3.3 HYDROLOGY AND WATER QUALITY

3.3.1 Affected Environment

3.3.1.1 Introduction

The hydrographic basin is the basic management unit used by the Nevada Division of Water Resources (NDWR). Generally, a hydrographic basin is defined by the topographic divide, or ridgeline, that separates adjacent basins. Most basins in the Basin and Range physiographic province are closed; surface waters in the basin originate in adjacent mountains and remain in the valley. In some cases, the boundary between basins may be arbitrarily defined at low divides covered by alluvial sediments. Surface drainage channels link a few of the hydrographic basins within the WFO assessment area; these include the hydrographic basins along the Humboldt River and those adjacent to the Quinn River. Table 3.3-1 identifies the 40 hydrographic basins of the WFO assessment area.

The WFO assessment area is located in the northwest corner of the Great Basin segment of the Basin and Range physiographic province. Topography of the area reflects that typical of the Great Basin in which mountain ranges are generally oriented north-south and intervening valleys are narrow relative to their length. Mountain ranges are typically 5-15 miles wide. Valleys are slightly wider, 10-20 miles (Plume, 1996), and commonly closed. Surface water drainage originates in the mountains and flows to a small lake or playa in the valley. Streams and lakes are typically ephemeral.

TABLE 3.3-1
HYDROGRAPHIC BASINS, PERENNIAL YIELDS, AND COMMITTED RESOURCES WITHIN THE ASSESSMENT AREA

Regions/Basins	Perennial Yield (Acre Feet/Year)	Committed Resources (Acre Feet/Year)
Northwest Region (1)		
1. Pueblo Valley	2,000	5,923
2. Continental Lake Valley	1,000	9,220
3. Gridley Lake Valley	3,000	13,990
4. Virgin Valley	6,000	9
Black Rock Desert Region (2)		
21. Smoke Creek Desert	16,000	6,392
22. San Emidio Desert	2,500	7,440
23. Granite Basin	200	0
24. Hualapai Flat	6,700	32,123

Regions/Basins	Perennial Yield (Acre Feet/Year)	Committed Resources (Acre Feet/Year)
25. High Rock Lake Valley	5,000	3541
26. Mud Meadow	13,000	3,892
27. Summit Lake Valley	1,000	12
28. Black Rock Desert	30,000	23,897
29. Pine Forest Valley	11,00	40,990
28. Black Rock Desert	30,000	23,897
29. Pine Forest Valley	11,000	40,990
30. Kings River Valley	17,000	60,223
31. Desert Valley	9,000	29,597
32. Silver State Valley	5,900	25,273
33. Quinn River Valley	60,000	92,355
Humbolt River Basin (4)		
64. Clovers Area	72,000	35,784
65. Pumpernickel Valley	*	27,756
66. Kelly Creek Area	*	29,647
67. Little Humbolt Valley	34,000	9,155
68. Hardscrabble Area	*	0
69. Paradise Valley	*	105,112
70. Winnemucca Segment	17,000	40,644
71. Grass Valley	13,000	42,938
72. Imlay Area	3,000	7,604
73. Lovelock Valley	45,000	9,358
74. White Plains	100	47
West Central Region (5)		
75. Brady Hot Springs Area	2,500	1,288
77. Fireball Valley	100	0
78. Granite Springs Valley	4,500	784
79. Kumiva Valley	500	2
Truckee Basin (6)		
80. Winnemucca Lake Valley	3,300	262
Carson River Basin (8)		
101A. Packard Valley (Carson Desert)	700	2,621
101. Carson Desert (Packard V)	710R	2,621

Regions/Basins	Perennial Yield (Acre Feet/Year)	Committed Resources (Acre Feet/Year)
Central Region (10)		
128. Dixie Valley	15,000	37,435
129. Buena Vista Valley	10,000	330,456
130. Pleasant Valley	2,600	1,699
131. Buffalo Valley	8,000	8,890
132. Jersey Valley	250	27

* Yield included in values listed above

Source: Nevada Water Facts, 1992, Nevada Division of Water Planning, Department of Conservation and Natural Resources, Carson City

3.3.1.2 Surface Water Resources

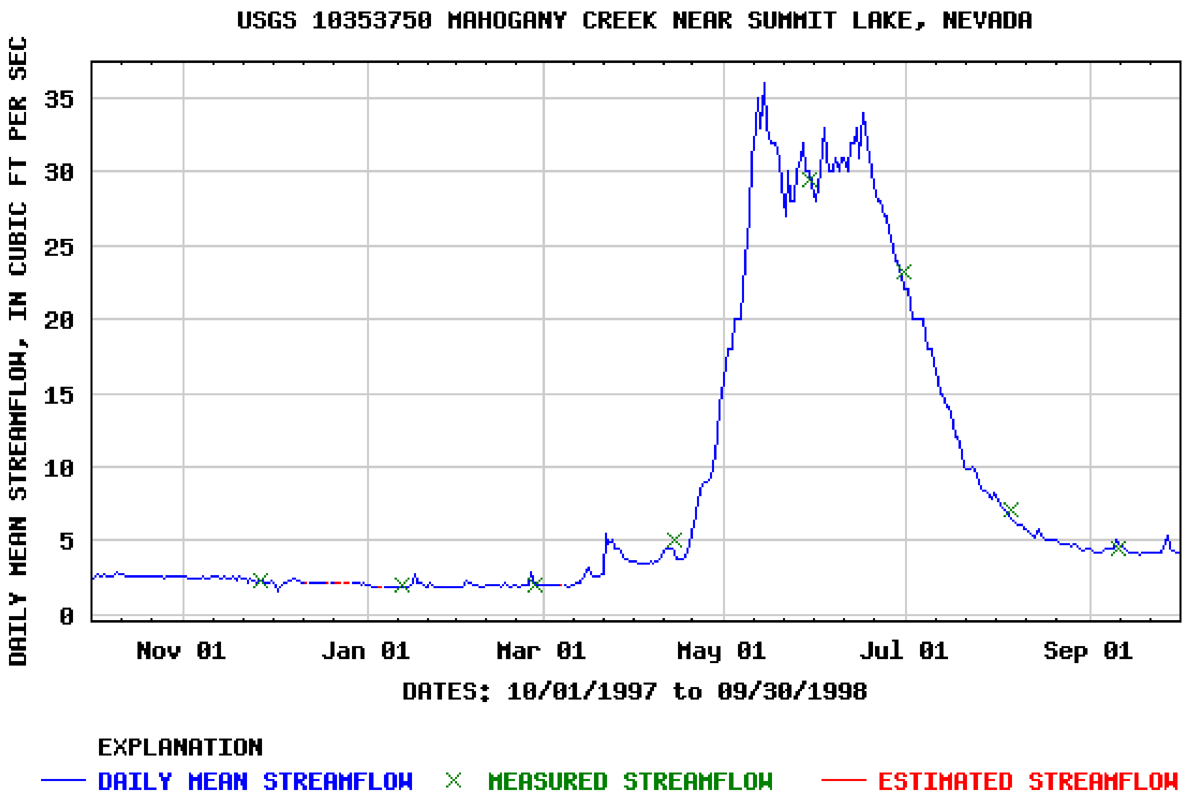
The geothermal leasing assessment area falls within the Great Basin physiographic province and can be accurately described as a high desert. Precipitation within the area is orographically controlled and elevation dependent. Much of the assessment area lies within the radius of influence of the rain shadow affect created by the Sierra Nevada Mountains. Average precipitation amounts across the area vary from 5-25 inches, with the majority of the precipitation being received as snow during the months of November through March.

Numerous small mountain streams flow within the area, many of which are perennial within their respective headwaters. The majority of stream flow is derived during the spring in direct response to the melting of the snow pack. Typical stream flow behavior, as shown in the annual hydrograph for Mahogany Creek (Northern Humboldt County), is depicted in Figure 3.3-1. Typical stream flow dynamics for the assessment area is for flow to originate at the upper elevations and enter the stream by way of overland flow and shallow groundwater discharge (interflow). As this flow exits the mountain block and onto the alluvial fan, the surface expression is quickly lost as it infiltrates into the valley fill aquifers through the coarse alluvial material at the upper end of the alluvial fan. Riparian vegetation exists in the mountainous areas prior to the water being lost as recharge. There are approximately 850 miles of perennial streams within the Winnemucca District.

There are three primary drainage features in the assessment area that are perennial on their respective valley floors. These are the Quinn, Kings, and Humboldt Rivers. The first two are small streams, which are perennial in their headwaters area and for a few miles on the valley floor.

The Quinn River originates in the mountains of southern Oregon and northern Nevada and flows southward. Mountain drainage converges in the vicinity of McDermit, Nevada. Flow appears to be perennial through the northern half of Quinn River Valley, although approximately 95 percent of the flow is lost over the upper 18 miles in Nevada. In the southern half of the Valley the river is ephemeral (Visher, 1957). The channel forms the boundary between the Kings River and Desert Valley hydrographic basins, crosses the southern end of Pine Forest Valley and eventually terminates on a playa in the Black Rock Desert hydrographic basin.

FIGURE 3.3-1
ANNUAL STREAM FLOW FOR MAHOGANY CREEK
(FISCAL YEAR 1998)



Source: http://waterdata.usgs.gov/nv/nwis/discharge

The principal source area of the Kings River is in the Bilk and Trout Creek Mountains at the north end of the valley. Additional contributing areas may exist in the mountains on the east and west sides of the south end of the valley; however, these areas likely produce surface water flow to the valley only during very wet years. All of the mountain drainages are appropriated for stock watering and irrigation. During low to normal flow, these diversions remove all the surface water at the mountain front. As a result, Kings River is generally dry over the majority of the valley. Malmberg and Worts (1966) estimate that the long-term average flow into southern Kings River Valley is no more than 1000 af/year.[10] This average relies on substantial

[10] Acre-foot per year. An acre-foot is the amount of water needed to cover one square acre, one foot deep.

flows during wet years because normal to dry years bring little or no flow to the southern end of the valley.

The Humboldt River flows through the southeast quarter of the Winnemucca District. The river enters the area west of Battle Mountain (Lander County) in the Clover Area hydrographic basin and flows northwestward toward the Golconda-Winnemucca area then southwestward through Rye Patch Reservoir to the Humboldt Sinks south of Lovelock at the south Pershing County line. Information provided on the U.S. Geological Service (USGS) Nevada website (http//waterdata.usgs.gov/nv/nwis/) identifies five gauging stations on the Humboldt River in Humboldt and Pershing counties. These stations are near Valmy and Comus in eastern Humboldt County, near Rose Creek in southern Humboldt County, and near Imlay and Lovelock in Pershing County. Currently operated gages are located at Comus and Imlay. Annual flow statistics available for these two gauges for the period 1990 thru 1999 indicate that on average the Humboldt River flows about 389 ft^3/s at Comus and 312 ft^3/s at Imlay.[11] These statistics are heavily influenced by irrigation diversions along the entire length of the river. South of Imlay, flow in the Humboldt River is impounded in a series of reservoirs (Rye Patch, Upper Pitt Taylor, and Lower Pitt Taylor). The Bureau of Reclamation developed these reservoirs for use in conjunction with the Pershing County Water Conservation District. In wet years, water that is not diverted for irrigation or held within the reservoirs, discharges to the Humboldt Sinks at the Pershing County line.

Springs

There are numerous springs within the assessment area. Perched or contact springs are the most common type of spring encountered. The source water for these springs is infiltrating precipitation that has been captured and concentrated in areas where fractured or unconsolidated material is underlain by less permeable material (aquitards) that inhibit the downward migration of water. These springs emanate at locations where the aquitard intersects the surface of the ground and the "perched" water seeps out. These springs are not directly connected with the surrounding water table and are generally unaffected by groundwater flow.

A less common, but ecologically and culturally significant spring that is encountered in the assessment area is the thermal spring. These springs are surface expressions of the geothermal resource and are discussed in further detail in section 3.12.1.3.

3.3.1.3 Groundwater Resources

Mountains in the area of study expose bedrock, which is usually igneous, intrusive or extrusive, but may locally be consolidated sediments. Materials eroded from the mountains fill the basins formed between with unconsolidated sediments, which range from coarse gravels to clays. The valley fill sediments may be associated with alluvial deposits or lake deposits. While alluvial fan deposits define the mountain/valley boundary at land surface the structural boundary is defined by the normal faults, which formed the mountains. All of these geologic elements are significant in the groundwater regime of the region.

[11] Cubic feet per second

Welch and Preissler (1990) describe a conceptual model of groundwater flow for the Black Rock Desert that is typical of basins in the assessment area. The greater portion of precipitation and recharge occurs in higher elevations owing to orographic effects. High evapotranspiration rates on the valley floor generally overwhelm precipitation and little recharge is thought to occur through the valley fill sediments. Precipitation in the mountains infiltrates the bedrock or flows from the mountain block and infiltrates as stream channels cross-mountain front faults or the apex of alluvial fans. Recharged waters flow through fractures and faults in the bedrock and from the bedrock to the valley fill. Ground water in the valley fill may rise to near ground surface and discharge as evapotranspiration or flow into an adjacent basin in the subsurface. Groundwater may also discharge as spring flow when geologic and hydraulic conditions force water upward to land surface.

The conceptual model recognizes three aquifers in the typical hydrographic basin: the valley fill aquifer, the alluvial aquifer, and the bedrock aquifer. Production of ground water by drilling wells is most commonly accomplished in the valley fill aquifer. Successful drilling in the bedrock aquifer is difficult and is usually only successful in areas of high fracture density.

Geothermal resources occur when infiltrating groundwater is directed into the vicinity of a heat source by flow along faults or deep in valley fill sediments. Conceptually, both geothermal and groundwater resources function similarly and frequently these resources may be interconnected not only in the recharge area but also in defining flow paths and discharge areas. For example, Campana (1980) suggests that the thermal waters which rise to create Leach Hot Springs in southeastern Grass Valley force non-thermal water to the south and east. Geothermal resources are discussed in more detail in section 3.12.1.3.

The Nevada State Engineer administers groundwater resources in Nevada by hydrographic basin. There are 40 hydrographic basins in the WFO area. The hydrographic basins of Nevada are grouped in hydrographic regions, eight of which are represented in the assessment area (see Table 3.3-1). The discussion of groundwater resources is organized by hydrographic regions. Because of the general character of the groundwater flow systems, conditions in individual hydrographic basins will be mentioned only to highlight unique features.

Northwest Region. The northwest corner of the assessment area is comprised of four hydrographic basins of the Northwest Region. The eastern side of this region exemplifies typical basin and range topography but to the west the basin and range topography is buried beneath volcanic flows (Sinclair, 1963). Surface water drainages connect the four basins during periods of excessive runoff. But the basins are considered independent from the standpoint of groundwater. The sand and gravel deposits of the valley fill sediments constitute the most productive aquifers in the region and yield moderate to large amounts of water. Flow may occur in the volcanic rocks but successful development would require intercepting productive fractures. Harrill and others (1988) indicate that the area receives underflow from the west and that discharge occurs by evapotranspiration. The principal areas of evapotranspiration are around Gridley Lake, Continental Lake, and along Thousand Creek in the eastern part of the region. Sinclair (1963) suggests that the perennial yield of the region is about 22,000 af/year. The Nevada Division of Water Planning (NDWP) (1992) indicates the perennial yield to be 12,000 af/year and that 29,142 af/year are committed. The greater portion of the commitment is in Gridley Lake Valley.

Black Rock Desert Region. This hydrographic region consists of 13 hydrographic basins and extends along a diagonal from the north central to the southwest portions of the assessment area. Quinn River, Silver State, Kings River, Desert, Pine Forest, and Black Rock Desert Basins are linked by the Quinn River surface drainage. Groundwater flow in these basins appears to be focused in the downstream direction (Harrill and others, 1988). Valley fill groundwater flow in other basins of the region is internal. All the basins, with the exception of the Smoke Creek Desert Basin, contribute underflow to the Black Rock Desert Basin. The Smoke Creek Desert Basin receives underflow from the west and from the San Emidio Desert basin to the east (Harrill and others, 1988). Discharge by evapotranspiration occurs in the central portion of each basin throughout the region, except in Desert Valley and High Rock Lake Valley Basins.

Visher (1957), Sinclair (1962a, 1962b), and Malmberg and Worts (1966) describe the groundwater conditions in the upper basins of the Quinn River drainage. Mountains adjacent to these basins are generally composed of rock through which groundwater does not flow freely. Groundwater recharge occurs principally by infiltration of streams, which originate in the surrounding mountains, as they flow across the valley fill sediments. Discharge occurs by evapotranspiration, domestic pumping, and by underflow in the valley fill sediments. Table 3.3-2 shows the estimated recharge, discharge, and perennial yield of these basins. The values of perennial yield are based on reconnaissance level studies and should be refined with detailed site-specific evaluations of yield if significant development is anticipated.

The Black Rock Desert Basin is the sink for much of the Black Rock Desert Hydrographic Region. It receives flow from the Quinn River during periods of high discharge (Sinclair, 1963a) and underflow from the upper Quinn River Basins (Harrill and others, 1988). Underflow is also received from basins along the west central, southwest, and southeast edges of the basin (Sinclair, 1963a; Harrill and others, 1988). Estimates of recharge, discharge, and perennial yield (Table 3.3-2) were made by analogy with other areas studied in the Great Basin because no access was available to low lying areas to measure plant cover (Sinclair 1963a).

Hualapai Flat Basin, in the southwest portion of the Black Rock Desert Hydrographic Region, is bordered principally by granitic and volcanic rocks. Precipitation in the mountains flows to the sediment filled valley and infiltrates as it crosses the alluvial sediments (Sinclair, 1962c). Harrill and others (1988) identify an area of evapotranspiration at the southeast edge of the flat and underflow from Hualapai Flat into the Black Rock Desert Basin.

The extreme southwest end of the Black Rock Desert Hydrographic Basin consists of Smoke Creek Desert and San Emidio Desert Basins. Mountains surrounding these basins are composed primarily of igneous rocks, consolidated sedimentary and metamorphosed rocks are present to a lesser extent (Glancy and Rush, 1968). The consolidated rocks receive and transmit water as evidenced by the presence of small springs. No estimate of the amount of water in these rocks or their ability to transmit the water is available. The principal aquifer in both basins is the alluvial sediments filling the valley. Harrill and others (1988) identify areas of evapotranspiration throughout the Smoke Creek Valley and at the northern end of the San Emidio Desert Basin.

They also indicate underflow from the San Emidio Desert to both the Smoke Creek Desert and the Black Rock Desert. The Smoke Creek Desert Basin has been considered a potential water source for urban development in Washoe County (Maurer, 1993).

Perennial yield in that portion of the region in the assessment area is estimated to be 177,300 af/year. Approximately 324,735 af/year have been committed for various uses (see Table 3.3-1). The greatest portion of water resources development occurs in those hydrographic basins, which lie along the Quinn River in the northern part of the region.

Humboldt River Region. That portion of the Humboldt River Region in the assessment area, extends from the eastern edge of Humboldt County in a southwesterly direction across central Pershing County and ends in northwest Churchill County. The Clovers Area, Kelly Creek Area, and Pumpernickel Valley Hydrographic Basins group around the river at the east Humboldt County line. North of the river in the upper portion of the hydrographic region are the Hardscrabble Area, Little Humboldt River, and Paradise Valley Hydrographic Basins which are tributary to the Little Humboldt River. Grass Valley Hydrographic Basin is tributary to the Humboldt River near Winnemucca. Below Winnemucca, the Humboldt River flows through the Winnemucca Segment, Imlay Area, Lovelock Valley, and White Plain hydrographic basins.

In broad terms, two lithologic units underlie the drainage area of the Little Humboldt River (Harrill and Moore, 1970). Unconsolidated sediments fill the valleys, are highly porous, and commonly transmit water readily. Consolidated rocks, which occur in the mountains and underlie valley fill, include volcanic rocks in the north and northeast, consolidated sedimentary rocks in the southeast, and granitic and metamorphic rocks in the Santa Rosa Range on the west side of Paradise Valley. These rocks have low porosity and permeability and do not readily transmit water.

Infiltration of mountain runoff is the principal source of recharge to the valley fill aquifers. A small quantity of mountain precipitation may infiltrate fractured consolidated rock (Harrill and Moore, 1970). Natural discharge by evapotranspiration occurs along the channel of the Little Humboldt River and on the floor of Paradise Valley (Harrill and others, 1988). Harrill and others (1988) suggest that groundwater moves from Hardscrabble Area and Little Humboldt River Basins to Paradise Valley and from Paradise Valley into the Humboldt Valley underflow. Recharge to these hydrographic basins is estimated to be in the range of 46,000 af/year (Harrill and Moore, 1970) and 54,000 af/year (Harrill and others, 1988). Evapotranspiration loss from these basins under natural conditions is estimated at about 50,000 af/year during dry years. Underflow from Paradise Valley into the Humboldt River Valley range from about 3,000 to 4,400 af/year (Harrill and Moore, 1970; Harrill and others, 1988).

Mountains bounding the Clovers Area, Kelly Creek Area, and Pumpernickel Valley Hydrographic Basins expose a variety of highly faulted igneous, metamorphic, and consolidated sedimentary rocks (Willden, 1963). Hydrologically these mountains likely behave similarly to those of the Little Humboldt River and adjacent basins where most precipitation runs off and recharges the valley fill aquifer at the alluvial fan margin while a small volume of water infiltrates through fractures in the bedrock. Harrill and others (1988) identify a broad area of evapotranspiration on the floor of these basins. They estimate that recharge to the valley fill aquifer is about 16,000 af/year and that underflow into and out of the basins follows the river channel.

Groundwater recharge in Grass Valley occurs as a result of snowmelt runoff infiltration on the alluvial fans at the mountain front. Cohen (1964) estimates natural recharge to be about 12,000 to 13,000 af/year. Natural discharge occurs as evapotranspiration, about 7,000 af/year, and underflow into the Humboldt River valley, 6,000 af/year.

In the three hydrographic basins along the central and lower reaches of the Humboldt River in the assessment area, recharge to the valley fill aquifer originates as precipitation within the area, seepage losses from the Humboldt River, and underflow through valley fill from the upstream section (Eakin, 1962; Harrill and others, 1988). Water moves down the river valley as underflow through the valley fill sediments in addition to the stream flow in the Humboldt River. Under normal flow conditions the river flows to the Humboldt Sinks south of Lovelock. Minor amounts of underflow may continue down valley from the Sinks and discharge to the Carson Sink Basin to the southeast. Additional groundwater discharge occurs by evapotranspiration from the narrow flood plain along the river channel. Recharge to these three basins is estimated to be about 14,400 af/year (Harrill and others, 1988). Surface flow and underflow from the basins is negligible, suggesting that this amount, plus flow in the river, is consumed as evapotranspiration by native vegetation and crops.

Within the Humboldt River Region, groundwater development appears to be the greatest in the northern hydrographic basins. Paradise Valley has the largest volume of committed water resources of any basin in the region. For the region as a whole, the perennial yield is estimated to be 184,100 af/year and committed resources are about 308,045 af/year (see Table 3.3-1).

West Central Region. The West Central Hydrographic Region includes four hydrographic basins and lies in the southwest corner of Pershing County, the southwest corner of the assessment area. It is bound on the east by the lower end of the Humboldt River Region and on the west by Winnemucca Lake Basin of the Truckee River Hydrographic Region. Mountains bounding basins of the region expose volcanic, consolidated sedimentary, granitic, and metamorphic rocks. These rock units generally transmit water only along fractures (Harrill, 1970). Alluvial sediments in the valleys constitute the major groundwater aquifers of the region. Groundwater systems in the region are recharged by infiltration of precipitation through fractures in the bedrock of the mountains and infiltration of stream flow at the edges of the valley fill. Most groundwater in Kumiva Valley moves as underflow into Granite Springs Valley. Groundwater in Granite Springs Valley moves from the mountains to the phreatophyte discharge area near the valley center. Groundwater in Fireball Valley likely enters Brady Hot Springs Area as under flow and discharges from the phreatophyte area north of Brady Hot Springs and the area surrounding the Fernley Sink. Brady Hot Springs Area may also receive underflow from the Fernley Area to the south. Groundwater recharge in the region is estimated to be about 4,900 af/year (Harrill, 1970). Evapotranspiration in the region is estimated at about 7,700 af/year. Harrill (1970) recognizes a significant imbalance between the inflow and outflow in the region. Several alternatives are described that might account for the imbalance but he does not resolve the difference. The perennial yield is 7,600 af/year; 2,704 af/year are committed to permintted uses (see Table 3.3-1). The greatest portion of these commitments are in Brady Hot Spring area.

Truckee River Region. Winnemucca Lake Valley is the only hydrographic basin in the Truckee River Hydrographic Region that is in the WFO assessment area. The valley is bordered on the east and west by mountains composed of igneous, metamorphic, and consolidated sedimentary rocks. Through untested, these consolidated rocks are considered to be the poorest water-yielding unit in the area (Van Denburgh and others, 1973). They yield minor amounts of water to springs and may yield minor amounts to wells, where fractures are intercepted. Generally, these rocks refuse precipitation infiltration (except in areas of fracturing). Precipitation runs off to the valleys and infiltrates as flow crosses the alluvial sediments. Recharge in this manner is estimated to be about 2,900 af/year (Van Denburgh and others, 1973; Harrill and others, 1988). The basin may also receive minor amounts of recharge by underflow across its southern end (Harrill and others, 1988). All recharge to the valley is thought to be discharged by evapotranspiration along the central axis of the valley fill sediments (Harrill and others, 1988). In addition, the valley fill aquifer water level may still be declining as a result of the drying up of Winnemucca Lake in 1940 (Van Denburgh and others, 1973). Lower water levels reflect the loss of water from storage in the valley fill aquifer. The long-term perennial yield of the basin is about equal to the natural recharge 2,900 af/year (Van Denburgh and others, 1973). Nevada Division of Water Planning (NDWP, 1992) estimates perennial yield to be 3,300 af/year and the committed resources to be 262 af/year (see Table 3.3-1).

Carson River Region. Packard Valley, a sub-basin in the Carson Desert Hydrographic Basin, is the only element of the Carson Desert Hydrographic Region within the WFO assessment area. Mountains composed of igneous, metamorphic, and consolidated sedimentary rocks define the sub-basin (Glancy and Katzer, 1975). The lack of springs along the mountain front in Packard Valley suggests that this area is relatively unfractured and that precipitation falling on the mountains runs off the adjacent valley. Glancy and Katzer (1975) estimated that recharge from infiltration of mountain runoff in Packard Valley is only about 77 af/year. Approximately 340 af/year of groundwater is discharged by transpiration within Packard Valley. Groundwater flow in the valley fill aquifer is southward toward the main area of the Carson Desert Basin where the water is likely lost by evapotranspiration. NDWP (1992) estimates perennial yield at 710 af/year and committed resource at 2,621 af/year (see Table 3.3-1).

Central Region. This hydrographic region consists of five hydrographic basins within the assessment area. Buena Vista Valley and Buffalo Valley are internally draining basins with no apparent underflow to adjacent basins (Harrill and others, 1988). They receive recharge of 10,000 and 12,000 af/year, respectively, from precipitation within each basin. Under natural conditions, all of the recharge is discharged by evapotranspiration from the valley in the central part of each basin.

Only the extreme northern end of Dixie Valley is included in the WFO assessment area. This portion of the valley contains evidence of significant geothermal resources. In addition, northern Dixie Valley appears to be hydrologically linked to Pleasant and Jersey Valleys to the north.

The consolidated rocks in the mountains surrounding the Dixie, Pleasant, and Jersey Valley areas are composed of igneous, metamorphic, and consolidated sedimentary rocks. These rocks have little or no internal porosity; thus, transmission of groundwater over large areas is unlikely (Cohen and Everett, 1963). Water may move through fractures in the consolidated rocks, however, resulting in transmission of water to springs or to the valley fill aquifer. Precipitation on the mountains may infiltrate through fractures or flow through ephemeral channels to the valley where runoff infiltrates the alluvial sediments recharging the valley fill aquifer. Natural discharge from the valleys is by evapotranspiration.

Cohen and Everett (1963) and Harrill and others (1988) suggest that recharge to Pleasant and Jersey Valleys is approximately 4,000 af/year. Flow in the valley fill aquifer directs some of this water to an area of evapotranspiration along the centerline of the valley. Pleasant and Jersey Valleys transmit about 1,000 af/year each into northern Dixie Valley by underflow. In addition, Dixie Valley is thought to receive approximately 6,000 af/year recharge by infiltration of precipitation and minor amounts of underflow from adjacent valleys at its southern end (Cohen and Everett, 1963; Harrill and others, 1988). Perhaps about 10 to 16 percent of the precipitation recharge to Dixie Valley occurs in the area within the WFO assessment area. Virtually all of the precipitation recharge to these valleys is believed to be discharged by evapotranspiration. Perennial yield is limited to the amount of natural discharge that can be intercepted (Cohen and Everett, 1963), a maximum of about 4,000 af/year in northern Dixie, and Pleasant, and Jersey Valleys.

For the five Central Region basins wholly or partly in the assessment area, 35,850 af/year is the perennial yield; 81,507 af/year is estimated to be the amount of committed water resources (see Table 3.3-1). The greatest portions of the commitments occur in Dixie Valley and Buena Vista Valley.

3.3.1.4 Water Quality

The chemical character and quality of a natural water source is determined by mineral content of the rock that water flows across or through and the ease with which the rock minerals dissolve into the water. Processes and conditions, which influence the concentration of dissolved constituents, include contact time between water and rock minerals, evaporation and evapotranspiration, and temperature.

Precipitation, because it has not yet come in contact with geologic materials, typically has very low concentrations of dissolved minerals and is considered very good quality. The contact time between precipitation runoff and rock minerals is short for water in streams and lakes at higher elevations where precipitation is most common. Generally, these waters also have low concentrations of dissolved minerals and are considered good quality. Groundwater moves relatively slowly through rocks that comprise an aquifer and therefore, has greater potential to dissolve minerals. Greater distance from the recharge area implies greater contact time between groundwater and the aquifer rocks. As a result, groundwater chemistry at discharge areas generally exhibits somewhat higher concentrations of dissolved minerals and is of somewhat lesser quality than water in the recharge area. However, these variations may be masked by other influences in complicated flow systems.

Evaporation and evapotranspiration can have a significant impact on water quality. Because these processes remove water molecules from the source but leave dissolved minerals, the concentration of dissolved minerals increases in the water which remains. In some circumstances, lakes or ponds that do not have a consistent supply of fresh water and are subject to evaporation would exhibit a decrease in water quality owing to the increase in dissolved minerals. Groundwater that rises to near ground surface, and is subject to evaporation and evapotranspiration, would have increased concentrations of dissolved minerals. For these reasons, groundwater resources near the center of hydrographic basins often may be somewhat saline.

Temperature also has potential to impact water chemistry and quality. Most rock minerals dissolve more easily under higher temperatures. Thus, groundwater that have been heated in geothermal systems typically contains higher levels of dissolved minerals than do low temperature groundwater resources. Additionally, thermal water may dissolve minerals that have potential to affect the pH (acidity) of the water.

In typical hydrographic basins, water quality would be best in the mountains where precipitation is most common. Surface water flowing from the mountains and groundwater near the mountain front would generally be of good quality. However, near the basin center or in discharge areas water quality would be less due to evapotranspiration. Thermal waters would have still lower quality resulting from the influence of temperature on mineral dissolution. Mixing of low quality thermal water with better quality waters would result in water of intermediate quality. The result of mixing would depend on the relative amounts of water from the various sources.

Northwest Region. Sinclair (1963) recognizes that four samples are inadequate to assess water quality in the Pueblo Valley-Continental Lake area. However, he notes that groundwater probably is satisfactory for irrigation and domestic use although areas of the central parts of the valley may be underlain by saline water.

Black Rock Desert Region. Generally, the water quality in all basins of the Black Rock Desert Hydrographic Region is suitable for irrigation, domestic, and stock uses (Visher, 1957; Sinclair, 1962a; Sinclair, 1962b; Sinclair, 1962c; Sinclair, 1963a; Malmberg and Worts, 1966; Glancy and Rush, 1968). In those basins where groundwater flows toward a central basin playa or lakebed, the water quality deteriorates from the valley margin toward the valley center. Thermal springs, where they are present, are described as unsuitable for irrigation use due to a high concentration of trace elements. Salinity may also be a concern in terms of irrigation applications.

Humboldt River Basin. Chemical quality of groundwater and surface water is generally suitable for irrigation and domestic use. A few wells in the south end of Paradise Valley produced waters with high salinity and sodium, which exceed drinking water standards and make them hazardous for irrigation use (Harrill and Moore, 1970).

Groundwater samples collected in Grass Valley indicated suitable quality for irrigation and domestic use. About 10 percent of the samples showed somewhat elevated salinity or trace elements, which would require special handling or would prevent use of the water for irrigation and domestic use (Cohen, 1964).

Chemical quality of the valley groundwater depends on location. Generally water obtained from the middle parts of the alluvial aprons near the areas of principal recharge is of better quality than groundwater obtained from the center of the valley (Eakin, 1962). Additionally, groundwater south of Lovelock is of poor quality and unsuitable for agricultural or domestic use (Everett and Rush, 1965).

West Central Region. Water quality in Kumiva and Granite Springs Valleys is suitable for irrigation or domestic use though the quality may deteriorate near the playa. In Brady Hot Springs area no samples were observed to have suitable quality for domestic use and high salinity levels would limit application for irrigation (Harrill, 1970).

Truckee Basin. Van Denburgh and others (1973) describe the quality of groundwater in Winnemucca Lake Basin to be of generally poor quality in the central and eastern parts of the area and therefore unsuitable for domestic use. Suitability for agricultural use must be determined locally.

Carson Desert Region. Water quality information is reported for only one well in the Packard Valley (Glancy and Katzer, 1975). This sample would be considered unsuitable for domestic use due to high total dissolved solids content, and marginal for irrigation use due to medium salinity levels.

Central Region. Buena Vista Valley is reported by Garcia and Jaconobi (1991) to have eight water analyses from wells in the valley. All but two of these well samples appear to have total dissolved solids concentrations in excess of drinking water standards. Buffalo Valley has no water analyses reported by Garcia and Jaconobi (1991).

3.3.2 Environmental Impacts

General Impacts. Potential impacts to water resources resulting from geothermal development derive from (1) the extraction of thermal fluids and groundwater from underground reservoirs, and (2) disposal of spent thermal fluids. Activities of the exploration phase would likely have minimum impact because the volumes of fluid concerned are minimal. Development phase activities would have a somewhat greater potential impact, primarily related to disposal of thermal fluids produced during reservoir testing. Impacts from these two phases would be of short duration and limited to a small area. Production would have the greatest potential for impacting water resources as a result of both changes to reservoir hydraulics and spent fluid disposal.

Geothermal and groundwater reservoirs are closely connected. Infiltration of precipitation on surrounding mountains is the source of recharge to both reservoirs. There are no impermeable boundaries, which separate hydraulic conditions of thermal and non-thermal flow systems. The thermal and non-thermal flow systems exist in the same area in equilibrium with each other. As a result of interconnections, changes in one reservoir would likely have an impact on the adjacent reservoir. Thus, extraction of geothermal fluid, which would cause a change in hydraulic head in the thermal reservoir, could also produce a change in hydraulic head and flow pattern in an adjacent groundwater reservoir. Loss of hydraulic head in either the geothermal reservoir or groundwater reservoir could result in decreased spring flow and decreased water levels in wells in the area. Users of impacted wells would likely see an increase in energy costs for pumping and in extreme cases shallow wells might dry up entirely. Timing and magnitude of these impacts depend upon the hydraulic connection between the point of geothermal extraction and springs and wells.

Re-injecting spent geothermal fluid into the source reservoir could minimize the loss of hydraulic head due to extraction. However, spent fluid is seldom re-injected at precisely the point of withdrawal because the cooler spent fluid would moderate the quality of the thermal resource. Therefore, a zone would exist around production wells in which hydraulic head is impacted by the withdrawal. The extent of that zone of influence would depend on specific reservoir characteristics, and any springs and wells within the zone of influence would be impacted. The magnitude of the impact could be a function of proximity of the spring or well to the production well.

Geothermal development could require process water derived from sources other than the geothermal reservoir. In such instances, groundwater is the most likely resource. Extraction of groundwater could result in an impact to the hydraulic character of the groundwater resource. These impacts could include: changes to the hydraulic head in the reservoir which could, in turn, result in reduced spring discharge and lower water levels in wells; or consumptive use of the groundwater, thereby limiting the resource available to other potential users.

Geothermal fluids produced during reservoir testing and development, and spent fluids not consumed in the industrial process, must be disposed after use. These fluids could be disposed by re-injection to the reservoir from which they were withdrawn, or by discharge to surface water or groundwater systems. Because geothermal fluids tend to be of lesser quality than groundwater or surface water resources, disposal could have an environmental impact. Re-injection of spent fluids to the source reservoir is generally considered to be environmentally benign with regard to water quality impacts. Discharge of thermal fluids produced during reservoir testing, or spent thermal fluids to surface water or groundwater resources would likely result in deterioration of the quality of these resources. Discharge of thermal fluids to surface water channels would potentially result in erosion of the channels and deposition of sediments downstream where flows terminate.

3.3.2.1 Proposed Action

Direct Impacts – There are no direct impacts to issuing leases for future geothermal exploration, development, and production activities.

Indirect Impacts – When considering the “reasonably foreseeable development scenario,” environmental impacts cannot be determined for individual leases or for exploration, development, or production activities. Existing data describing surface water systems, groundwater reservoirs, geothermal reservoirs, the interrelationships of these systems, or specific exploration, development, and production activities are inadequate to determine specific effects of these activities on the region, PVAs, KGRAs, or pending leases. This updated PEA would permit inclusion of updated stipulations, mitigation measures, and/or performance standards specific to each lease, and could help ensure the long-term health of the area’s hydrologic system and water quality.

The following are the potential environmental impacts on hydrology and water quality when analyzing the "reasonably foreseeable development scenario."

Exploration. Industrial applications of geothermal resource would involve exploration, development, and production activity. In addition to data collection at land surface, exploration could include drilling holes for collection of subsurface information such as temperature gradient data and cores for lithology and permeability analysis, or for setting explosive charges for seismic analysis. It is assumed that this phase of activity would not produce significant quantities of groundwater or geothermal fluids. However, small volumes of fluid would be produced as a result of drilling into the saturated zone. Fluids produced during drilling are generally incorporated into the drilling fluid. On completion of drilling, remaining drilling fluids are contained in a sump or mud pit and must be disposed.

Development. Development, or testing, of the geothermal resource is focused on evaluation of the hydraulic and production character of the geothermal reservoir. Wells would be drilled into the geothermal reservoir and production of geothermal fluids would be necessary to evaluate the reservoir. The volume of fluid produced would depend on the duration of tests performed, which could last from 10s of hours to 10s of days. Fluid volumes produced during this phase of activity could be small relative to production but they would likely be significant and must be disposed during or following testing. Disposal could be an issue depending upon the chemical quality of the geothermal fluids.

Production. The final phase of activity would involve the production and disposal of large volumes of geothermal and spent fluids. Disposal options could include re-injection to the source reservoir or release to the land surface. Production could also involve the extraction of groundwater resources for cooling or other process related needs. Impact issues associated with the production phase of geothermal development are related to hydraulic and hydrologic changes in the geothermal and adjacent groundwater reservoirs and to disposal of spent fluids, which are likely to be of poor quality.

Specific impacts to water resources resulting from geothermal development would depend on the specific character and location of the development. Production features (number and location of wells, pumping rates, and disposal methodology), thermal reservoir character (thermal quality, chemical quality, hydraulics and hydrology), and groundwater reservoir factors (chemical quality, recharge, hydraulics and hydrology, spring discharge, other users) would all be critical in evaluating the impacts of geothermal development. Because these factors are either not known or are known only in a general way, it is not possible to assess the specific impact of individual geothermal developments.

Close-Out. During the close-out phase, production and injection wells would be capped and the geothermal resources would no longer be extracted from, or re-injected into, the geothermal reservoirs.

3.3.2.2 No Action Alternative

Direct Impacts – There are no direct impacts to issuing leases for future geothermal exploration, development, and production activities.

Indirect Impacts – Indirect impacts from the No Action Alternative would be similar to those described in the Proposed Action; however, updated mitigation measures and stipulations would not apply using the 1982 Geothermal EA.