term. Text has been added to the report concerning water level projections for 300 and 400 years post project to more clearly document projected long-term water level trends near the pit (see Page 187, 2nd paragraph).

    Additionally, the data for several spring sites were found to be in error in previous reporting. The errors were related to inconsistent data processing which affected the results for sites where small shifts in site location produce notable differences water table elevation, particularly relevant to sites near Mt Hope. The inconsistencies have been corrected in updated Tables 4.4-8 through 4.4-10 and impact tables in Appendix M.

36. *Table 4.6-1 – It would be helpful to add a footnote to the "scene" columns, indicating the data source.*

    As requested, a footnote indicating the data source has been added.

37. *Figure 4.1-3 – The Model Layer Description indicates that Layer 2 represents confining layer for valley floor alluvium. To be consistent with the description on p. 114, this should be changed to read: "...represents upper portions of valley floor alluvium below root zone." Also, the Layer 6 description has an extraneous bit of text at the end (Layer Type 3), which should be removed.*

    Figure 4.1-3 has been revised as suggested.

38. *Figure 4.1-6 – I suggest changing the Explanation to read "Specified Flux" instead of "Major Flowing Wells or Springs". Also, see previous Specific Comment No. 3 regarding labeling the spring/well boundary nodes with the ID's from Table 4.1-2.*

"Specified Flux" has been added parenthetically to the Explanation in Figure 4.1-6.

39. *Figure 4.1-8 – The figure shows two thin zones with exceptionally high simulated recharge (No. 31 at 13.1 in/yr to the west of Mount Hope and No. 62 at 26.7 in/yr to the north of Mount Hope). These should be explained in the text.*

Text has been added to section 4.1.3.6 to explain the thin zones of high simulated recharge.

40. *Figures 4.1-9 through 4.1-24 – Although these figures provide the requisite information on the distribution of hydraulic parameter values in the model, they would be much more effective if the gradational color scheme was used to show ascending (or descending) parameter values, rather than just distinguishing the different zones. These appear to be the only color-flood figures in the report that do not represent the displayed quantities in a monotonic sequence. Also, the Explanations on Figures 4.1-16, -20, -22, and -24 contain errors of content and/or number formatting.*

Hydraulic conductivity and specific yield values were sorted and color designations were reassigned accordingly. Editorial changes were made to the referenced Explanations.

41 *Figure 4.1-55 The title indicates that the steady-state Regional Model was used to assess sensitivity to changes in storage coefficient and specific yield, but clearly that was not the case. Also, it would be appropriate to indicate on the figure the point in time in the transient model run at which the storage sensitivity values were derived.*

The title of the figure was changed to indicate that sensitivity analysis was for the transient model rather than steady-state. The time period of the analysis has been added to the figure title.

42 *Figure 4.4-11 It would be helpful to add the pre-development water table to these cross sections for reference.*

The figure was revised to include the pre-development water table.

43. *Figure 4.5-7 – The Explanation should read "Projected Evaporation" (no transpiration component).*

Figure has been edited as suggested.

44. *Figure 4.6-1 – Why does the indicated 0.0-ft subsidence contour extend beyond the limits of the dark blue-colored area (indicating 0 to 0.25 feet of subsidence)? Conversely, why does the dark blue color not fill the area encompassed by the 0.0-ft contour?*

Figure 4.6-1 was modified to explain that the source of the subsidence contours is Bell and Aria (2009). A sentence was added to the explanation to indicate that "Non-colored areas between outer contour and colored InSAR zones are a result of temporal decorrelation."

Eureka County, Verbal Comments at Meeting in Battle Mountain, Nevada, May 26, 2010

1. *Are the Buckingham Ranch water rights in Pine Valley included in the water rights plate/summary?*

   According to the water rights database provided by NDWR in January of 2010, water rights and vested claims identified for Kenneth Buckingham include numerous spring, underground, and surface water rights throughout Pine Valley, in both the basin and in the mountain block. The majority of the points of diversion are associated with stock watering, with the remainder associated with irrigation. These rights are identified on Plate 1, and appear in tabular form in Appendix C. Rights or vested claims explicitly identified under the owner Kenneth Buckingham are not within the projected 10-foot cone of depression at any time. The closest rights to the project area are springs in the Roberts Mountains that are approximately 7.6 miles from Mt. Hope, and about 8.3 miles to the closest well in the proposed well field area. Buckingham water rights on Tonkin Spring/Denay Creek and from wells west of Tonkin Spring are at least 14.7 miles from Mt. Hope, and 13.3 miles to the nearest proposed production well in the well field area.

2. *Is Bobcat Ranch pumping that is shown on Figure 4.4-2 actual pumping or consumptive use?*

   The pumping shown on the figure is consumptive use. An explanatory note was added to the figure.

3. *Page 144, 2nd paragraph: Add pit bottom elevation and clarify 2,550 feet of drawdown. It is not clear what the reference elevation is for this drawdown.*

   Page 146, 2nd paragraph: Text was added to provide a reference elevation for the reported drawdown values.

4. *Please provide additional water level data for the period 2006 through 2009 to assist model evaluation.*

   The observed and simulated water levels shown on Figures 4.1-33 through 46 have been updated to include data from 2006 through 2010 where available.

5. *Check references to 3F Ranch; for example, in Figure 2.0-1, 3 Bar may be referred to as 3F.*

On Figure 2.0-1, reference to 3 Bar Ranch was incorrectly shown as 3F Ranch. The figure has been corrected.

6. *Clarify the use of Beowawe vs. Grass Valley precip/evap station.*

   Reference to the UNR Beowawe Research station has been changed to the University of Nevada Gund Ranch station.

<u>Jon Sherve, Bureau of Land Management, Comments Submitted via Email, June 17, 2010</u>

1. *Page 3, top paragraph: The reference to Appendix A is made but there is not an appendix in the appendices.*

   Appendix A is provided electronically on an enclosed DVDs.

2. *Page 32, second paragraph: Table 3.1-1 should be Table 3.1-2.*

   Page 32, 2nd paragraph: Reference to the table has been corrected.

3. *Page 137, second paragraph, first sentence: "The usual method for calibrating a transient model, at least from a statistical viewpoint, is to match changes in water level...." Add "trends" after first water level.*

   Page 138, last paragraph: The sentence has been revised as suggested.

The report presented herewith is intended to represent the final version to be used for evaluation of hydrologic impacts in preparation of the Mt. Hope EIS. Review and approval of the report will allow preparation of the Preliminary Draft EIS, and thus your prompt attention is greatly appreciated. Please call me if you have any questions.

Sincerely,

Patrick Rogers
Director, Environmental and Permitting

Enclosure

cc: Derek Blazer - Montgomery & Associates, without attachment
Dale Bugenig - Eco-Logic with attachment

Rich DeLong - Enviroscientists with attachment
Steve Drummond - BLM BMFO without attachment
Carrie DuBray - EMLLC with attachment
Brian Hanson - BHW without attachment
Dave Hawkins - Barranca Group, LLC without attachment
Bruce Holmgren - NDEP/BMRR with attachment
Lee Kreutzer - NPS without attachment
Katie Miller - NDOW with attachment
Tom Olsen - BLM NSO with attachment
Angelica Ordaz - BLM MLFO without attachment
Robert Pennington - GMI without attachment
Jon Sherve - BLM MLFO with attachment
Dwight Smith - Interflow without attachment
Daniel B. Stone - ITASCA with attachment
Eric Swanson - AquaLithos Consulting without attachment
Jake Tibbetts - Eureka County with attachment (2 copies)

SUMMARY OF CHANGES TO MT. HOPE FIGURES

FIGURE NO.	RESPONSE TO COMMENT NO.*	DESCRIPTION OF CHANGES MADE
ES-1	---	Added Stevens Basin label & shading
ES-2	---	Updated wellfield corridor & well locations
ES-5	---	Added phreatophyte areas; edited title to be consistent with Figure 4.4-20
1.1-2	---	Updated wellfield corridor & well locations
2.0-1	EC 5	Changed label for "3F Ranch" to "3Bar Ranch"
3.3-1	---	Added Stevens Basin label & shading; added stream discharge measurement locations; added surface water impoundments
3.4-1	---	Added Stevens Basin label & shading
3.4-2	---	Added Stevens Basin shading; added spring symbol in northeast Kobeh Valley
3.4-3	---	Added Stevens Basin label & shading
3.4-4	---	Added Stevens Basin label & shading
3.4-5	---	Added Stevens Basin label & shading
3.4-8	SC 18	Added locations and labels of model hydrographs 4-4.4, 17, 18, and 19
3.5-2	---	Added phreatophyte areas
3.7-7	---	Adjusted labels on graph
4.1-3	SC 37	Edited text to model layer descriptions
4.1-6	SC 4 and SC 38	Added simulated springs and flowing wells from Table 4.1-2; added "specified flux" to Explanation
4.1-8	---	Minor edit in explanation
4.1-9 thru 4.1-24	SC 40	Resorted K values and reassigned color designations
4.1-30	SC 7	Added locations of 414 additional wells used in transient calibration
4.1-33 thru 46	GC 3 and EC 4	Replaced transient WL plots
4.1-47	---	Updated wellfield corridor & well locations
4.1-55	SC 41	Modified title of figure to reflect transient model instead of steady-state
4.4-2	EC 2	Adjusted Kobeh Valley pumpage graph; also added note explaining pumpage is equal to consumptive use
4.4-3	---	Modified phreatophyte area shading in southern Pine Valley
4.4-7, 4.4-10, and 4.4-20	---	Added phreatophyte areas
4.4-8	SC 16	Removed inset graphic. Also added note referring to Figures 4.5-8 through 4.5-12 for greater detail. Modified phreatophyte area shading in southern Pine Valley
4.4-11	SC 42	Added pre-development water level to cross-sections
4.4-12 and 4.4-13	SC 18	Added locations and labels of model hydrographs 4.4-4, 17, 18, and 19; updated wellfield corridor & well locations
4.4-15	---	Updated wellfield corridor & well locations
4.4-16	SC 18	Added locations and labels of model hydrographs 4.4-4, 17, 18, and 19
4.4-21	---	Updated wellfield corridor & well locations
4.4-22	---	Updated wellfield corridor & well locations
4.5-7	SC 43	Changed "evapotranspiration" to "evaporation"
4.6-1	SC 44	Edited explanation and added reference
4.6-5	SC 25	Title modified
4.6-6	---	Updated wellfield corridor & well locations
4.6-7	SC 25	Added new figure
Plate 2	---	Spring 1101 added in Kobeh Valley; Rabbit Spring (285) renumbered to 1102

* GC = Itasca General Comment; SC = Itasca Specific Comment; EC = Eureka County Verbal Comment
--- = Change not directly related to comments received

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PLATES

Plate

* in pocket

APPENDICES
(All on electronic media)

Appendix

* Paper copy included in this report

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Appendix

* Paper copy included in this report

ABBREVIATIONS AND ACRONYMS

AF/yr	acre-feet per year
amsl	above mean sea level
bgs	below ground surface
BLM	U.S. Bureau of Land Management
°C	degrees Celsius
CHB	constant head boundary
cfs	cubic feet per second
DEM	digital elevation model
EC	electrical conductivity
EIS	Environmental Impact Statement
EMLLC	Eureka Moly, LLC
EPM	equivalent porous medium
ERS	European Remote Sensing
ET	evapotranspiration
°F	degrees Fahrenheit
ft/d	feet per day
ft/yr	feet per year
ft^2/d	square feet per day
ft^3/d	cubic feet per day
GBCGR	Great Basin Center for Geothermal Research
GHB	general head boundary
GMI	General Moly, Inc.
gpd/ft	gallons per day per foot
gpm	gallons per minute
GPS	Global Positioning System
HFB	horizontal flow barrier
HSU	hydrostratigraphic unit
I	gradient
in/yr	inches per year
K	hydraulic conductivity
$K_{x,y}$	horizontal hydraulic conductivity
K_z	vertical hydraulic conductivity
KVCWF	Kobeh Valley Central Well Field
KVR	Kobeh Valley Ranch, LLC
LEA	Lower Eastern Assemblage
LGO	low grade ore
meq/L	milliequivalents per liter
mg/L	milligrams per liter

July 2010
REPORT

HYDROGEOLOGY AND NUMERICAL MODELING MT. HOPE PROJECT EUREKA COUNTY, NEVADA

EXECUTIVE SUMMARY

INTRODUCTION

Eureka Moly, LLC (EMLLC) is applying for permits to operate an open pit mine and mill at the Mt. Hope molybdenum deposit in Eureka County, Nevada. This base metal resource is world class and would become the largest primary molybdenum mine in the world. The project life is 44 years and includes conventional open pit mining methods, crushing, grinding, and flotation technologies. Roasting will be used to convert molybdenum disulfide into molybdenum trioxide. Approximately 11,300 acre-feet per year (7,000 gallons per minute) of groundwater is required to process the molybdenum ore.

The proposed Mt. Hope project is situated in Eureka County, Nevada on BLM lands, with some private land ownership. The project location is shown on **Figure ES-1**. The proposed Mt. Hope project ("Project") is located east of the Roberts Mountains, near the triple hydrographic basin divide between Diamond, Kobeh, and Pine Valleys. Proposed facilities include the open pit mine, ore and waste stockpiles, crushing plant, grinding mills and flotation facilities, roasters, tailings facilities, wellfield, roads, power lines, and pipeline corridors. A new 230-kV high-tension power line will supply the mine facility from an existing substation located north of Eureka. Proposed facilities are shown on **Figure ES-2**.

For purposes of this report and references to water rights, Eureka Moly, General Moly, and Kobeh Valley Ranch are used interchangeably, unless otherwise specified. References are also made to Idaho General Mines, Inc; General Moly, Inc. is a successor to Idaho General Mines, Inc., and absorbed all its assets in October 2008.

This study describes the existing hydrogeological conditions and uses numerical flow modeling to predict impacts that will result from groundwater withdrawals from the wellfield and open pit dewatering of the proposed Mt. Hope mine. Impacts are projected for three different scenarios:

- The No Action Alternative consists of continued agricultural pumping in Diamond Valley and Kobeh Valley and continued minor amounts of industrial and municipal pumping.
- The Cumulative Action Scenario consists of pumping described above, plus construction and operation of the Mt. Hope mine project, including Kobeh Valley Central Well Field (KVCWF) pumping, construction water supply pumping, and open pit dewatering.
- The Proposed Action Alternative exclusively examines the effect of the Mt. Hope project, which results from KVCWF pumping, construction water supply pumping, and open pit dewatering.

Substantial agricultural groundwater pumping and resulting overdraft has occurred in Diamond Valley. Diamond Valley is the terminus of a regional flow system which includes Kobeh Valley and the Mt. Hope area. Agricultural pumping from both Diamond Valley and Kobeh Valley are included as part of the Cumulative Action Scenario.

HYDROLOGIC SETTING

The mine site and proposed infrastructure are located within the Diamond Valley Regional Flow System (Harrill et al., 1968), which consists of Antelope, Diamond, Kobeh, and North and South Monitor Valleys, and Stevens Basin. These hydrographic basins are connected by surface and/or groundwater flow, and form an internally drained hydrologic system within the Great Basin Physiographic Province. Pine Valley to the north of Mt. Hope is part of the Humboldt River drainage. The Study Area is defined as the Kobeh, Antelope, and Diamond Valley hydrographic basins and the southern portion of Pine Valley, as shown on **Figure ES-1**. Groundwater flowing into Diamond Valley is eventually discharged to springs, lost to evapotranspiration (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.

The proposed Mt. Hope open-pit mine is located in a faulted and fractured metasedimentary complex that has been intruded by rhyolitic rocks. Surrounding country rocks are predominantly sedimentary rocks of the Ordovician Vinini Formation.

The primary aquifer units in the Study Area are valley fill deposits of upper Tertiary and Quaternary age and Paleozoic carbonate rocks that are found in the mountain blocks and underlie the valley fill deposits within the structural basins.

The wellfield that will provide process water for operations is approximately 8 miles southwest of the mine site and is located in north-central Kobeh Valley. The primary source of water is within the valley fill deposits and, to a lesser extent the carbonate rocks. Pit dewatering, a necessity for open pit mine operations, will extract groundwater from both the Kobeh Valley and Diamond Valley watersheds because the open pit mine resides along the hydrographic basin boundaries. The open pit will be excavated in low permeability clastic sedimentary (predominantly shale) and intrusive rocks.

For the hydrographic basins in the Study Area, groundwater recharges the mountain blocks and alluvial fans surrounding the valley floor, flowing from these higher elevations toward the valley floors, where the depth to groundwater becomes shallow. In central portions of the basins where the water table is within 50 feet of land surface, phreatophytic vegetation occurs and is a major consumer of groundwater.

There are no perennial streams on the valley floor of Kobeh, Diamond, Monitor or Antelope Valleys. Slough Creek is an ephemeral drainage at the southeast side of the Kobeh Valley basin which occasionally provides surface flow through Devils Gate to Diamond Valley. Perennial flow occurs in some reaches of Pine Creek and in some streams in the Roberts Mountains.

Springs in Kobeh Valley occur mostly in the mountains with only a few occurring on the valley floor. Most springs in the Study Area are presently understood to be locally recharged. In Diamond Valley, significant geothermal and non-geothermal springs, including Shipley Hot Spring, discharge along the northwestern valley periphery. Springs along the southern portion of the Diamond Valley playa have ceased to flow during the past 2 to 3 decades, as a result of water level drawdown from agricultural pumping in south-central Diamond Valley. In Pine Valley, Tonkin Spring is a major spring resource, situated at the northwestern base of the Roberts Mountains. Several small springs occur in the vicinity of the proposed open pit; the largest discharge occurs from old mine workings.

CURRENT AND PROPOSED GROUNDWATER USE

The Nevada Division of Water Resources (NDWR) has established the perennial yield of Kobeh Valley as 16,000 acre-feet per year (AF/yr). The consumptive use in Kobeh Valley has historically been considerably less than the perennial yield. EMLLC has applied for 11,300 AF/yr of water rights for the project, through change applications for groundwater rights and groundwater applications that have been purchased in Kobeh Valley. These change applications seek to change the manner of use from agricultural to mining/milling and to change the points of diversion from agricultural lands scattered around Kobeh Valley to the proposed Kobeh Valley Central Wellfield. The existing agricultural rights in Kobeh Valley on which the change applications have been filed total approximately 16,131 AF/yr, although actual pumping under those existing rights has typically been less.

Applications for an additional 3,570 AF/yr of agricultural consumptive use water rights have been submitted and are pending in the State Engineer's office. The consumptive use associated with the mining and milling rights and the agricultural rights and applications would be approximately equal to the perennial yield for the basin of 16,000 AF/yr.

NDWR has established the perennial yield of Diamond Valley as approximately 30,000 AF/yr. Diamond Valley is substantially over-appropriated, as agricultural consumptive use totals approximately 55,000 AF/yr. Groundwater resources in Pine Valley and Antelope Valley are not currently fully appropriated.

Three sources of groundwater have been identified to supply the water needs of the project:

- Mine construction water will be supplied by wells located in the vicinity of proposed tailings facilities or west of the proposed south tailings facility in Kobeh Valley. Estimated water demand is 480 AF/yr for 1 year.
- Mine dewatering rate will be variable depending on local-scale hydraulic properties in the area of pit advancement. Estimated quantities of groundwater supplied from pit dewatering over time range from 94 to 742 AF/yr. All of this water will be consumed in mining and milling operations.
- The principal source of water for mining and milling operations will be from the KVCWF wellfield located in Kobeh Valley, about 8 miles from the proposed open pit. Principal source of groundwater will be from valley fill deposits, with some contribution from carbonate bedrock. Estimated water supply from the wellfield will be 10,560 to 11,300 AF/yr, depending on the quantity of dewatering contribution.

A timeline of events associated with the mine water supply and pit dewatering is shown on **Figure ES-3**. The timeline references historical pumping in Diamond Valley and Project events together with numerical flow modeling key periods.

GROUNDWATER MODELING

Two groundwater flow models were developed concurrently: a large regional-scale model, "Regional Model", and a smaller embedded local-scale model, "Local Model", for the vicinity of the mine pit. The Regional Model domain encompasses the Study Area and the Local Model utilizes telescopic mesh refinement (TMR) to separately simulate the smaller area for the proposed mine pit and facilities. Regional and Local model domains are shown on **Figure ES-4**. The refined Local Model grid allows a more detailed simulation of pit dewatering and subsequent development of a pit lake. The Regional Model and Local Model are "coupled" to allow accurate representation of groundwater stresses between the two model domains. Together, the two models are used to predict:

- Regional groundwater level drawdown effects due to construction water pumping, KVCWF mine supply pumping, and pit-dewatering; and
- Local mine area groundwater impacts due to pit-dewatering and pit-lake development.

Model simulations were conducted for projection of drawdown impacts for the No Action Alternative, Cumulative Action Scenario, and Proposed Action Alternative. The Regional Model and Local Model were coupled to evaluate regional-scale impacts from pit dewatering.

SUMMARY OF FINDINGS

Figure ES-5 shows the projected maximum extent of the 10-foot drawdown contour for the Proposed Action Alternative, and includes identified springs, water rights, and wells included within the 10-foot drawdown contour. The contour is a composite of the maximum lateral extent of projected 10-foot drawdown occurring over time.

No measurable detrimental effects would be expected to occur to Diamond Valley from wellfield or mine dewatering pumping. The subsurface outflow from Kobeh Valley to Diamond Valley would not be meaningfully affected, with an estimated reduction in flow of approximately 25 AF/yr at Mine Year 44. Water level drawdown in the agricultural center that could result from wellfield and pit dewatering pumping is not detectable, compared to a total pumping drawdown of up to 70 to 100 feet caused by continued agricultural pumping.

The following are key findings:

- The amount of proposed water use is 11,300 AF/yr and would be less than the perennial yield of the Kobeh Valley basin (16,000 AF/yr)
- Projected drawdown in the KVCWF area at the end of process water supply pumping will be up to 130 feet, and generally ranges from 30 to 100 feet.
- Projected reduction in ET in central Kobeh Valley will be about 4,300 AF/yr due to drawdown in areas of shrub, salt-grass and meadow communities
- Projected drawdown in Diamond Valley resulting from KVCWF pumping is negligible
- KVCWF pumping is projected to reduce groundwater outflow from Kobeh to Diamond Valley by 25 AF/yr at end of the project life
- Pumping from the KVCWF is projected to cause land subsidence in the range of less than 1 foot to 3 feet
- Local Model simulations indicate that inflow to the pit would average 330 AF/yr during dewatering and will be less during pit infill
- A pit lake is projected to form in the mine pit after pit excavation operations cease. Water levels in the lake would rise slowly, approaching equilibrium approximately 1,220 years after mining ceases

- Groundwater levels are projected to remain above the level of the pit lake throughout the model simulation period, which would prevent movement of water from the lake into the aquifer. Thus, for existing climatic conditions, the pit lake is projected to behave as a hydrologic sink with evaporation consuming all precipitation and groundwater inflow to the lake.

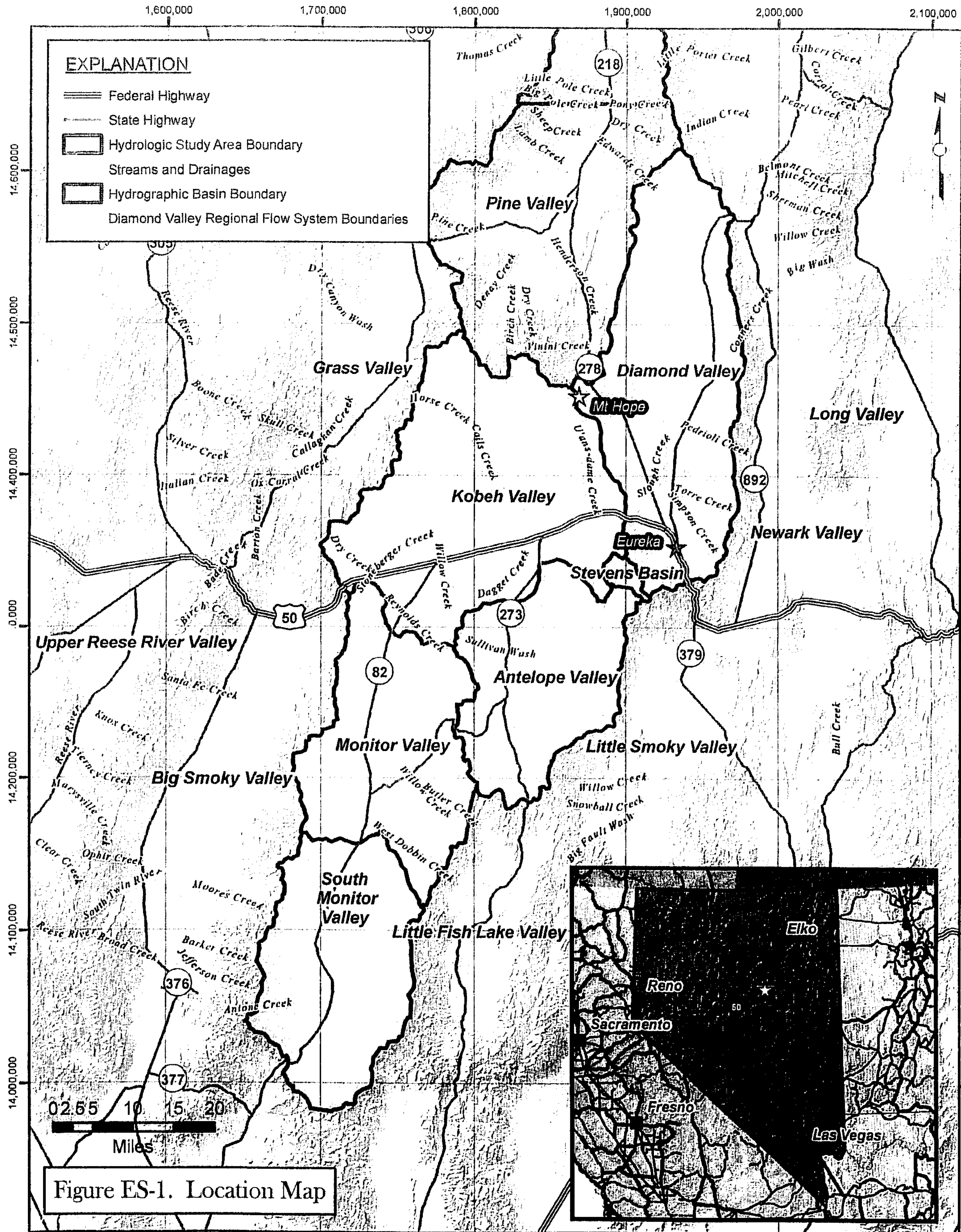

Figure ES-1. Location Map

Date: 07/07/10 Filname: Z:\Interflow\RevisedFigures_June2010\Figure_ES-1_Area_Location_map_Rev.mxd UTM NAD83, Zone 11

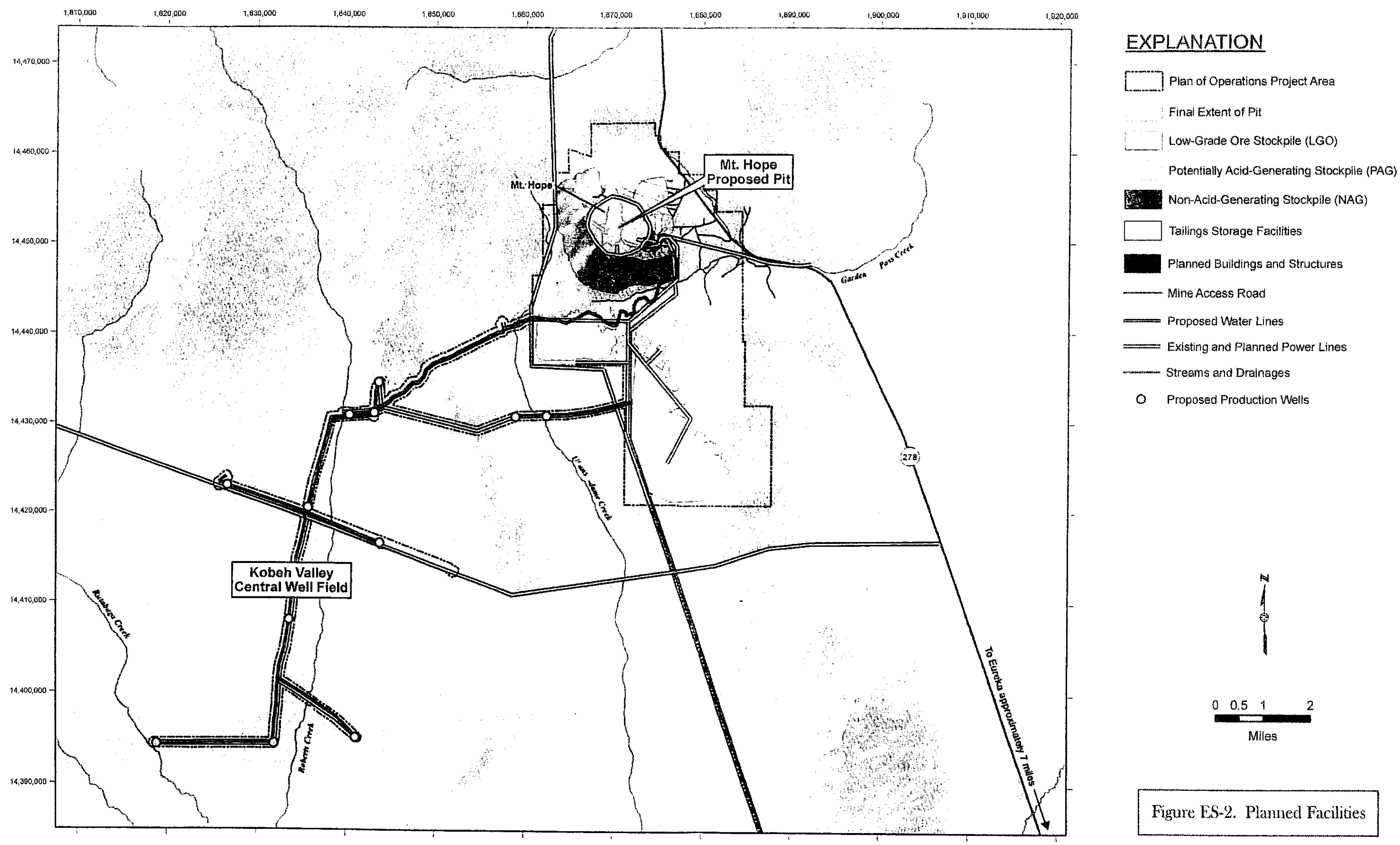

Figure ES-2. Planned Facilities

Date: 07/07/10 Filename: Z:\MountHope_GIS_Project\RevisedFigures_June2010\ExecSum_Facilities_Rev UTM NAD 83, Zone 11

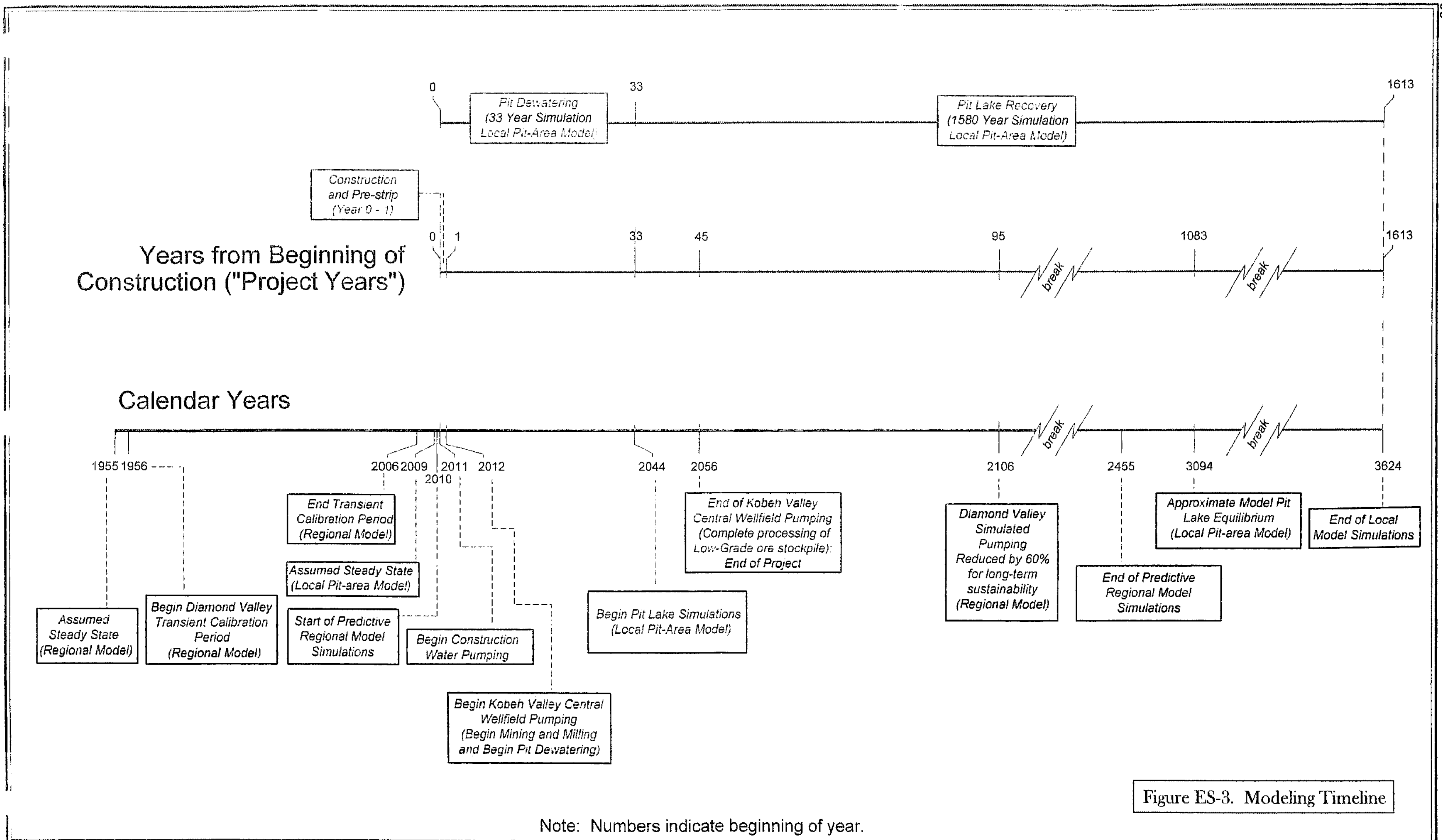

Figure ES-3. Modeling Timeline

Date: 04/20/2010 Filename: Drafting\1212.01\Timeline_graphic_RevES.dwg